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Desktop Computer Displays:

A Life-Cycle Assessment

VOLUME 1

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EXECUTIVE SUMMARY

This report presents the results of a voluntary, cooperative project among the Design for the Environment (DfE) Program in the Economics, Exposure, and Technology Division of the U.S. Environmental Protection Agency's (EPA) Office of Pollution Prevention and Toxics, the University of Tennessee (UT) Center for Clean Products and Clean Technologies, the electronics industry, and other interested parties to develop a model and assess the life-cycle environmental impacts of flat panel display (FPD) and cathode ray tube (CRT) technologies that can be used for desktop computer displays. The DfE Computer Display Project (CDP) report provides a baseline analysis and the opportunity to use the model as a stepping stone for further analyses and improvement assessments for these technologies.

The DfE CDP uses life-cycle assessment (LCA) as an environmental evaluation tool that looks at the full life cycle of the product from materials acquisition to manufacturing, use, and final disposition. As defined by the Society of Environmental Toxicology and Chemistry, there are four major components of an LCA study: goal definition and scoping, life-cycle inventory, impact assessment, and improvement assessment. The more recent International Standards Organizations definition of LCA includes the same first three components, but replaces the improvement assessment component of LCA with a life-cycle interpretation component. LCAs are generally global and non-site specific in scope.

The DfE CDP analysis also incorporates some elements of the Cleaner Technologies Substitutes Assessment (CTSA) methodology (Kincaid *et al.,* 1996), which was developed under the DfE Program to help businesses make environmentally informed choices and design for the environment. The CTSA process involves comparative evaluations of the relative human and ecological risk, energy and natural resource use, performance, and cost of substitute technologies, processes, products, or materials.

This project focuses on the LCA, while including some CTSA-related analyses. It performs the broad analysis of the LCA, which also incorporates many of the CTSA components (e.g., risk, energy impacts, natural resource use) into the impact assessment. The analysis also assesses more specific impacts for selected materials and acknowledges product cost and performance, typical of a CTSA. As only selected materials are qualitatively evaluated for the CTSA, this project is an LCA with a streamlined CTSA component.

LCAs evaluate the environmental impacts from each of the following major life-cycle stages: raw materials extraction/acquisition; materials processing; product manufacture; product use, maintenance, and repair; and final disposition/end-of-life. The inputs (e.g., resources and energy) and outputs (e.g., products, emissions, and waste) within each life-cycle stage, as well as the interaction between each stage (e.g., transportation) are evaluated to determine the environmental impacts.

In this study and project report, the goal and scope of the CDP are the subject of Chapter 1. The life-cycle inventory (LCI), which involves the quantification of raw material and fuel inputs, and solid, liquid, and gaseous emissions and effluents, is the subject of Chapter 2. The life-cycle impact assessment (LCIA) involves the translation of the environmental burdens identified in the LCI into environmental impacts and is the subject of Chapter 3. The improvement assessment or life-cycle interpretation is left to the electronics industry given the results of this study. The report also includes a qualitative risk screening of selected materials to represent the CTSA component of the report in Chapter 4. The summary and conclusions are presented in Chapter 5.

I. GOAL DEFINITION AND SCOPE

Purpose and Need

The purpose of this study is two-fold: (1) to establish a scientific baseline that evaluates the life-cycle environmental impacts of active matrix liquid crystal display (LCD) and cathode ray tube (CRT) technologies for desktop computers, by combining LCA and CTSA methodologies; and (2) to develop a model that can be used with updated data for future life-cycle analyses. This study is designed to provide the electronics industry with information needed to improve the environmental attributes of desktop computer displays. The evaluation considers impacts related to material consumption, energy, air resources, water resources, landfills, human toxicity, and ecological toxicity. It is intended to provide valuable data not previously published, and an opportunity to use the model developed for this project in future improvement evaluations that consider life-cycle impacts. It will also provide the industry and consumers with valuable information to make environmentally informed decisions regarding display technologies, and enable them to consider the relative environmental merits of a technology along with its performance and cost. While there has been some work done on the life-cycle environmental impacts of either CRTs or LCDs, there has not been a quantitative LCA of both CRTs and LCDs.

At present, computer displays using CRTs dominate worldwide markets. The LCD, first used predominately in notebook computers, is now moving into the desktop computer market. CRTs use larger amounts of energy to operate than LCDs, and are associated with disposal concerns due to leaded glass in the displays. LCDs may consume more energy during manufacturing and contain small amounts of mercury. Given the expected market growth of LCDs for computer displays, the various environmental concerns throughout the life cycle of the computer displays, and the fact that the relative life-cycle environmental impacts of LCDs and CRTs have not been scientifically established to date, there is a need for an environmental life-cycle assessment of both of these types of desktop computer display technologies.

Targeted Audience and Use of the Study

The electronics industry is expected to be one of the primary users of the study results. The study is intended to provide industry with an analysis that evaluates the life-cycle environmental impacts of selected computer display technologies. Another result of the study is an accounting of the relative environmental impacts of various components of the computer displays, thus identifying opportunities for product improvements to reduce potential adverse environmental impacts and costs. Since this study incorporates a more detailed health effects component than in traditional LCAs, the electronics industry can use the tools and data to evaluate the health, environmental, and energy implications of the technologies. With this evaluation, the U.S. electronics industry may be more prepared to meet the demands of extended product responsibility that are growing in popularity in the global marketplace, and better able to meet competitive challenges in the world market. In addition, the results and model in this study will provide a baseline LCA upon which alternative technologies can be evaluated. This will allow for more expedited display-related LCA studies, which are growing in popularity by industry and may be demanded by original equipment manufacturers (OEMs) or international organizations.

EPA and interested members of the public can also benefit from the results of the project. The project has provided a forum for industry and public stakeholders to work cooperatively, and the results can be used by stakeholders as a scientific reference for the evaluated display technologies. The results of the project could also be of value to other industries involved in designing environmental improvements into the life cycle of consumer products.

Product System

The product system being analyzed in this study is a standard desktop computer display that functions as a graphical interface between computer processing units and users. Besides the CRT display, several FPD technologies were considered for inclusion in this study. Among the FPD technologies that exist, the amorphous silicon (a:Si) thin-film transistor- (TFT) active matrix LCD technology meets the requirements of the functional unit within the parameters of this analysis and is assessed in this study.

The product system is the computer display itself and does not include the central processing unit (CPU) of the computer that sends signals to operate the display. It is assumed that the LCDs operate with an analog interface, and therefore are compatible with current CRT CPUs as plug-and-play alternatives.

In an LCA, product systems are evaluated on a functionally equivalent basis. The functional unit is used as the basis for the inventory and impact assessment to provide a reference to which the inputs and outputs are related. For this project, the functional unit is one desktop computer display over its lifespan, which meets the functional unit specifications presented in Table ES-1. The CRT technology is the current industry standard for this product system.

Table ES-1. Functional unit specifications

Specification	Measure
display size [a]	17" (CRT); 15" (LCD)
diagonal viewing area [a]	15.9" (CRT); 15" (LCD)
viewing area dimensions	12.8" x 9.5" (122 in^2) (CRT); 12" x 9" (108 in^2) (LCD)
resolution	1024 x 768 color pixels
brightness	200 cd/m^2
contrast ratio	100:1
color	262,000 colors

[a] An LCD is manufactured such that its nearest equivalent to the 17" CRT display is the 15" LCD. This is because the viewing area of a 17" CRT is about 15.9 inches and the viewing area of a 15" LCD is 15 inches. LCDs are not manufactured to be exactly equivalent to the viewing area of the CRT.

Assessment Boundaries

In a comprehensive cradle-to-grave analysis, the display system includes five life-cycle stages: (1) raw materials extraction/acquisition; (2) materials processing; (3) product manufacture; (4) product use, maintenance and repair; and (5) final disposition/end-of-life. Also included are the activities that are required to affect movement between the stages (e.g., transportation).

The geographic boundaries of this assessment depend on the life-cycle stage. This LCA focuses on the U.S. display market; therefore, the geographic boundary for the use and disposition stages of displays is limited to the United States. The geographic boundaries for raw material extraction, material processing, and product manufacture are worldwide (although actual product manufacturing data were only collected from the United States, Japan, and Korea, described in Chapter 2 of the report). While the geographic boundaries show where impacts might occur for various life-cycle stages, traditional LCAs do not provide an actual spatial relationship of impacts. That is, particular impacts cannot be attributed to a specific location. Rather, impacts are generally presented on a global or regional scale.

Considering the temporal boundaries, this study addresses impacts from the life cycle of a desktop computer display manufactured using 1997-2000 technology. The use and disposition stages cover a period that represents the life of a display. The lifespan, labeled as the “effective” life, is defined as the period of time the display is in use by primary, secondary, or even tertiary users before reaching its final disposition. The effective life, used as the baseline scenario, is estimated based on past and current use patterns of displays and represents a realistic estimate of the lifespan. As the effective life is subject to many variables, including fluctuating market trends, an alternative lifespan is presented in a sensitivity analysis. The alternative lifespan, or “manufactured” life, defined as the designed durability of a display (e.g., the time a display or key display component will operate before failing), is approximated based on the manufacturer’s estimated durability of the display.

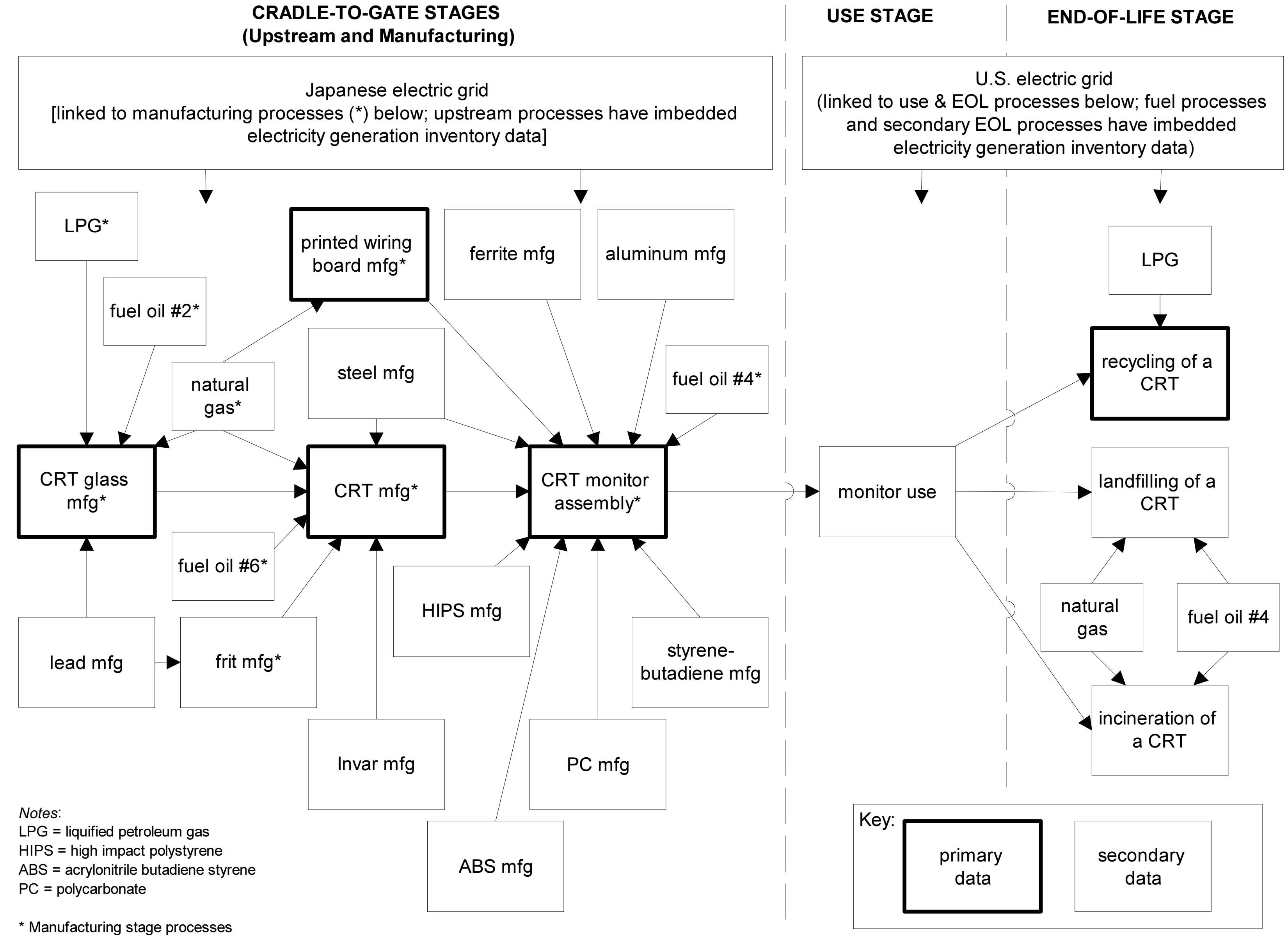
Impacts from the infrastructure needed to support the manufacturing facilities (e.g., maintenance of manufacturing plants) are beyond the scope of this study. However, maintenance of clean rooms used in the manufacturing of LCDs (and other components), which require substantial amounts of energy, are considered part of the manufacturing process.

Impacts from the transportation and distribution of materials, products, and wastes throughout the life-cycle of a display were originally included in the scope of the CDP LCA. However, only a small part of the overall transport in the life of a monitor was either reported in primary data collected for this project or available in secondary data. Inconsistencies between primary and secondary transportation data sources and the overall poor quality of transport data prevented an accurate assessment of the transportation inventory and impacts. Therefore, transportation impacts were excluded from the analysis. Section 2.6 describes transport data limitations and uncertainties in detail.

II. LIFE-CYCLE INVENTORY (LCI)

General Methodology

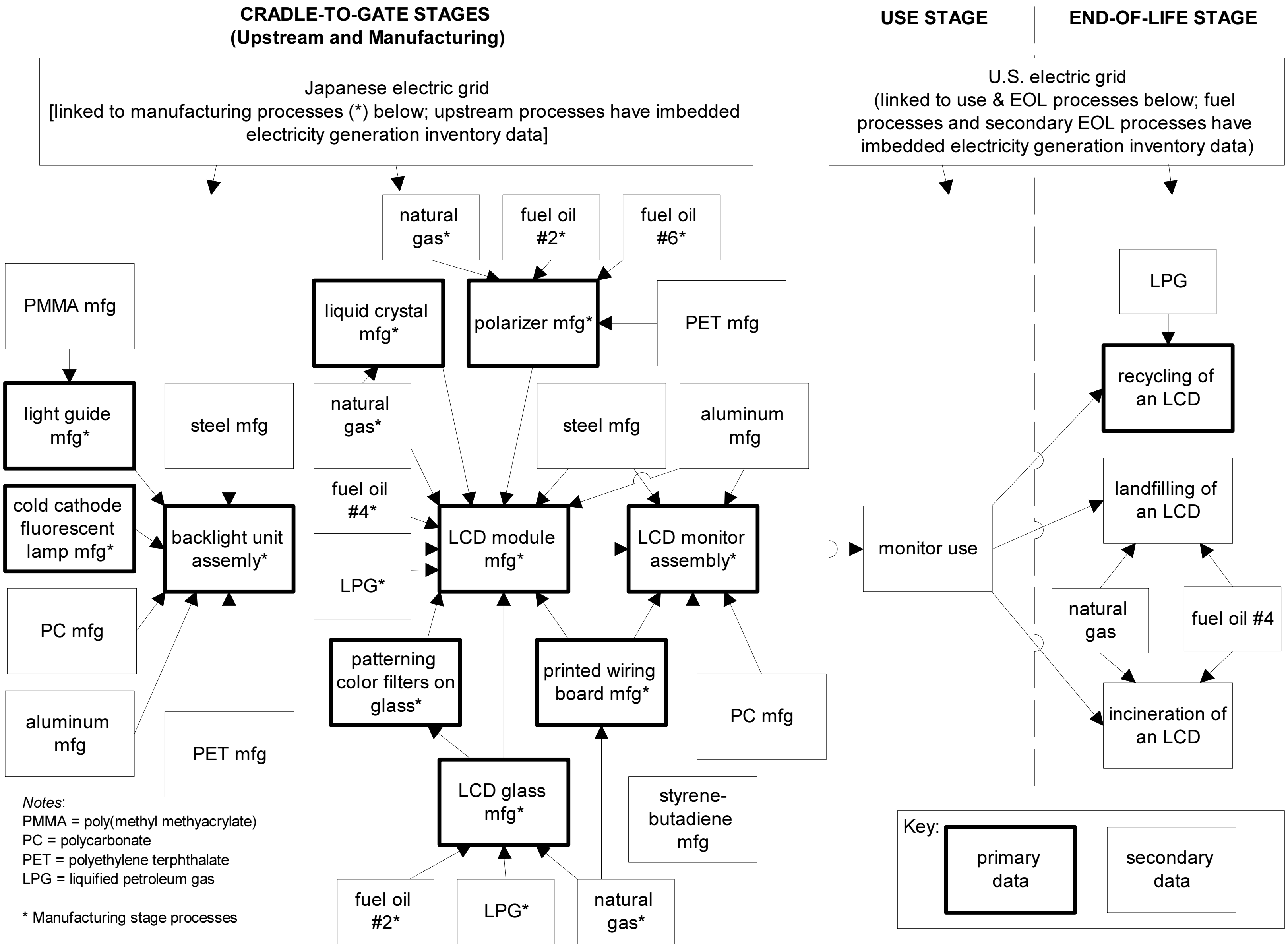
An LCI is the identification and quantification of the material and resource inputs and emission and product outputs from the unit processes in the life cycle of a product system. For the DfE CDP, LCI inputs include materials used in the computer display product itself, ancillary materials used in processing and manufacturing the displays, and energy and other resources consumed in the manufacturing, use, or final disposition of the displays. Outputs include products, air emissions, water effluents, and releases to land. Figures ES-1 and ES-2 show the unit processes that are included in the scope of this project for the CRT and LCD life cycles, respectively.



Notes:
LPG = liquified petroleum gas
HIPS = high impact polystyrene
ABS = acrylonitrile butadiene styrene
PC = polycarbonate

* Manufacturing stage processes

Figure ES-1. CRT linked processes



Notes:
PMMA = poly(methyl methyacrylate)
PC = polycarbonate
PET = polyethylene terphthalate
LPG = liquified petroleum gas

* Manufacturing stage processes

Figure ES-2. LCD linked processes

Data were also collected on the final disposition of emissions outputs, such as whether outputs are released directly to the environment, recycled, treated, and/or disposed. This information helps determine which impacts will be calculated for a particular inventory item. Methods for calculating impacts are discussed in Chapter 3, Life-cycle Impact Assessment.

Given the enormous amount of data involved in inventorying all of the inputs and outputs for a product system, decision rules, based on the mass, environmental, energy, and functional significance, were used to determine which materials or unit processes to include in the LCI. Decision rules are designed to make data collection manageable while still representative of the product system and its impacts. Data were collected from both primary and secondary sources. Table ES-2 lists the types of data (primary or secondary) used for each life-cycle stage in the CDP LCI. In general, greater emphasis was placed on collecting data and/or developing models for the product manufacturing, use, and end-of-life life-cycle stages.

Table ES-2. Data types by life-cycle stage

Life-cycle stage	Data types
Upstream (materials extraction and processing)	Secondary data.
Product and component manufacturing	Primary data, except secondary data used for frit.
Use	Modeled using secondary data; maintenance and repair are not included in the analysis.
Final disposition (recycling and/or disposal)	Modeled using secondary data plus primary data from CRT recycling facilities.
Packaging, transportation, distribution	Not included.

In the CDP LCI, data were allocated to the functional unit (i.e., a desktop computer display over its lifetime) as appropriate. The data that were collected for this study were either obtained from questionnaires developed for this project (i.e., primary data) or from existing databases (i.e., secondary data). LCI data were imported into a Life-Cycle Design Software Tool developed by the UT Center for Clean Products and Clean Technologies with funding from the EPA Office of Research and Development and Saturn Corporation. The UT Life-Cycle Design Software Tool organizes data in such a way that each process inventory is independent. Customized “profiles” (e.g., the manufacture of a CRT or the whole life-cycle of an LCD) can be developed by linking processes.

LCI data quality was evaluated based on the following data quality indicators (DQIs): (1) the source type (i.e., primary or secondary data sources); (2) the method in which the data were obtained (i.e., measured, calculated, estimated); and (3) the time period for which the data are representative. Any proprietary information required for the assessment was aggregated to protect confidentiality.

A critical review process was maintained in the CDP LCA to help ensure that appropriate methods were employed and study goals were met. A project Core Group and Technical Work Group, both consisting of representatives from industry, academia, and government, including EPA’s DfE Work Group, provided critical reviews of the assessment. The Core Group served as the project steering committee and was responsible for approving all major scoping assumptions and decisions. The Technical Work Group and EPA’s DfE Work Group provided technical guidance and were given the opportunity to review all major project deliverables, including the final LCA report.

Upstream Life-cycle Stage Methodology

The materials extraction and processing inventories for key materials were obtained from a secondary LCI database developed by *Ecobilan* (1999). The U.S. electric grid inventory was developed from secondary sources by UT. The U.S. electric grid inventory was then modified, based on the distribution of fuels used in Japan, to develop the Japanese electric grid, which was used where manufacturing occurs in Asia. Electricity consumed in the life-cycles of the monitors was linked to the inventory of inputs and outputs from the U.S. or Japanese electric grid inventories, as appropriate.

Manufacturing Stage Methodology

The inventories for the product manufacturing life-cycle stage were developed from primary data collected from manufacturers in Asia and the United States. The manufacturing processes included in the study, as well as the number of data sets for each process and the country of origin of the data, are presented in Table ES-3. A total of 27 product manufacturing questionnaires were collected for 11 different processes. Allocation of data to the functional unit was conducted as necessary. Processes for which we collected more than one company's data were averaged together.

The quality of the manufacturing stage data can be evaluated against two factors: (1) the date of the data; and (2) the type of data (i.e., measured, calculated or estimated). The data collection phase of this project began in 1997 and extended through 2000. Some processes are more sensitive to production dates than others. Most processes included in this analysis are mature technologies and are not expected to differ significantly between the years 1997 and 2000. However, an exception is LCD panel/module manufacturing, which is an evolving and rapidly advancing process and has seen changes between these years. For the LCD panel and module manufacturing process, most data were from 1998 and 1999.

Data quality indicators were developed based on whether data were measured, calculated, or estimated, as reported in company data questionnaires. The weighted average of data collected and their associated DQIs are as follows: for the CRT, 43% of the data were measured, 34% calculated, 13% estimated, and 10% were not classified. For the LCD, a similar distribution shows 33% measured, 30% calculated, 23% estimated, and 14% not classified.

Product Use Life-cycle Stage Methodology

The baseline analysis in this project employs an effective life use stage scenario (the actual amount of time a monitor is used, by one or multiple users, before it is disposed of, recycled, or re-manufactured). A manufactured life scenario (the amount of time either an entire monitor or a single component will last before reaching a point where the equipment no longer functions, independent of user choice) is evaluated in a sensitivity analysis.

Table ES-3. Location of companies and number of process data sets

Process	**Country of origin of data (# of data sets)**
CRT monitor assembly	Japan (2), U.S. (1)
CRT (tube) manufacturing	Japan (2), U.S. (1)
CRT leaded glass manufacturing	Japan (1), U.S. (2)
CRT frit manufacturing	generic secondary data from the U.S.
LCD monitor assembly	Japan (2)
LCD panel and module manufacturing [a]	Japan (5), Korea (2)
LCD - glass manufacturing	Japan and U.S. (1) [b]
LCD - color filter patterning on front glass	Japan (1)
LCD - liquid crystal manufacturing	Japan (2)
LCD - polarizer manufacturing	Japan (1)
LCD - backlight unit assembly	Japan (3)
LCD - backlight light guide manufacturing	Japan (1)
LCD - cold cathode fluorescent lamp (CCFL) manufacturing	Japan (1)
PWB manufacturing (for CRT and LCD monitors)	generic secondary data from the U.S.

[a] The LCD *panel* consists of two glass panels patterned with transistors and color filters, liquid crystals inserted between the panels, and associated row and column drivers. The LCD *module* consists of the panel, backlight unit, and associated electronic boards for the entire panel, and the backlight.

[b] The average of three data sets for CRT leaded glass manufacturing was modified to remove lead from the inventory.

To develop the use stage inventory, energy use rates [e.g., kilowatts (kW)] were combined with the time a desktop monitor is on during its lifespan (hours/life) to calculate the total quantity of electrical energy consumed during the use life-cycle stage [e.g., kilowatthours (kWh)/life]. This was then combined with the electric grid inventory of inputs and outputs per kWh to make up the use stage inventory per monitor. The effective life scenario models the actual quantity of hours that an average monitor spends in each of the two primary power consumption modes (full-on and a lower power state) during its lifetime. Assumptions used to calculate the kilowatthours per effective life are detailed in Section 2.4. The total electricity consumption for each monitor was calculated to be 634 kWh/effective life (2,282 MJ/effective life) for the CRT and 237 kWh/effective life (853 MJ/effective life) for the LCD.

End-of-life (EOL) Methodology

For the EOL analysis, a monitor is assumed to have reached EOL status when:

- it has served its useful life;
- is no longer functional; and/or
- is rendered unusable due to technological obsolescence.

The major EOL dispositions considered in this analysis are as follows:

- recycling - including disassembly and materials recovery;
- landfilling - including hazardous [Resource Conservation and Recovery Act (RCRA), Subtitle C] and non-hazardous (RCRA, Subtitle D) landfills;
- remanufacturing - including refurbishing or reconditioning (to make usable again); and
- incineration - waste to energy incineration.

The functional unit in this analysis is one monitor; therefore, the different EOL dispositions were allocated as a probability of one monitor going to a certain EOL disposition. Data were somewhat scarce on the percent of monitors going to each disposition, especially for LCD monitors, which have not as yet reached EOL. After literature research and consultation with the project's Technical Work Group, as well as various other industry experts, project partners chose best estimates of disposition distributions (Table ES-4).

Table ES-4. Distribution of EOL disposition assumptions for the CRT and LCD

Disposition	CRT	LCD
Incineration	15%	15%
Recycling	11%	15%
Remanufacturing	3%	15%
Hazardous waste landfill	46%	5%
Solid waste landfill	25%	50%

Sources: NSC, 1999; EPA, 1998; CIA, 1997; EIA, 1999; Vorhees, 2000; TORNRC, 2001

Primary data were collected for CRT recycling from three companies. The data from these companies represent facility operations ranging from October 1999 to February 2000. In the absence of actual data for LCD recycling, data on a CRT shredding-and-materials-recovery process was used to model LCD recycling.

Hazardous/solid waste landfilling and incineration were developed from secondary data obtained from *Ecobilan*. Although data specific to landfilling and incineration operations for monitors alone were not available, existing inventories were available for landfilling and incinerating the following major monitor materials (by weight): steel, glass, plastic, and aluminum. These inventories were combined, based on the approximate proportion of each material in a CRT and an LCD, to create individual processes for landfilling and for incineration (for each monitor type). The majority of the assembled monitors by weight is accounted for in the overall incineration and landfilling processes.

Remanufacturing data were excluded from the assessment because no single set of operations could be identified to adequately represent remanufacturing activities that could be incorporated in our model.

LCI Limitations and Uncertainties

Several factors contribute to the overall quality of data for each life-cycle stage. For example, the manufacturing stage includes several different processes that were collected from several different companies. The quality of one data set from one company may be very different from that of another company. Relative data quality estimates have been made for each life-cycle stage, including electricity generation, which is included in the results of more than one life-cycle stage (Table ES-7). The table also lists the major limitations associated with each life-cycle stage.

Table ES-7. Relative data quality and major limitations

Life-cycle stage	Relative data quality	Major limitations
Upstream	Moderate	Used only secondary data, which has undetermined quality and not originally collected for the purpose of the CDP.
Manufacturing	Moderate to high	A few data points remain in question.
Use	Moderate to high	Assumptions regarding use patterns were made.
EOL	Low to moderate	Used only secondary data for incineration and landfilling processes; no data available for remanufacturing process.
Electricity generation	High	Used secondary data, however it was collected and modeled for the CDP, resulting in a higher quality rating despite use of secondary data.

Although the manufacturing stage was rated in Table ES-7 as having moderate to high data quality, some of the few data points that remained in question had large effects on the results and are therefore described below. Of the data collected from manufacturers, several attempts were made to verify or eliminate outliers in the data; however, uncertainty in some data remained due to large data ranges and outliers. Specific data with the greatest uncertainty include: (1) LCD glass manufacturing data; (2) CRT and LCD glass manufacturing energy inputs; (3) the distribution and amount of fuel/electricity inputs for LCD module manufacturing; and (4) the use of a large amount of liquified natural gas (LNG) as an “ancillary material” in LCD module manufacturing and not as a fuel.

Uncertainties in the LCD glass manufacturing data stem from the fact that no LCD glass manufacturers were willing to supply inventory data. Therefore, the LCD glass manufacturing inventory was derived from the CRT glass manufacturing data modified to exclude leaded compounds from the inventory. Thus, the baseline analysis in this study assumes the energy use per kilogram of CRT glass and LCD glass are equivalent, which is uncertain. In addition to the uncertainty in the difference between energy used to manufacture CRT glass and LCD glass, the energy reported to produce a kilogram of CRT glass varied greatly between the three data sets received for this project, with the highest total energy value being about 150 times that of the smallest value. Due to this large discrepancy and because there were not enough data sets to evaluate the data for outliers, the glass energy data were evaluated in a sensitivity analysis. The high glass energy use values were mostly a function of liquefied petroleum gas (LPG) used as a fuel.

Other data for which large ranges were reported, and which could be important to the results, are energy data from LCD panel/module manufacturing. Energy data provided by six LCD panel/module manufacturers were highly variable in both the distribution of energy sources and the total energy required to produce one LCD panel. The percent of energy from electricity ranged from approximately 3% to 87%, and the total energy per panel ranged from 440 MJ to 7,000 MJ. The average energy use per panel was approximately 2,270 MJ, and the standard deviation was about 2,910 MJ.

Given the wide variability in the data and large standard deviation, CDP researchers evaluated these data for outliers. One data set was found to be a minor outlier and another was found to be a major outlier. These outliers were excluded from the averages used in the baseline analysis, but included in the averages used in a sensitivity analysis (see Section 2.7.3.3).

Finally, a large amount of LNG (194 kg, on average) was reported to be used as an ancillary material (not a fuel) in LCD panel/module manufacturing. CDP researchers confirmed this application of LNG and the amount with the company providing the data, but it is still uncertain due to problems in communication (e.g., the language barrier). This data point remained in the inventory data set for LCD manufacturing, and was assumed to indeed be an ancillary material, and not a fuel. Keeping the LNG ancillary material in the inventory will not affect the energy impact results, since LNG used as an ancillary material is only linked to the production of that material, and not to the use of it as a fuel.

Baseline LCI Results

Tables ES-5 and ES-6 present the total quantity of inputs and outputs for each life-cycle stage of the CRT and LCD based on input and output types.

Table ES-5. CRT inventory by life-cycle stage

Inventory type	Upstream	Mfg	Use	EOL	Total	Units [a]
Inputs						
Primary materials	1.58e+01	4.21e+02	2.19e+02	-3.32e+00	6.53e+02	kg
Ancillary materials	2.11e+00	3.54e+00	3.47e+00	1.07e+01	1.98e+01	kg
Water	5.54e+02	1.14e+04	1.14e+03	-2.73e+01	1.31e+04	kg (or L)
Fuels	8.00e+00	4.28e+02	0	-2.95e+00	4.33e+02	kg
Electricity	7.32e+01	1.29e+02	2.29e+03	2.29e-01	2.49e+03	MJ [b]
Total energy	3.66e+02	1.83e+04	2.29e+03	-1.28e+02	2.08e+04	MJ [b]
Outputs						
Air pollutants	3.00e+01	1.83e+02	4.49e+02	2.47e+00	6.64e+02	kg
Wastewater	1.70e+01	1.51e+03	0	-3.65e+00	1.52e+03	kg (or L)
Water pollutants	8.12e-01	2.01e+01	7.02e-02	-6.18e-02	2.09e+01	kg
Hazardous waste	4.89e+02	1.13e+02	0	8.28e+00	9.46e+00	kg
Solid waste	9.55e+00	8.12e+01	8.33e+01	-1.66e+00	1.72e+02	kg
Radioactive waste	4.39e-04	1.80e-04	2.28e-03	2.29e-07	2.90e-03	kg
Radioactivity	3.80e+07	3.78e+06	4.80e+07	4.80e+03	8.98e+07	Bq

[a] Per functional unit (i.e., one CRT monitor over its effective life).

[b] 3.6 MJ = 1 kWh

Table ES-6. LCD inventory by life-cycle stage

Inventory type	Upstream	Mfg	Use	EOL	Total	Units [a]
Inputs						
Primary materials	2.35e+02	4.92e+01	8.01e+01	-2.19e+00	3.62e+02	kg
Ancillary materials	1.06e+00	2.04e+02	1.29e+00	2.11e+00	2.08e+02	kg
Water	2.63e+02	2.15e+03	4.25e+02	-1.80e+01	2.82e+03	kg
Fuels	1.47e+01	2.58e+01	0	-1.95e+00	3.86e+01	kg (or L)
Electricity	3.46e+01	3.16e+02	8.53e+02	1.62e-01	1.20e+03	MJ [b]
Total energy	6.33e+02	1.44e+03	8.53e+02	-8.44e+01	2.84e+03	MJ [b]
Outputs						
Air pollutants	1.12e+02	6.48e+01	1.68e+02	1.30e+00	3.46e+02	kg
Wastewater	8.57e+00	3.12e+03	0	-2.41e+00	3.13e+03	kg
Water pollutants	4.60e-01	1.23e+00	2.62e-02	-4.09e-02	1.68e+00	kg (or L)
Hazardous waste	6.72e-03	4.64e+00	0	1.64e+00	6.29e+00	kg
Solid waste	1.31e+01	1.26e+01	3.11e+01	-4.42e+00	5.23e+01	kg
Radioactive waste	2.21e+01	3.14e+03	3.11e+01	-5.23e+00	3.19e+03	kg
Radioactivity	1.20e+07	1.02e+07	1.79e+07	3.40e+03	4.01e+07	Bq

[a] Per functional unit (i.e., one LCD monitor over its effective life).

[b] 3.6 MJ = 1 kWh

The total inventory results for life-cycle inputs reveal that more primary materials,[1] water, fuels, electricity, and total energy (i.e., fuel energy plus electricity) are used throughout the CRT life-cycle, while more ancillary materials are used throughout the LCD life-cycle. For the life-cycle outputs, the CRT releases more air emissions; water pollutants; hazardous, solid, and radioactive waste; and radioactivity than the LCD. The LCD releases more total wastewater than the CRT. Complete inventory tables for each input and output type by life-cycle stage for the CRT and LCD are provided in Appendix J.

For the CRT (Table ES-5), of the inputs measured in mass, the water inputs in the manufacturing life-cycle stage constitute the majority of the inputs for the entire life cycle. Water inputs from the LPG production process constitute almost 80% of the water inputs for all life-cycle stages. In this inventory, the LPG is used in large quantities as a fuel in CRT glass manufacturing. When considering which life-cycle stage contributes most to an inventory category, the manufacturing stage has the largest inventory by mass for primary materials, ancillary materials, water inputs, and fuel inputs. This is also due to the production of LPG as needed for CRT glass production. Fuel inputs are dominated by the manufacturing stage and electricity inputs are dominated by the use stage. The total energy (which is calculated by converting the mass of the fuel into units of energy and combining the fuel energy with the electrical energy) is dominated by the manufacturing life-cycle stage, again mostly due to the large LPG fuel energy used in CRT glass production.

CRT outputs measured in mass include air emissions, wastewater, water pollutants, and hazardous, solid, and radioactive waste. Wastewater, by mass (or volume), constitutes the greatest output; however, total wastewater volume is not used to calculate water-related impacts. Instead, individual water pollutants are used to calculate water-related impacts. Of the remaining outputs measured in mass, which are used to calculate impacts (i.e., air emissions, and hazardous, solid and radioactive waste), air emissions are the greatest contributor to outputs in mass. Note that radioactivity is measured in Bequerels (Bq) and cannot be compared on the same scale.

Considering each CRT inventory type and their contributions by life-cycle stage, the mass of wastewater and water pollutants are greatest in the manufacturing life-cycle stage (again due to LPG consumption). The outputs of air emissions, hazardous waste, solid waste, radioactive waste, and radioactivity all have the greatest contribution from the use stage.

For the CRT outputs, all the totals represented in Table ES-5 include outputs to all dispositions. For example, water outputs sent offsite to treatment as well as those directly discharged to surface waters are all included. Similarly, hazardous, solid and radioactive waste outputs may be landfilled, treated, or recycled. The inventory shows these as totals; however, when impacts are calculated, the dispositions dictate which inventory items will be used to calculate impacts (Chapter 3).

For the LCD (Table ES-6), of the inputs measured in mass, the water inputs constitute the majority of the inputs for the entire life cycle, and most of the water inputs are in the manufacturing life-cycle stage. When considering which life-cycle stage contributes most to an inventory category, the manufacturing stage has the largest inventory by mass for ancillary materials, fuels, and water inputs. Primary material inputs are dominated by the upstream stages,

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[1] Note that the total mass of primary materials includes the inputs to each process, which may duplicate materials used in processes subsequent to other processes. For example, the primary materials used in steel production are added to the steel used as a primary material for monitor assembly.

while electricity inputs are dominated by the use stage. The total energy is dominated by the manufacturing life-cycle stage. Note that LPG production from glass manufacturing does not dominate much of the LCD inventory as it did for the CRT, because of the smaller amount of glass used in the LCD compared to the CRT.

Of the LCD outputs measured in mass (air emissions, wastewater, water pollutants and hazardous, solid, and radioactive waste), wastewater constitutes the greatest output; however, total wastewater volume alone is not used to calculate impacts. Of the remaining outputs measured in mass, which are used to calculate impacts (i.e., air emissions, water pollutants, and hazardous, solid and radioactive waste), air emissions are the greatest contributor to the outputs. Note again, as mentioned for the CRT, that radioactivity is measured in Bequerels (Bq) and cannot be compared on the same scale.

Considering each LCD output type and their contributions by life-cycle stage, the mass of water pollutants is greatest in the manufacturing life-cycle stage, due to the fuel production processes that support fuel consumption in the manufacturing processes being included in the manufacturing life-cycle stage. Wastewater and hazardous waste outputs are greatest in the manufacturing stage; air emissions, solid waste, radioactive waste, and radioactivity have the greatest contribution from the use stage. As with the CRT, all the output totals represented in Table ES-6 include outputs to all dispositions.

III. LIFE-CYCLE IMPACT ASSESSMENT (LCIA)

LCIA Methodology

LCIA involves the translation of the environmental burdens identified in the LCI into environmental impacts. LCIA does not seek to determine actual impacts, but rather to link the data gathered from the LCI to impact categories and to quantify the relative magnitude of contribution to the impact category (Fava *et al.,* 1993; Barnthouse *et al.,* 1997). Further, impacts in different impact categories are generally calculated based on differing scales and therefore cannot be directly compared.

Within LCA, the LCI is a well established methodology; however, LCIA methods are less well defined and continue to evolve (Barnthouse *et al.,*1997; Fava *et al.,* 1993). For toxicity impacts in particular, there are some methods being applied in practice (e.g., toxicity potentials, critical volume, and direct valuation) (Guinee *et al*., 1996; ILSI, 1996; Curran, 1996), while others are in development. However, there is currently no general consensus among the LCA community as to one method over another.

The UT LCIA methodology employed in this study calculates life-cycle impact category indicators for a number of traditional impact categories, such as global warming, stratospheric ozone depletion, photochemical smog, and energy consumption. Furthermore, the method calculates relative category indicators for potential chronic human health, aquatic ecotoxicity, and terrestrial ecotoxicity impacts in order to address project partner's interest in human and ecological toxicity and to fill a common gap in LCIAs.

LCIAs generally classify the consumption and loading data from the inventory stage into various impact categories (know as "classification"). "Characterization" methods are then used to quantify the magnitude of the contribution that loading or consumption could have in producing the associated impact. The impact categories included in the CDP LCIA are as follows: renewable resource use, nonrenewable materials use/depletion, energy use, solid waste landfill use, hazardous waste landfill use, radioactive waste landfill use, global warming, stratospheric ozone depletion, photochemical smog, acidification, air quality (particulate matter loading), water eutrophication (nutrient enrichment), water quality (biological oxygen demand [BOD] and total suspended solids [TSS]), radioactivity, chronic human health effects (occupational and public), aesthetic impacts (odor), aquatic ecotoxicity, and terrestrial ecotoxicity.

Classification of an inventory item into impact categories depends on whether the inventory item is an input or output, what the disposition of the output is, and in some cases the material properties of the inventory item. Outputs with direct release dispositions are classified into impact categories for which impacts will be calculated in the characterization phase of the LCIA. Outputs sent to treatment or recycle/reuse are considered inputs to treatment or recycle/reuse processes and impacts are not calculated until direct releases from these processes occur. Once impact categories for each inventory item are classified, life-cycle impact category indicators are quantitatively estimated through the characterization step.

The characterization step of LCIA includes the conversion and aggregation of LCI results to common units within an impact category. Different assessment tools are used to quantify the magnitude of potential impacts, depending on the impact category. Three types of approaches are used in the characterization method for the CDP:

- **Loading** - An impact score is based on the inventory amount (e.g., resource use).
- **Equivalency** - An impact score is based on the inventory amount weighed by a certain effect, equivalent to a reference chemical [e.g., global warming impacts relative to carbon dioxide (CO_2)].
    - *Full equivalency* - all substances are addressed in a unified, technical model.
    - *Partial equivalency* - a subset of substances can be converted into equivalency factors.
- **Scoring of inherent properties** - An impact score is based on the inventory amount weighed by a score representing a certain effect for a specific material (e.g., toxicity impacts are weighed using a toxicity scoring method).

The scoring of inherent properties method is employed for the human and ecological toxicity impact categories, based on the CHEMS-1 method described by Swanson *et al*. (1997). The scoring method provides a hazard value (HV) for each potentially toxic material, which is then multiplied by the inventory amount to calculate the toxicity impact score.

Using the various approaches, the UT LCIA method calculates impact scores for each inventory item for each applicable impact category. Impact scores are therefore based on either a direct measure of the inventory amount or some modification (e.g., equivalency or scoring) of that amount based on the potential effect the inventory item may have on a particular impact category. The specific calculation methods for each impact category are detailed in Chapter 3. Impact scores are then aggregated within each impact category to calculate the various life-cycle impact category indicators.

General LCIA Methodology Limitations and Uncertainties

The purpose of an LCIA is to evaluate the *relative potential* impacts of a product system for various impact categories. There is no intent to measure the *actual* impacts or provide spatial or temporal relationships linking the inventory to specific impacts. The LCIA is intended to provide a screening-level evaluation of impacts. In addition to lacking temporal or spatial relationships and providing only relative impacts, LCA is also limited by the availability and quality of the inventory data. Data collection can be very time consuming and expensive. Confidentiality issues may also inhibit the availability of primary data.

Uncertainties are inherent in each parameter used to calculate impacts. For example, toxicity data require extrapolations from animals to humans and from high to low doses (for chronic effects) and can have a high degree of uncertainty.

Uncertainties also are inherent in chemical ranking and scoring systems, such as the scoring of inherent properties approach used for human health and ecotoxicity effects. In particular, systems that do not consider the fate and transport of chemicals in the environment can contribute to misclassifications of chemicals with respect to risk. Also, uncertainty is introduced where it was assumed that all chronic endpoints are equivalent, which is likely not the case. The human health and ecotoxicity impact characterization methods presented here are screening tools that cannot substitute for more detailed risk characterization methods. However, it should be noted that in LCA, chemical toxicity is often not considered at all. This methodology is an attempt to consider chemical toxicity where it is often ignored.

Uncertainty in the inventory data depends on the responses to the data collection questionnaires and other limitations identified during inventory data collection. These uncertainties are carried into impact assessment. In this LCA, there was uncertainty in the inventory data, which included but was not limited to the following:

- missing individual inventory items,
- missing processes or sets of data,
- measurement uncertainty,
- estimation uncertainty,
- allocation uncertainty/working with aggregated data, and
- unspeciated chemical data.

The goal definition and scoping process helped reduce the uncertainty from missing data, although it is certain that some missing data still exist. As far as possible, the remaining uncertainties were reduced primarily through quality assurance/quality control measures (e.g., performing systematic double-checks of all calculations on manipulated data).

Baseline LCIA Results

Table ES-8 presents the baseline CRT and LCD LCIA indicator results for each impact category. Appendix M presents complete LCIA results by material, process, and life-cycle stage. The indicator results presented in Table ES-8 are the result of the characterization step of LCIA methodology where LCI results are converted to common units and aggregated within an impact category. Note that the impact category indicator results are in a number of different units and therefore can not be summed or compared across impact categories.

As shown in the table, under the baseline conditions the CRT indicators are greater than the LCD indicators in the following categories: renewable resource use, nonrenewable resource use, energy use, solid waste landfill use, hazardous waste landfill use, radioactive waste landfill use, global warming, ozone depletion, photochemical smog, acidification, air particulates, biological oxygen demand (BOD), total suspended solids (TSS), radioactivity, chronic public health effects, chronic occupational health effects, aesthetics, and terrestrial toxicity. The LCD indicators are greater than the CRT indicators in the following categories: water eutrophication and aquatic toxicity. In addition, as noted in Table ES-8, if phased-out substances are removed from the CRT and LCD inventories, the LCD ozone depletion indicator would exceed that of the CRT. Details of each impact category and major contributors to the impacts in those categories are presented in Chapter 3.

Summary of Top Contributors by Impact Category

Tables ES-9 and ES-10 summarize the top contributors to CRT and LCD life-cycle impacts by impact category. As shown in Table ES-9, CRT impacts are largely driven by two factors: (1) the large amount of LPG fuel used in CRT glass/frit manufacturing, and (2) the relatively large amount of electricity consumed during the use stage. The LPG production process yields the CRT's top contributor in eight of 20 impact categories. Most of this LPG is used as a fuel source in CRT glass manufacturing in the glass/frit process group, which, in turn, produces the top contributor to two of 20 impact categories. Thus, LPG used in the glass/frit process group (primarily CRT glass manufacturing) is ultimately the key driver for CRT impacts in ten categories. Similarly, outputs from electricity generation during the use stage result in the

Table ES-8. Baseline life-cycle impact category indicators[a]

Impact category	Units per monitor	CRT	LCD
Renewable resource use	kg	**1.31E+04**	2.80E+03
Nonrenewable resource use	kg	**6.68E+02**	3.64E+02
Energy use	MJ	**2.08E+04**	2.84E+03
Solid waste landfill use	m^3	**1.67E-01**	5.43E-02
Hazardous waste landfill use	m^3	**1.68E-02**	3.61E-03
Radioactive waste landfill use	m^3	**1.81E-04**	9.22E-05
Global warming	kg-CO_2 equivalents	**6.95E+02**	5.93E+02
Ozone depletion	kg-CFC-11 equivalents	2.05E-05[b,c]	1.37E-05[b]
Photochemical smog	kg-ethene equivalents	**1.71E-01**	1.41E-01
Acidification	kg-SO_2 equivalents	**5.25E+00**	2.96E+00
Air particulates	kg	**3.01E-01**	1.15E-01
Water eutrophication	kg-phosphate equivalents	4.82E-02	**4.96E-02**
Water quality, BOD	kg	**1.95E-01**	2.83E-02
Water quality, TSS	kg	**8.74E-01**	6.15E-02
Radioactivity	Bq	**3.85E+07**[d]	1.22E+07[d]

Table ES-8. Baseline life-cycle impact category indicators[a]

Impact category	Units per monitor	CRT	LCD
Chronic health effects, occupational	tox-kg	**9.34E+02**	6.96E+02
Chronic health effects, public	tox-kg	**1.98E+03**	9.02E+02
Aesthetics (odor)	m^3	**7.58E+06**	5.04E+06
Aquatic toxicity	tox-kg	2.25E-01	**5.19E+00**
Terrestrial toxicity	tox-kg	**1.97E+03**	8.94E+02

[a] Bold indicates the larger value within an impact category when comparing the CRT and LCD.

[b] Several of the substances included in this category were phased out of production by January 1, 1996. Excluding phased out substances decreases the CRT ozone depletion indicator to 1.09E-05 kg CFC-11 equivalents per monitor and the LCD ozone depletion indicator to 1.18E-05 kg CFC-11 equivalents per monitor. These ozone depletion indicators are probably more representative of the CDP temporal boundaries and current operating practices. See section 3.3.6 for details.

[c] Although the CRT indicator appears larger than the LCD indicator, uncertainties in the inventory make it difficult to determine which monitor has the greater value. Therefore, this value is not shown in bold.

[d] Radioactivity impacts are being driven by radioactive releases from nuclear fuel reprocessing in France, which are included in the electricity data in some of the upstream, materials processing data sets. See section 3.3.12 for details.

top contributor to seven CRT impact categories. Note that in 14 of the 20 impact categories, the top contributor to CRT impacts is responsible for more than 50% of impacts.

LCD impacts are not as dominated by a few data points, but a few processes (LCD monitor/module manufacturing and electricity generation in the use stage) are responsible for a large percent of the impacts. As shown in Table ES-10, both of these processes result in the top contributors to six LCD impact categories each. In addition, the process to produce LNG used as an ancillary material in LCD monitor/module manufacturing is the top contributor to an additional impact category (photochemical smog). Note that in 11 of the 20 impact categories, the top contributor to LCD impacts is responsible for more than 50% of impacts.

As a number of the impact results for both monitor types, and for the CRT in particular, are being driven by a few data points with relatively high uncertainty, sensitivity analyses of the baseline results were also conducted.

Table ES-9. Summary of top contributors to CRT impacts by impact category

Impact category	Top contributors			
	Life-cycle stage	Process group	Material	Contribution to impact score
Renewable resource use	Manufacturing	LPG production	water	79%
Nonrenewable resource use	Manufacturing	LPG production	Petroleum (in ground)	56%
Energy use	Manufacturing	CRT glass/frit mfg.	Liquefied petroleum gas	72%
Solid waste landfill use	Use	U.S. electric grid	Coal waste	38%

Table ES-9. Summary of top contributors to CRT impacts by impact category

Impact category	**Top contributors**			
	Life-cycle stage	**Process group**	**Material**	**Contribution to impact score**
Hazardous waste landfill use	End-of-life	CRT landfilling	EOL CRT monitor, landfilled	91%
Radioactive waste landfill use	Use	U.S. electric grid	Low-level radioactive waste	61%
Global warming	Use	U.S. electric grid	Carbon dioxide	64%
Ozone depletion	Use	U.S. electric grid	Bromomethane	49%
Photochemical smog	Manufacturing	LPG production	Hydrocarbons, unspeciated	36%
Acidification	Use	U.S. electric grid	Sulfur dioxide	47%
Air particulates	Manufacturing	LPG production	PM	43%
Water eutrophication	Manufacturing	LPG production	COD	72%
Water quality, BOD	Manufacturing	LPG production	BOD	96%
Water quality, TSS	Manufacturing	LPG production	Suspended solids	97%
Radioactivity	Materials Processing	Steel production, cold-rolled, semi-finished	Plutonium-241 (isotope)	62%
Chronic health effects, occupational	Manufacturing	CRT glass/frit manufacturing	Liquefied petroleum gas	78%
Chronic health effects, public	Use	U.S. electric grid	Sulfur dioxide	83%
Aesthetics (odor)	Manufacturing	LPG production	Hydrogen sulfide	94%
Aquatic toxicity	Manufacturing	CRT tube manufacturing	Phosphorus (yellow or white)	26%
Terrestrial toxicity	Use	U.S. electric grid	Sulfur dioxide	83%

Table ES-10. Summary of top contributors to LCD impacts by impact category

Impact category	**Top contributors**			
	Life-cycle stage	**Process group**	**Material**	**Contribution to impact score**
Renewable resource use	Manufacturing	LCD monitor/module mfg.	Water	38%
Nonrenewable resource use	Materials processing	Natural gas production	Natural gas (in ground)	65%
Energy use	Use	LCD monitor use	Electricity	30%
Solid waste landfill use	Use	U.S. electric grid	Coal waste	44%
Hazardous waste landfill use	End-of-life	LCD landfilling	EOL LCD monitor, landfilled	97%
Radioactive waste landfill use	Use	U.S. electric grid	Low-level radioactive waste	44%

Table ES-10. Summary of top contributors to LCD impacts by impact category

Impact category	**Top contributors**			
	Life-cycle stage	**Process group**	**Material**	**Contribution to impact score**
Global warming	Manufacturing	LCD monitor/module mfg.	Sulfur hexafluoride	29%
Ozone depletion	Manufacturing	LCD panel components manufacturing	HCFC-225cb	34%
Photochemical smog	Materials processing	Natural gas production	Nonmethane hydrocarbons, unspeciated	45%
Acidification	Use	U.S. electric grid	Sulfur dioxide	31%
Air particulates	Materials processing	Steel production, cold-rolled, semi-finished	PM	45%
Water eutrophication	Manufacturing	LCD monitor/module mfg.	Nitrogen	67%
Water quality, BOD	Manufacturing	LCD monitor/module mfg.	BOD	61%
Water quality, TSS	Manufacturing	LPG production	Suspended solids	66%
Radioactivity	Materials processing	Steel production, cold-rolled, semi-finished	Plutonium-241 (isotope)	96%
Chronic health effects, occupational	Manufacturing	LCD monitor/module mfg.	Liquefied natural gas	58%
Chronic health effects, public	Use	U.S. electric grid	Sulfur dioxide	68%
Aesthetics (odor)	Manufacturing	LPG production	Hydrogen sulfide	94%
Aquatic toxicity	Manufacturing	LCD monitor/module mfg.	Phosphorus (yellow or white)	98%
Terrestrial toxicity	Use	U.S. electric grid	Sulfur dioxide	68%

Sensitivity Analyses

Due to assumptions and uncertainties in this LCA, as in any LCA, the following sensitivity analyses of the baseline results were conducted: use stage manufactured life scenario, modified glass energy assumptions, modified LCD module manufacturing energy assumptions, and modified LCD EOL distribution assumptions. The sensitivity analyses were chosen because they evaluated data with either the greatest uncertainties or with large uncertainty and major contributors to the inventory results. Table ES-11 shows the different sensitivity analyses or scenarios that are considered in the impact assessment results.

Table ES-11. List of sensitivity analysis scenarios

Monitor type	Sensitivity analysis scenario
Baseline analyses (for reference)	
CRT	Effective life scenario with average glass energy inputs (all glass manufacturing energy data used)
LCD	Effective life scenario with average glass energy inputs (all glass manufacturing energy data used) and outliers in the LCD module manufacturing energy data removed
Sensitivity analyses	
CRT	Manufactured life scenario same as baseline except lifespan is based on manufactured life instead of effective life, which results in some revised functional equivalency calculations
LCD	Manufactured life scenario same as baseline except lifespan is based on manufactured life, which results in some revised functional equivalency calculations
CRT	Modified glass energy scenario same as baseline except comparatively high glass manufacturing energy inputs are removed
LCD	Modified glass energy scenario same as baseline except comparatively high glass manufacturing energy inputs are removed
LCD	Modified LCD module energy scenario same as baseline except LCD monitor/ module manufacturing energy outliers are included in the average
LCD	Modified LCD EOL scenario same as baseline except LCD EOL dispositions are modified

Based on the sensitivity analyses, it appears that CRT life-cycle impacts are highly sensitive to the glass energy data, and less sensitive to the lifespan assumptions (lifespan assumptions greatly affect the magnitude of CRT life-cycle impacts, but they do not greatly affect the distribution of impacts among life-cycle stages). LCD impacts are less sensitive to the glass energy data and in fact are not greatly affected by any of the sensitivity analysis scenarios, except the longer lifespan under the manufactured life scenario.

Sensitivity results are also useful to interested members of the public who may be evaluating the relative impacts of different monitor types and are interested in whether the CRT or LCD has greater life-cycle impacts in any given impact category. Table ES-12 presents the monitor type with greatest impacts by impact category and by scenario. This information helps us determine whether major assumptions (e.g., the monitor lifespan and LCD EOL distribution assumptions) or uncertain data (e.g., glass energy data and LCD monitor manufacturing energy) are driving results. As shown in the table, the modified glass energy scenario is the only scenario that significantly changes from the baseline. Under this scenario, life-cycle impact results in seven categories reverse direction from the baseline assessment, such that the LCD has greater impacts than the CRT. Therefore, under this scenario, a total of nine out of 20 categories are greater for the LCD than the CRT, compared to two out of 20 categories under the baseline scenario. The only other scenario that affects these results is the manufactured life scenario, when impacts in the water eutrophication category are greater for the CRT than the LCD.

Table ES-12. Summary of CRT and LCD LCIA results

Impact category	Monitor type with greatest impacts by scenario				
	Baseline	Manu-factured life	Modified glass energy	Modified LCD module energy	Modified LCD EOL distribution[a]
Renewable resource use	CRT	CRT	CRT	CRT	CRT
Nonrenewable resource use	CRT	CRT	LCD	CRT	CRT
Energy use	CRT	CRT	CRT	CRT	CRT
Solid waste landfill use	CRT	CRT	CRT	CRT	CRT
Hazardous waste landfill use	CRT	CRT	CRT	CRT	CRT
Radioactive waste landfill use	CRT	CRT	CRT	CRT	CRT
Global warming	CRT	CRT	LCD	CRT	CRT
Ozone depletion	b	b	b	b	b
Photochemical smog	CRT	CRT	LCD	CRT	CRT
Acidification	CRT	CRT	CRT	CRT	CRT
Air particulates	CRT	CRT	CRT	CRT	CRT
Water eutrophication	LCD	CRT	LCD	LCD	LCD
Water quality, BOD	CRT	CRT	LCD	CRT	CRT
Water quality, TSS	CRT	CRT	LCD	CRT	CRT
Radioactivity	CRT	CRT	CRT	CRT	CRT
Chronic health effects, occupational	CRT	CRT	LCD	CRT	CRT
Chronic health effects, public	CRT	CRT	CRT	CRT	CRT
Aesthetics (odor)	CRT	CRT	LCD	CRT	CRT
Aquatic toxicity	LCD	LCD	LCD	LCD	LCD
Terrestrial toxicity	CRT	CRT	CRT	CRT	CRT

[a] Based on a qualitative evaluation, not quantitative results.

[b] CRT impacts are greater than LCD impacts in this category when all data are included in the inventories, including data for substances that have been phased out. However, LCD impacts are greater than CRT impacts when phased out substances are removed from the inventories (see Section 3.3.6).

IV. QUALITATIVE RISK SCREENING OF SELECTED CHEMICALS

The scope of the DfE CDP included a streamlined Cleaner Technologies Substitutes Assessment (CTSA) component to perform a qualitative risk screening of specific materials or processes. Traditionally, the DfE Program has conducted CTSAs that perform detailed risk characterizations of alternative chemical processes. The streamlined CTSA for the CDP takes a more detailed look than the LCA at the toxic effects of chemicals used in a process, without conducting a complete risk characterization typical of past CTSAs.

Within the human and environmental health effects impact categories of the LCIA, the input and output amounts are used as surrogates for exposure. The additional CTSA-related analyses are intended to better understand the potential exposures to those materials, during any processes that use those materials, in order to try to better understand potential chemical risks.

Lead, mercury, and liquid crystals were selected by the CDP Core Group for further analysis. These materials were selected for their known or suspected toxicity to humans and the environment, or because they are of particular interest to industry or the U.S. EPA. The analysis of each material summarized or evaluated the following key areas:

- Use of the materials in computer displays;
- Life-cycle inputs and outputs of the materials from computer displays;
- Life-cycle impacts associated with the material inputs and outputs;
- Potential exposures to the material including occupational, public, and ecological exposures;
- Potential human health effects;
- U.S. environmental regulations for the material; and
- Alternatives to reduce the use of the material in computer displays.

The following are the conclusions drawn from the analyses of lead, mercury, and liquid crystal use in the life cycle of both CRTs and LCDs.

Lead

Lead is found in glass components of CRTs, as well as in electronics components (printed wiring boards and their components) of both CRTs and LCDs. It is also a top priority toxic material at the U.S. EPA and the subject of electronics industry efforts to reduce or eliminate its use. The following conclusions were drawn from a focused look at lead's role in the life cycle of the computer display, and its effects on human health and the environment:

- Due to the much greater quantity of lead in the CRT than the LCD, lead-based life-cycle impacts from the CRT ranged from moderately to significantly greater than those from the LCD in every category, with the exception of solid waste landfill use. The most significant difference was in non-renewable resource consumption, where the CRT consumed over 40 thousand times the mass of non-renewable resources attributable to lead over the course of its life cycle than those consumed by the LCD. Other categories where CRTs had notably greater differences in impacts occurred in hazardous waste landfill use, chronic public health effects, and terrestrial toxicity.
- Contributions of lead-based impacts are small relative to the total life-cycle impacts from other materials in the CRT (e.g., glass, copper wire), with the greatest impacts from lead-based CRT outputs occurring in the categories of non-renewable resources, aquatic toxicity, and chronic public health effects (ranging from 0.1 to 0.2% of the overall impact scores in each category).
- For workers, inhalation is the most likely route of exposure to lead which may result in health concerns. General population exposure to lead is most likely to come from incidental ingestion of lead in the soil, or ingestion of lead brought into the household on workers clothing or on shoes. Studies have discovered potentially high concentrations of lead in households within close proximity to certain facilities that use lead.
- Significant worker exposures to lead have been documented by existing studies of several processes which contribute to the life-cycle of the computer displays (e.g., lead smelting). These exposures have been as high as 90 times the OSHA recommended safety levels for exposure to workers at lead smelters. The resulting occupational chronic health effects to

workers from lead exposure likely have been underestimated by the CDP LCIA methodology, which uses material inputs, and not outputs, as surrogates for exposure.

- Lead and lead compounds pose serious chronic health hazards to humans who may become over-exposed either in the workplace, or through the ambient environment. Lead exposure is associated with a range of adverse human health effects, including effects on the nervous system, reproductive and developmental problems, and cancer. Lead persists in the environment, but is relatively immobile in water under most surface and groundwater conditions.
- Alternatives are being developed, such as lead-free solders and glass components, that will potentially minimize the future lead content in both CRTs and LCDs.

Mercury

Mercury is contained within the fluorescent tubes that provide the source of light in the LCD. Mercury is also emitted from some fuel combustion processes, such as coal-fired electricity generation processes, which contribute to the life-cycle impacts of both CRTs and LCDs. EPA's concern with mercury and the potential for exposure during manufacturing and end-of-life processes warranted a more detailed analysis of mercury in the CDP. The following conclusions were drawn from a focused look at mercury's role in the life cycle of the computer display, and its effects on human health and the environment:

- The mercury emitted from the generation of power consumed by the CRT (7.75 mg) exceeds the entire amount of mercury emissions from the LCD, including both the mercury used in LCD backlights (3.99 mg) and the mercury emissions from electricity generation (3.22 mg). Although this was not expected because mercury is used intentionally in an LCD, but not in a CRT, the results are not surprising since mercury emissions from coal-fired power plants are known to be one of the largest anthropogenic sources of mercury in the United States. Because the CRT consumes significantly more electricity in the use stage than the LCD, its use stage emissions of mercury are proportionately higher than those of the LCD.
- Contributions from mercury-based impacts are not significant relative to the total life-cycle impacts from other materials (e.g., glass, copper wire) in the CRT or LCD, with the greatest impacts from mercury-based outputs occurring in the aquatic toxicity category (0.4% for CRTs, 0.01% for LCDs).
- Possible pathways of worker exposure during backlight fabrication include inhalation of mercury vapors, and dermal exposure or ingestion of mercury on skin. The most likely pathway for general population exposure is inhalation of mercury released into the air.
- Exposure data relevant to the manufacturing of mercury backlights were not available, therefore specific conclusions about the potential magnitude of worker exposures could not be made. Occupational chronic health effects to workers from mercury exposures calculated during the impact assessment (3.99e-06 tox-kg for LCD, none for CRT) likely have been underestimated by the CDP LCIA methodology, which uses material inputs as surrogates for exposure.
- Mercury and mercury compounds pose serious chronic health hazards to humans who are exposed. EPA has determined that mercury chloride and methyl mercury are possible

human carcinogens. Mercury poses serious chronic health hazards to humans, affecting the nervous system, brain, and kidneys.

- Alternative backlights have been developed that not only eliminate mercury from the light, but also improve on many of the optical characteristics of the displays. Current development is focused on improving the energy efficiency of the alternative lights.

Liquid Crystals

Liquid crystals (LCs) are organic compounds responsible for generating the image in an LCD. LCs are not present in CRTs. The toxicity of the LCs in LCDs has been alluded to in the literature, yet there is very little known about the toxicity of these materials. By including LCs in a more detailed analysis, this section attempted to better characterize any potential hazard and/or potential exposure of LCs from the manufacturing, use, and disposal of LCD monitors. The following conclusions were drawn from a focused look at LC's role in the life cycle of the computer display, and its effects on human health and the environment.

- LCs are combined into mixtures of as many as 20 or more compounds selected from hundreds of potential liquid crystal compounds. Because of the possible variations in mixtures and the sheer number of compounds available, a select number of liquid crystals were used to assess potential human health hazards.
- LCs do not appear to contribute significantly to any of the impact categories defined for this study. The total score for LCD occupational impacts based on potential worker exposure to LCs of 4.18 tox-grams, calculated using default toxicity values, represents less than 0.01% of the total overall chronic occupational health effects impact score of 898 tox-kg for the functional unit of one LCD.
- Impacts were not calculated for LC releases in the CDP LCIA because data regarding LC outputs were not available to the project. LCs are not used to fabricate CRTs and so have no environmental impacts in the CRT life cycle.
- Occupational exposures to LCs during the fabrication of the LCD panels are not expected to be significant. The enclosed nature of the chamber in which the LCDs are assembled, combined with the equipment (e.g., gloves, aprons) worn by workers in a clean room environment, are both expected to act to minimize exposures. Other occupational exposures may exist that have not been identified.
- Toxicological testing by a manufacturer of LC substances and mixtures showed that 95.6% (562 of 588) of the liquid crystals tested displayed no acute toxic potential to humans. Twenty-five of the remaining twenty-six chemicals had the potential to exhibit harmful effects to humans, while the remaining crystal was classified as toxic (EU classification) and thus was discontinued. An EPA review of toxicity data for the confidential LC compounds was unable to identify any relevant toxicity information. Insufficient toxicity data exist to assess the toxicity of specific LC compounds.
- Testing for mutagenic and carcinogenic effects by the supplier showed that 99.9% (614 out of 615) of the liquid crystal compounds tested displayed no mutagenic effects. The remaining chemical that showed mutagenic potential was excluded from further development. Additionally, mutagenicity testing of ten LC substances using mammalian cells showed no suspicion of mutagenic potential.

V. SUMMARY AND CONCLUSIONS

The purpose of the CDP, as stated in Chapter 1, is to provide a scientific baseline of life-cycle environmental impacts of CRTs and LCDs, and to develop a life-cycle model for future analyses. The primary targeted audience is the electronics industry, for whom results may provide insight into improvement opportunities in the life cycle of CRTs and/or LCDs. In addition, the general public may also find results useful when considering environmental impacts of each display type. This report, however, does not include direct comparative assertions or improvement assessments based on the results. Alternatively, results and conclusions are described in terms of the overall LCI versus the LCIA, and details of the impact assessment, including the additional assessments of lead, mercury and liquid crystals, and the sensitivity analyses. Major uncertainties, cost and performance considerations, suggestions for improvement opportunities, and suggestions for further research are also provided.

LCI vs. LCIA

Inventory data provide information on how much material is being consumed in the life cycle (i.e., inputs) and how much material is generated/released (i.e., outputs). The LCI alone, however, does not always translate directly into impact categories that may be of interest. Impacts are sometimes driven by materials other than the top inventory contributors. For example, the top air emission for LCDs is carbon dioxide, however the greatest global warming impact score is from SF_6 in the LCD monitor/module manufacturing process.

Some impact categories associated with ancillary materials and water pollutant inventory types had different outcomes in the LCI versus the LCIA. For example, the three impact categories affected by the ancillary materials inventory had greater *impacts* for the CRT (Table ES-8), although the ancillary material *inventory* had greater amounts of inputs for the LCD (see Tables ES-5 and ES-6). In this case, both primary and ancillary materials contribute to the impact categories, contributing to the differing results.

In addition, the LCD had greater inventory amounts of wastewater outputs than the CRT; however, the impacts related to water releases are in some cases greater for the CRT than the LCD. In the LCIA, the LCD has greater impacts for water eutrophication and aquatic toxicity, but not for the two water quality categories (BOD and TSS), chronic health effects to the public, nor terrestrial toxicity, all of which include water emissions in calculating the impact score. These results show that the inventory results may not directly translate into impact results.

CRT and LCD Baseline LCIA Results

The LCIA results showed that the CRT has greater total life-cycle impact indicators than the LCD in most of the impact categories (see Table ES-8). In the baseline scenario, the CRT has greater impacts than the LCD in all but two impact categories (eutrophication and aquatic toxicity). However, note that for the ozone depletion category, the LCIs for both the CRT and LCD contain data for substances that were phased out of production by 1996 due to their ozone depletion potential. Whether these emissions still occur in countries that were signatories to the Montreal Protocol and its Amendments and Adjustments (such as the United States and Japan) is not known, but considered to be unlikely. When phased-out substances are included in the inventory, the CRT has greater ozone depletion impacts than the LCD. However, if phased-out substances are removed from the inventories, the results are switched, with the LCD having greater impacts.

When considering which life-cycle stage has greater impacts, the LCIA results showed that the manufacturing life-cycle stage dominates impacts for most impact categories for both the CRT and LCD. Table ES-13 lists the number of impact categories with the greatest impacts by life-cycle stage.

A more detailed evaluation of lead, mercury and liquid crystals was completed in Chapter 4. As expected, the CRT, which has lead in the glass, frit, and printed wiring boards (PWBs), had greater impacts from lead than did the LCD, which only has lead in the PWBs. Regarding mercury, there were greater inventories of mercury in the CRT life cycle than in the LCD life cycle, despite the fact that only the LCD has mercury directly in the product. The greater amount of mercury in the CRT life cycle is from the release of mercury and mercury compounds from the generation of electricity. The CRT consumes significantly more electricity in the use stage than the LCD. Liquid crystals are only found in LCDs, and therefore, there are no associated impacts for the CRT. Little conclusive information was available on the liquid crystal materials. A detailed literature search was conducted, however very little data were available on the toxicity of these materials. Based on the limited toxicity data obtained, liquid crystals currently do not appear to be a significant human health or environmental hazard in the LCD life cycle. However, there were insufficient toxicity data available to make a definitive conclusion about LC toxicity.

Table ES-13. Number of impact categories in each life-cycle stage with greatest impacts among life-cycle stages (baseline scenario)

Monitor type	# of impact categories with greatest impacts among life-cycle stages			
	Upstream	Manufacturing	Use	EOL
CRT	3	9	6	2
LCD	3	11	4	2

CRT Results

For the CRT, many of the impacts were driven by a single material in the inventory. As shown in Table ES-9, in 14 of the 20 impact categories, the top individual contributor to the impacts was responsible for greater than 50 percent of the impacts. This shows that the CRT data are highly sensitive to a few data points. Major conclusions from the CRT LCIA are as follows:

- Energy used in glass manufacturing and associated production of LPG are driving the baseline CRT results (they dominate ten impact categories, including overall life-cycle energy use).
- The large amounts of fuel used as energy sources are driving occupational health effects. Occupational impacts are calculated from inventory input amounts, and therefore there may or may not actually be exposure to these fuels (e.g., they may be contained);

however, the results illustrate the potential for health effects, especially under spill or upset conditions.

- The generation of electricity for the use stage dominates seven impact categories.
- Air emissions of sulfur dioxide from electricity generation (for the use life-cycle stage) drive chronic public health effects, acidification, and terrestrial toxicity impacts. This may be a concern, for example, in areas in nonattainment of regulated levels of sulfur dioxide in the United States.

The use of LPG fuel in glass manufacturing dominated ten impact categories: two directly from the LPG used in glass/frit manufacturing (energy use impacts and chronic occupational health effects) and eight from LPG production (renewable resource use, nonrenewable resource use, photochemical smog, air particulates, water eutrophication, BOD water quality, TSS water quality, and aesthetics). In addition, impacts from the generation of electricity during the use stage dominated seven impact categories: solid waste landfill use, radioactive waste landfill use, global warming, ozone depletion, acidification, chronic public health, and terrestrial toxicity. The CRT tube manufacturing process, which represents the most functionally and physically (by mass) significant component of the CRT monitor, only dominated one impact category (aquatic toxicity). Twenty-six percent of the aquatic toxicity score was from phosphorus outputs from tube manufacturing, while most of the rest were from the materials processing life-cycle stage. The remaining two impact categories (hazardous waste landfill use and radioactivity) had greatest impacts from the landfilling of the assumed hazardous proportion of CRT monitors, and the release of Plutonium-241 in steel production, respectively (Table ES-9). The radioactivity impacts are driven by the radionuclide Pu-241, due to the electric grid inventory included in the steel production secondary data set, which includes nuclear fuel reprocessing.

The large amount of LPG reported for glass manufacturing was originally questioned during the data collection and verification stage of this project. While no compelling reason could justify removing the LPG data in the baseline case, a sensitivity analysis was conducted in which the glass energy data were modified. Other sensitivity analyses were also conducted (i.e., manufactured life, modified LCD monitor manufacturing energy, and modified LCD EOL distributions). However, the only scenario that substantially altered results was the modified glass energy scenario (see Table ES-12). It is likely that the actual energy inputs to the glass manufacturing process is somewhere between the baseline and modified glass scenarios. More information is needed on energy used in glass manufacturing, which is driving CRT baseline results.

The additional analyses for the CRT of lead and mercury also revealed that the use of lead could present health risks, but the CDP method for calculating occupational impacts uses only process *inputs* (not outputs) and may not adequately represent occupational exposures and risks. Further refinement of the occupational impact analysis may be warranted.

Although there is no mercury in the CRT monitor, mercury emissions from electricity generation in the CRT life cycle were greater (in mass) than the mercury used in the LCD. Therefore, to reduce mercury emissions from the CRT life cycle, efforts to reduce electricity consumption could be taken. Additionally, changes to the electric grid could also reduce mercury emissions from the CRT life-cycle.

LCD Results

The LCD impact results were less sensitive to an individual input or output than the CRT results, although in 11 of the 20 impact categories an individual input was still responsible for greater than 50% of the total impacts. In general, the LCD results are less uncertain than the CRT results. This is because most of the CRT results are being driven by either glass input data or data from secondary sources, while LCD impacts are being driven more by data from primary sources. Some results to note are as follows:

- The LCD monitor/module manufacturing process group had greatest impacts in six impact categories (Table 3-58).
- Although the top contributor to the energy impact category was electricity consumed in the use stage (30%), the overall energy impacts were greater from the manufacturing stage than the use stage.
- In the glass energy sensitivity scenario, the use stage had greatest energy impacts, although only by a small margin over the manufacturing stage (see Figure 3-26).
- Sulfur dioxide [emitted from electricity generation in the use stage, and constituting only 0.37% of the air emission inventory (see Table 2-49)] dominates the acidification, chronic public health, and terrestrial toxicity impact categories (Table 3-58). The high public health and terrestrial toxicity scores are due to its low non-cancer toxicity value and resulting high hazard value (HV).
- Sulfur hexafluoride (SF_6) from LCD monitor/module manufacturing was the single greatest contributor to the global warming impact score; however, carbon dioxide from the use stage and the materials processing stage also contributed significantly to the global warming impacts (Table 3-25).
- The glass energy inputs did not directly dominate any impact categories, as they did for the CRT (due to the smaller mass of glass in the LCD); however, LPG production (required for the glass energy fuel) dominated two categories: TSS water quality and aesthetics (Table 3-58).
- LNG as an ancillary inventory material was questionably very large and had greatest impacts in two categories: nonrenewable resource use and photochemical smog (Table 3-58; shown there as "Natural Gas Production" due to that process being used as a surrogate for LNG production).

The additional analyses of lead, mercury, and liquid crystals showed that the LCIA alone is not adequate enough to determine all the potential impacts within the life-cycle of the LCD monitors. Further, the LCIA method in this LCA used only process inputs as surrogates for occupational exposure. If the occupational impacts methodology were refined, outputs into the occupational environment should also be considered.

For mercury, which is found in the backlights of the LCD monitors, there is nearly the same amount of mercury by mass emitted to the air during electricity generation as there is mercury used to make the backlight unit. The mass of mercury input for backlights is only about 20% greater than the mercury air emissions from electricity generation (across all life-cycle stages).

Liquid crystals were also identified by the CDP Core Group as a material for which additional information would be reviewed. The LCIA did not find the liquid crystals to be significant contributors to any impact categories; however, this could partially be due to the lack of information on them. The additional analysis revealed limited information; however, qualitatively, it did not show significant potential risk.

CRT vs. LCD Sensitivity Analysis Results

The only sensitivity analysis to show significant difference in the results was the modified glass energy scenario. In comparing the CRT and LCD, the CRT *baseline* scenario had greater impacts than the LCD in all but two impact categories (eutrophication and aquatic toxicity) and possibly three (ozone depletion). In the *modified glass energy scenario*, nine of the 20 categories had greater impacts from the LCD life-cycle than the CRT. Energy use remained greater for the CRT; however, nonrenewable resource use, global warming, photochemical smog, eutrophication, BOD and TSS water quality, chronic occupational health effects, and aesthetics all reversed such that the LCD had greater impacts than the CRT (Table ES-12). As stated above, it is believed that a more true representation of the monitor life cycles lies somewhere between the baseline and modified glass energy scenario. Further work is recommended in clarifying and refining glass energy input information.

Uncertainties

As with any LCA, it is not uncommon for there to be uncertainty associated with such a large data collection effort. The limitations and uncertainties associated with this LCA and LCAs in general have been discussed elsewhere in the executive summary. Two of the largest sources of uncertainty in this LCA that have a significant effect on the results are as follows:

- *CRT and LCD glass manufacturing energy inputs (from primary data)*: The larger amount of glass used in CRTs than LCDs results in the CRT having greater associated uncertainty than the LCD results.
- *Secondary data for upstream and fuel production processes*: When any one material is used in the life-cycle of either monitor in large quantities, the impacts associated with the inputs and outputs from the production of that material may become significant. For example, LPG and LNG production were both used in significant enough amounts to influence some impact categories. Therefore, the uncertainty in the secondary data becomes important. This highlights the need for a consistent, national (or international) LCI database that is updated regularly.

Other uncertainties associated with individual data points had less effect on the overall results than the uncertainties mentioned above. For manufacturers interested in conducting improvement assessments, closer review of such uncertainties may be warranted.

Another point that should be recognized in the overall LCA of CRTs and LCDs is that CRTs are a more mature technology than LCDs. Changes in LCD manufacturing processes have likely occurred during the development and publication of this report. Therefore, conclusions must be carefully drawn when evaluating the mature CRT compared to the newer LCD technology.

Cost and Performance Considerations

The focus of this study has been on the environmental effects associated with CRTs and LCDs. The environmental attributes or burdens of a product are not expected to be considered alone when evaluating the marketability and commercial success of a product. The cost and performance of each monitor type are obviously critical components to a company's or consumer's decisions of whether to produce or purchase a product. The report briefly addresses direct retail costs of the monitors and electricity costs associated with the monitors; however, a complete cost analysis, including all direct costs (e.g., material costs) and indirect costs (e.g., environmental costs to society) is beyond the scope of this report.

The average retail price of 1997-2000 model year monitors, collected from the manufacturers who supplied data for this project, is $541 for the CRT and $1,450 for the LCD. From these data, the LCD is approximately 2.7 times more costly. More recent data show that prices have come down, and the difference in prices between the CRT and LCD has also been reduced.

The costs from the use stage can be represented by the use stage electricity costs. Based on the average cost of residential and commercial electricity in the United States, and the amount of energy consumed per functional unit in the use stage (baseline scenario), the electricity costs to consumers over the life of the monitors during the use stage are $48 for the CRT and $18 for the LCD. In addition, the upstream and manufacturing costs of electricity in the baseline scenario for the CRT are approximately $1.3/functional unit and $1.5/functional unit, respectively; for the LCD they are $0.10/functional unit and $3.4/functional unit, respectively.

The LCA is defined such that the monitor assessments are performed on a functionally equivalent basis. To the extent possible, data were collected on functionally equivalent monitors. When companies were approached to participate in the study, they were informed of the performance specification parameters within which the study boundaries were defined. Therefore, it is assumed that they meet the specifications as presented in Table ES-1, and that they perform relatively equivalently. From the primary data, the reported brightness of the CRT was less than the LCD, otherwise, they are functionally similar.

Improvement Assessment Opportunities and Targeted Audience Uses of Report

To meet the primary objective of providing the display industry with data to perform improvement assessments, the industry should look at the manufacturing life-cycle stage, while recognizing the influences of the other stages. CRT improvement opportunities could include improved energy efficiency during glass manufacturing and display use, as well as reductions in lead content. LCD improvement opportunities could also include improved energy efficiency, especially during manufacturing. Certain materials, such as SF_6 and its contribution to global warming, may also be of concern and an area to focus on in future improvement assessments.

In addition, any improvement assessment should consider how changes in one life-cycle stage will affect impacts in other stages. For example, in Chapter 4 we saw that the mercury inputs and outputs from the intentional use of mercury in an LCD backlight are less (by mass) than the mercury emissions from the CRT use stage, due to the relative energy usage by the CRT and the emissions of mercury from electricity generation. In this example, we can see that on a pure mass basis, a product's energy efficiency is a key consideration and any changes in manufacturing should consider if it will affect changes in use.

Another objective of this study was to provide an LCA model for future analyses. Companies or individuals who have more current data for the CRT or LCD can apply them to the model presented here. For example, changes in an individual process can be identified and incorporated into the model. The other processes that are not expected to change significantly can be left unchanged, and only limited data would need to be altered. This would reduce the time and resources that would normally be required for a complete analysis.

Finally, those interested in comparing the results of the two monitors can apply their own set of importance weights to each impact category to determine their individual decision. For example, if energy impacts are much more important than aesthetics to a particular person, they can weigh energy more heavily in concluding which monitor may have fewer environmental impacts, while keeping in mind the data limitations and uncertainties, as well as cost and performance considerations.

Suggestions for Future Research

Areas where future research could be conducted to refine and/or continue the use of the results in this study are as follows:

- gather more information on energy use in glass manufacturing;
- develop consistent materials and fuel processing data in a national (or international) LCI database that is updated regularly;
- refine and/or update some of the LCD manufacturing data (e.g., LNG data);
- collect more complete EOL data (e.g., remanufacturing data, and primary data for incineration and landfilling) to determine better representation of the EOL impacts;
- conduct more research on the EOL options for LCDs;
- collect more detailed data on landfilling and other treatment processes, such as water treatment where no impacts were calculated;
- update manufacturing data to meet more recent monitor model years;
- conduct a more focused analysis on selected areas for detailed improvement assessments; and
- evaluate process changes or other alternatives against an "average 1997-2000 model year" to evaluate impacts of changes or improvements over time.

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Chapter 1

GOAL DEFINITION AND SCOPE

1.1 BACKGROUND

This report presents the results of a voluntary, cooperative project among the Design for the Environment (DfE) Program in the U.S. Environmental Protection Agency's (EPA) Office of Pollution Prevention and Toxics, the University of Tennessee (UT) Center for Clean Products and Clean Technologies, the electronics industry, and other interested parties to develop a model and assess the life-cycle environmental impacts of flat panel display (FPD) and cathode ray tube (CRT) technologies that can be used for desktop computers. The DfE Computer Display Project (CDP) analysis provides a baseline report and the opportunity to use the model as a stepping stone for further analyses and improvement assessments for these technologies.

EPA's Office of Pollution Prevention and Toxics established the DfE Program in 1992 to encourage businesses to incorporate environmental concerns into their business decisions. DfE industry projects are cooperative, joint efforts with trade associations, businesses, public-interest groups, and academia to assist businesses in specific industries to identify and evaluate more environmentally sound products, processes, and technologies. The DfE CDP partnership consists of members of electronic industry trade associations, computer monitor and component manufacturers, suppliers to the electronics industry, academic institutions, EPA, and a public interest group. The direction and focus of this project was chosen by the project partners.

The DfE CDP uses life-cycle assessment (LCA) as an environmental evaluation tool, which is increasingly being used by industry. LCA can be used to evaluate the environmental effects of a product, process, or activity. An LCA looks at the full life cycle of the product from materials acquisition to manufacturing, use, and final disposition. It is a comprehensive method for evaluating the full environmental consequences of a product system. There are four major components of an LCA study: goal definition and scoping, life-cycle inventory, impact assessment, and improvement assessment. LCAs are generally global and non-site specific.

Under the DfE Program, the Cleaner Technologies Substitutes Assessment (CTSA) methodology (Kincaid *et al.,*1996) was developed to generate information needed by businesses to make environmentally informed choices and to design for the environment. The CTSA process involves comparative evaluations of substitute technologies, processes, products, or materials. Impact areas that are evaluated include human and ecological risk, energy and natural resource use, performance, and cost.

Both evaluation tools have similar objectives; however, their applications generally differ. A CTSA is more site specific and evaluates actual (predicted) impacts. For example, techniques such as health risk assessment are incorporated into a CTSA. An LCA is more global and generic in nature and generally would not incorporate site-specific parameters when evaluating impacts. The LCA may also use surrogate measures to represent impacts instead of predicting or measuring actual impacts.

This project focuses on the LCA, while including some CTSA-related analyses. It performs the broad analysis of the LCA, which also incorporates many of the CTSA components (e.g., risk, energy impacts, natural resource use) into the impact assessment. The analysis also assesses more specific impacts for selected materials and acknowledges product cost and performance, typical of a CTSA. Because both methodologies require intensive data gathering efforts and can be extensive undertakings, the scope must be carefully and clearly defined. As only selected materials are evaluated for the CTSA, this project could be considered an LCA with a streamlined CTSA component.

Life-cycle assessment (LCA) is a comprehensive method for evaluating the full environmental consequences of a product system. Another related assessment strategy *is life-cycle design*, which is a systems-oriented approach for designing more ecologically and economically sustainable product systems. It integrates environmental requirements into the earliest stages of design so total impacts caused by product systems can be reduced. Environmental, performance, cost, cultural, and legal requirements are balanced (Curran, 1996). Environmental impacts and health risks caused by product development are intended to be reduced. This is very similar to *design for environment* (DfE) programs where environmental issues are incorporated into a product system design process. DfE and life-cycle design have similar objectives, although their origins differ. DfE was developed as an off-shoot of *design for X*, where *X* could be any number of criteria (e.g., manufacturability, testability, reliability, recyclability). In DfE, *X* is environmental protection and sustainability.

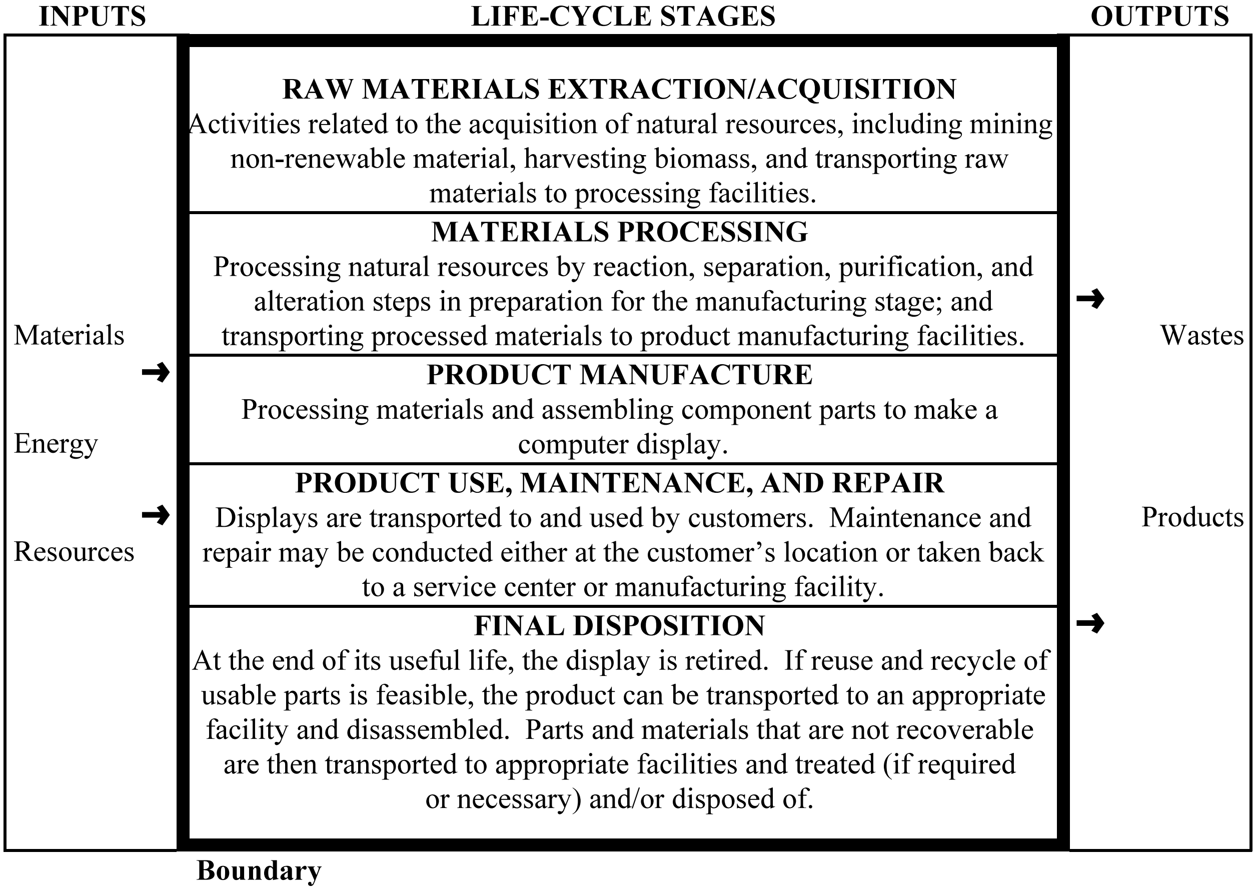
The EPA DfE Program, where *X* is also environmental protection and sustainability, promotes risk reduction, pollution prevention, energy efficiency, and other resource conservation measures through process choices at a facility level. EPA's DfE CTSA process also includes an analysis of performance and cost. Typically, EPA's DfE Program focuses less on the entire life cycle and more on evaluating technology or material substitutes to reduce environmental impacts. This project combines the DfE Program's CTSA process (Kincaid *et al.*, 1996) and the LCA process, and thus resembles a life-cycle design approach.

LCAs evaluate the environmental impacts from each of the following major life-cycle stages:

- Raw materials extraction/acquisition;
- Materials processing;
- Product manufacture;
- Product use, maintenance, and repair; and
- Final disposition/end-of-life.

Figure 1-1 briefly describes each of these stages for a computer display product system. The inputs (e.g., resources and energy) and outputs (e.g., product and waste) within each life-cycle stage, as well as the interaction between each stage (e.g., transportation) are evaluated to determine the environmental impacts.

As defined by the Society of Environmental Toxicology and Chemistry (SETAC), the four major components of an LCA are: (1) goal definition and scoping; (2) inventory analysis; (3) impact assessment; and (4) improvement assessment. More recently, the international standard, ISO 14040: Environmental Management—Lifecycle Assessment—Principles and Framework, has defined the four major components of an LCA as: (1) goal and scope; (2) inventory analysis; (3) impact assessment; and (4) interpretation of results. The SETAC and International Standards Organization (ISO) framework are essentially synonymous with respect to the first three components, but differ somewhat with respect to the fourth component, improvement assessment or life cycle interpretation. Improvement assessment is the systematic evaluation of opportunities for reducing the environmental impacts of a product, process, or activity. Interpretation is the phase of LCA in which the findings from the inventory analyses and the impact assessment are combined together, consistent with the defined goal and scope in order to reach conclusions and recommendations. In this study and project report, the goal and scope are the subject of Chapter 1. The inventory analysis and impact assessment are the subjects of Chapters 2 and 3 respectively; and the improvement assessment or life-cycle interpretation are left to the electronics industry given the results of this study. The life-cycle inventory and impact assessment strategies are briefly described below.



RAW MATERIALS EXTRACTION/ACQUISITION
Activities related to the acquisition of natural resources, including mining non-renewable material, harvesting biomass, and transporting raw materials to processing facilities.

MATERIALS PROCESSING
Processing natural resources by reaction, separation, purification, and alteration steps in preparation for the manufacturing stage; and transporting processed materials to product manufacturing facilities.

PRODUCT MANUFACTURE
Processing materials and assembling component parts to make a computer display.

PRODUCT USE, MAINTENANCE, AND REPAIR
Displays are transported to and used by customers. Maintenance and repair may be conducted either at the customer's location or taken back to a service center or manufacturing facility.

FINAL DISPOSITION
At the end of its useful life, the display is retired. If reuse and recycle of usable parts is feasible, the product can be transported to an appropriate facility and disassembled. Parts and materials that are not recoverable are then transported to appropriate facilities and treated (if required or necessary) and/or disposed of.

Figure 1-1. Life-cycle stages of a computer display

The life-cycle inventory (LCI) involves the quantification of raw material and fuel inputs, and solid, liquid, and gaseous emissions and effluents. Traditional LCIs quantify pollutant categories (e.g., volatile organic compounds [VOCs]) rather than particular chemicals. This project also includes a more detailed evaluation of a few specific chemicals found in computer displays (lead, mercury, and liquid crystals) to enable a more thorough evaluation of risk from chemical exposure. The approach to the LCI in this study involves defining product components, developing a bill of materials (BOM), and collecting inventory data on each life-cycle stage for computer displays. Details of the LCI data gathering activities are provided in Chapter 2.

The life-cycle impact assessment (LCIA) involves the translation of the environmental burdens identified in the LCI into environmental impacts. LCIA is typically a semi-quantitative process involving characterization of burdens and assessment of their effects on human and ecological health, as well as other effects such as smog formation and global warming. Details of the LCIA methodology and results are presented in Chapter 3. This project has furthered the development of LCIA methodology by including health effect concerns into the LCIA. This study also qualitatively assesses exposure and chemical risk of selected chemicals in the life cycles of the computer displays (Chapter 4).

1.2 INTRODUCTION

Goal and scope definition is the first phase of LCA and is important to the CTSA as well. This phase is important because it determines why the LCA or CTSA is being conducted and its intended use, as well as the system and data categories to be studied.

This chapter presents the goal and scope of the DfE CDP, including its purpose and goals, previous research and market trends, descriptions of the product systems being evaluated, and the boundaries used in this study. It incorporates scoping as it is recommended in both the LCA (e.g., Curran, 1996; Fava *et al.,* 1991; ISO, 1996) and CTSA processes (Kincaid *et al.*, 1996).

1.2.1 Purpose

The purpose of this study is two-fold: (1) to establish a scientific baseline that evaluates the life-cycle environmental impacts of flat panel displays (FPDs) and cathode ray tubes (CRTs) for desktop computers, by combining LCA and CTSA methodologies; and (2) to develop a model that can be used with updated data for future analyses. This study evaluates the newer active matrix liquid crystal display (LCD) and the more traditional CRT technologies. The evaluation considers impacts related to material consumption, energy, air resources, water resources, landfills, human toxicity, and ecological toxicity. This study is designed to provide the electronics industry with information needed to improve the environmental attributes of desktop computer displays. It is intended to provide valuable data not previously published, and an opportunity to use the model developed for this project in future improvement evaluations that consider life-cycle impacts. It will also provide the industry and consumers with valuable information to make environmentally informed decisions regarding display technologies, and enable them to consider the relative environmental merits of a technology along with its performance and cost.

1.2.2 Previous Research

While there has been some work done on the life-cycle environmental impacts of either CRTs or LCDs, there has not been a quantitative LCA addressing both CRTs and LCDs. For example, Microelectronics and Computer Technology Corporation (MCC) published an *Electronics Industry Environmental Roadmap* (1994) that qualitatively discussed environmental issues and priority needs for reducing impacts from computer CRTs and FPDs, but this project did not, nor was it intended to, focus on all aspects of the displays' life cycles.

Some of the environmental impacts of CRTs (e.g., energy use, disposal of lead, and other end-of-life issues such as recycling) have been identified but not quantified in previous work, such as that done by EPA's Common Sense Initiative Computer and Electronics Subcommittee. Atlantic Consulting completed a draft LCA of the personal computer (including a 15" monitor) for the European Union's (EU) Eco-Label program (Atlantic Consulting and IPU, 1998). Further, the New Jersey Institute of Technology conducted an LCA of television CRTs, which have the same technology as the computer monitor CRT.

Studies on the environmental impacts of FPDs are much less prevalent. A University of Michigan master's thesis (Koch, 1996) evaluated the environmental performance of an LCD manufacturer. The thesis did not quantitatively assess environmental impacts from all life-cycle stages, as would be done in an LCA. The EU Eco-Label Program also evaluated a portable computer with a 13.3" LCD screen (Orango AB and Atlantic Consulting, 1999). The scope was limited to energy consumption for the impact assessment, and it provided some inventories for raw materials production. Human and ecological toxicity were excluded from the scope of the portable computer analysis.

1.2.3 Market Trends

At present, computer displays using CRTs dominate worldwide markets. They provide a rich, high-resolution display well suited to a wide range of user requirements. However, CRT displays are bulky, use larger amounts of energy to operate than LCDs, and are associated with disposal concerns due to the presence of lead in the glass. Color CRT monitors contain lead to help shield the users from x-rays (x-ray attenuation) and can, under some circumstances, be classified as a hazardous waste when disposed of. Newer technologies, collectively referred to as FPDs, have captured significant market segments. FPDs exhibit desirable qualities such as reduced size and weight and greater portability. Environmentally, they are expected to consume less energy during use and do not use leaded glass. However, they may consume more energy during manufacturing, contain small amounts of mercury, are more costly, and in the past have had lower resolution and image quality than the CRT. The LCD, first used predominately in notebook computers, is now moving into the desktop computer market. The 1998 worldwide market for desktop computer monitors was 90 million units. The 1998 actual and 2001 projected markets for desktop computer CRTs and LCDs are presented in Table 1-1. Market projections anticipate that LCDs will capture sizable market share for desktop computer displays.

Table 1-1. Desktop display markets - actual for 1998 and projected for 2001

	Number of displays (thousands of units)	
Technology	1998	2001
CRT		
Worldwide	88,600	119,100
North America	33,801	42,609
LCD		
Worldwide	1,300	14,300
North America	229	3,787

Sources: DisplaySearch, 2001.

1.2.4 Need for the Project

Given the expected market growth of LCDs for computer displays, the various environmental concerns throughout the life cycle of the computer displays, and the fact that the relative life-cycle environmental impacts of LCDs and CRTs have not been scientifically established to date, there is a need for a quantitative environmental life-cycle analysis of desktop computer display technologies. Manufacturers can use these results or the model developed here to identify areas for improvement concerning the environmental burdens. Further, as companies or consumers are considering investing in certain displays, they can refer to the results of this study to assist them in making environmentally informed decisions.

1.2.5 Targeted Audience and Use of the Study

The electronics industry is expected to be one of the primary users of the study results. The study is intended to provide industry with an analysis that evaluates the life-cycle environmental impacts of selected computer display technologies. Scientific verification of the relative environmental impacts will allow industry to consider environmental concerns, along with traditionally evaluated parameters of cost and performance, and to potentially redirect efforts towards products and processes that reduce releases of toxic chemicals and reduce risks to health and the environment. Given the results, the industry can then perform an improvement assessment of the display technologies. This also allows the electronics industry to make environmentally informed choices about display technologies when assessing and implementing improvements such as changes in product, process, and activity design; raw material use; industrial processing; consumer use; and waste management.

Another result of the study is an accounting of the relative environmental impacts of various components of the computer displays, thus identifying opportunities for product improvements to reduce potential adverse environmental impacts and costs. Identification of impacts from the computer display technologies can also encourage industry to implement pollution prevention options, such as development and demonstration projects, and technical assistance and training. Since this study incorporates a more detailed health effects component than in traditional LCAs, the electronics industry can use the tools and data to evaluate the health, environmental, and energy implications of the technologies. With this evaluation, the U.S. electronics industry may be more prepared to meet the demands of extended product responsibility that are growing in popularity in the global marketplace, and better able to meet competitive challenges in the world market. In addition, the results and model in this study will provide a baseline LCA upon which alternative technologies can be evaluated. This will allow for more expedited display-related LCA studies, which are growing in popularity by industry and may be demanded by original equipment manufacturers (OEMs) or international organizations.

EPA and interested members of the public can also benefit from the results of the project. The project has provided a forum for industry and public stakeholders to work cooperatively, and the results can be used by stakeholders as a scientific reference for the evaluated display technologies. The results of the project could also be of value to other industries involved in designing environmental improvements into the life cycle of consumer products.

1.3 PRODUCT SYSTEM

1.3.1 Functional Unit

The product system being analyzed in this study is a standard desktop computer display that functions as a graphical interface between computer processing units and users. The desktop market was chosen to evaluate CRTs and FPDs because it represents a large market for CRTs and an anticipated large market for some FPDs. Also, there are a limited number of technologies that meet desktop specifications. Therefore, focusing on the desktop market will affect a significant number of products, while keeping the scope of this project manageable.

The product system is the computer display itself and does not include the central processing unit (CPU) of the computer that sends signals to operate the display. It is assumed that the LCDs operate with an analog interface, and therefore are compatible with current CRT CPUs as plug-and-play alternatives.

In an LCA, product systems are evaluated on a functionally equivalent basis. The functional unit is used as the basis for the inventory and impact assessment to provide a reference to which the inputs and outputs are related. For this project, the functional unit is one desktop computer display over its lifespan. Data collected in this project have been normalized to a display that meets the functional unit specifications, which are presented in Table 1-2. These product performance specifications are assumed to meet the requirements of the system functional unit in the predictable future (i.e., computer technology as predicted through the year 2001). The CRT technology is the current industry standard for this product system.

Table 1-2. Functional unit specifications

Specification	Measure
display size [a]	17" (CRT); 15" (LCD)
diagonal viewing area [a]	15.9" (CRT); 15" (LCD)
viewing area dimensions	12.8" x 9.5" (122 in^2) (CRT); 12" x 9" (108 in^2) (LCD)
resolution	1024 x 768 color pixels
brightness	200 cd/m^2
contrast ratio	100:1
color	262,000 colors

[a] An LCD is manufactured such that its nearest equivalent to the 17" CRT display is the 15" LCD. This is because the viewing area of a 17" CRT is about 15.9 inches and the viewing area of a 15" LCD is 15 inches. LCDs are not manufactured to be exactly equivalent to the viewing area of the CRT.

Besides the CRT display, several FPD technologies were considered for inclusion in this study. Among the FPD technologies that exist, the amorphous silicon (a:Si) thin-film transistor-(TFT) active matrix LCD technology meets the requirements of the functional unit within the parameters of this analysis and is assessed in this study. Section 1.3.3.1 describes the LCD technology further, and Appendix A briefly describes several FPD technologies and explains why the non-LCD technologies are not considered for standard desktop computer uses as defined for this study. The following subsections briefly describe both CRT and LCD technologies.

1.3.2 Cathode Ray Tube

1.3.2.1 CRT technology

CRT monitors are a mature technology and are the current industry standard for desktop computer displays. The technology is the same as that for a television. CRT displays use high voltages to accelerate electrons toward a luminescent material (phosphor) that is deposited on a faceplate. The phosphor converts the kinetic energy of the electrons into light. In color CRTs, the phosphors are patterned in dots or stripes of red, green, and blue phosphors. The electrons are emitted from three cathodes in an electron gun assembly and pass through an apertured metal "shadow mask" during their passage to the phosphor. Electrons from each cathode that are directed at the wrong color phosphor are absorbed by the shadow mask. Pictures are created by first focusing the electron beams into tiny spots, which are moved by deflecting the electron beams electromagnetically with the "yoke." This system is extremely efficient in that it only requires three video drivers and connections instead of the 2000 or so in the most common FPD (MCC, 1994).

The high voltages used to accelerate the electrons must be insulated from the external surfaces of the tube and the CRT must have excellent electrical insulating properties. The decelerating electrons produce x-rays and the CRT must also be a good x-ray absorber. Leaded glass surrounds the cathode ray tube to absorb the x-rays.

The major parts of the CRT display are the faceplate (glass panel), shadow mask (also referred to as the aperture mask), a leaded glass funnel, and the electron gun with the deflection yoke. Various connectors, wiring, an implosion band, printed wiring boards (PWBs), and the casing comprise most of the rest of the display. Table 1-3 presents a more comprehensive list of the CRT components and a list of the component materials identified from disassembling a monitor, and additional research to identify the material makeup of some components (MCC, 1998).

Table 1-3. Preliminary list of CRT display components and materials

Component parts				Materials
Tube	Faceplate assembly	Phosphor-coated faceplate	Glass panel (faceplate)	Glass (1-2.5% PbO alkali/alkaline earth aluminosilicate)
			Phosphors	ZnS, Y_2O_2S (powders): Sn, Si, K, Cd
			Photoresist	Polyvinyl alcohol
			Black matrix coating (grille dag)	Aquadag**
			Lacquer coating	Mixture of alcohol and plastics
			Aluminum coating	Al
		Internal electron shield *		Al
		Shadow mask assembly	Mask	Steel, Ni
			Supports	CrNiFe and NiFe
	Frit (lead solder glass)			Lead oxide, zinc borate (~70% PbO)
	Conductively coated funnel	Glass funnel		Leaded glass (~24% PbO)
		Conductive coating		Aquadag** (may also add iron oxide)
		Frit		PbO, zinc oxide, boron oxide
		Binder		Nitrocellulose binder, amyl acetate
	Neck	Neck glass		Leaded glass (30% PbO alkali/alkaline earth silicate)
		Deflection yoke		Cu, ferrite
		Base & top neck, rings		Polystyrene
		Brass ring, brackets		Brass
		Rubber gaskets		Rubber
		Screws, washers		Zn-plated steel
		Neck clamp		Steel
		Insulating rings		Polysulphone
		Neck PWB		Misc. electronics and resin board
	Implosion band			Steel

Table 1-3. Preliminary list of CRT display components and materials

Component parts			Materials
Electron gun	Electrostatic field shaping electrodes	→	300/400 series steels (Fe, Ni, Cr)
	Cathodes	→	Ni (coated with mixtures of Ba, Sr, CaCO3)
	Glass pillars	→	Borosilicate glass
	Wire heater (filament heater)	→	Tungsten, aluminum oxide
	Glass stem	→	Leaded glass (29% PbO alkali aluminosilicate)
	Springs and washers	→	Steel
	Gunmount (glass)	→	Potassium aluminosilicate sintering
Powerboard	Main CRT PWB (includes power supply PWB, etc.)	→	Misc. electronics and resin board
	Flyback transformer	→	Misc.: e.g., potting material (epoxy), steel, Cu
Casing (chassis and base)	→		Polystyrene
Other misc. parts	Brackets	→	Brass
	Brackets	→	Polystyrene
	XY controls	→	Polycarbonate
	Connectors	→	Al
	Screws	→	Zn-plated steel
	Brackets, anode connection	→	Steel
	Shields (right, left, top, back)	→	
	Rubber feet	→	Silicone rubber
	Anode cap	→	Rubber
	Insulator pad	→	Polyester

1.3.2.2 CRT manufacturing

The manufacturing process of the CRT (Figure 1-2) involves first preparing the glass panel and shadow mask. The shadow mask is a steel panel with a mask pattern applied through photolithography. The color phosphors and a black matrix coating (aquadag) are applied to the faceplate, also using photolithography, which involves several steps and several chemicals that etch the material into specific patterns. A lacquer coating is applied to the phosphor-coated glass to smooth and seal the inside surface of the screen, and an aluminum coating is added to enhance brightness and as a conductor to allow the use of voltages over 12 kilovolts without charging of the phosphor screen. An electron shield (typically aluminum) is attached to the shadow mask assembly to prevent stray electrons from reaching outside the screen area (EPA, 1995; MCC, 1994). This then comprises the faceplate assembly. The two major remaining parts are the funnel and electron gun.

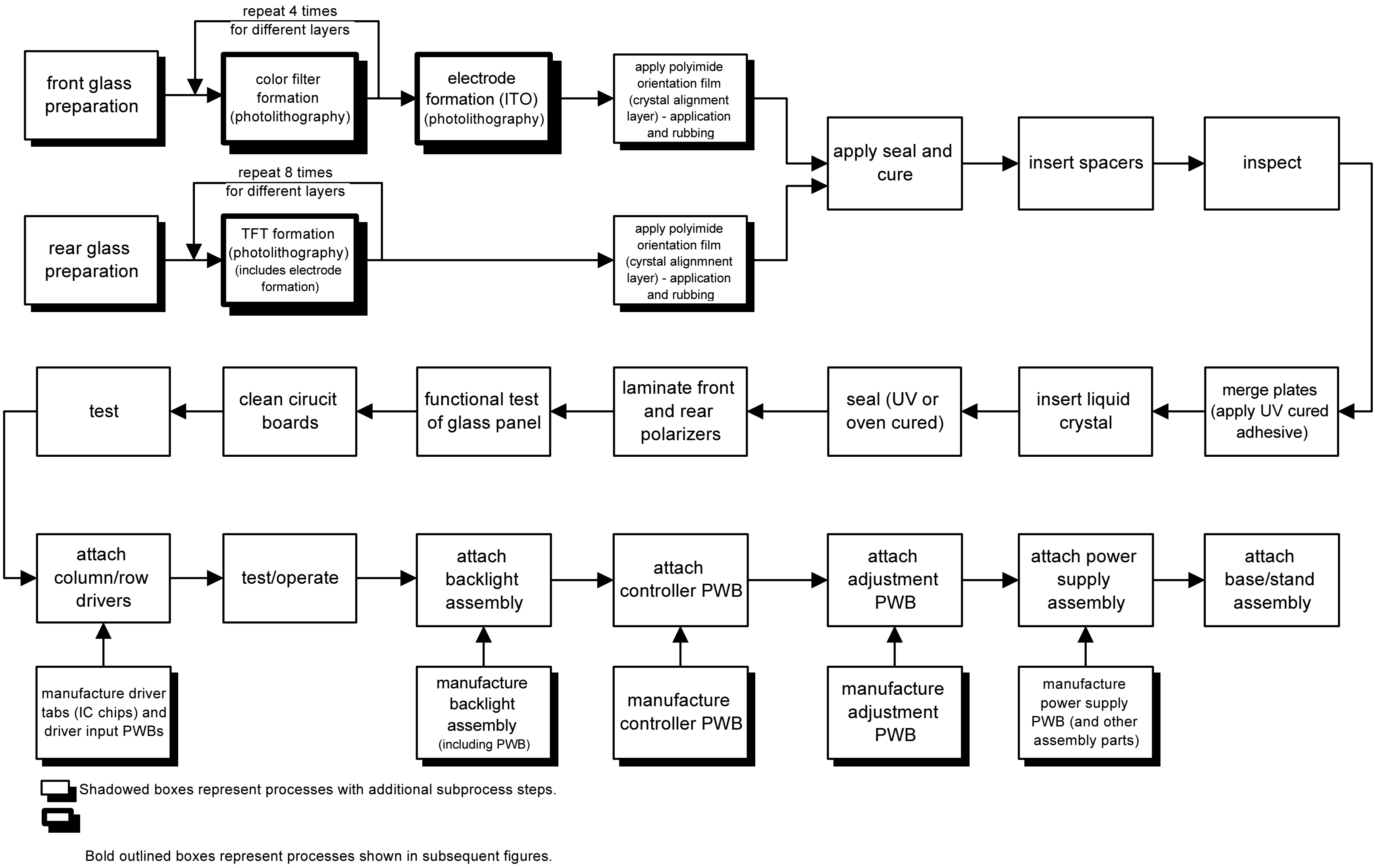


Figure 1-2. Traditional twisted nematic AMLCD manufacturing process

The leaded-glass funnel is washed and coated with a black coating (aquadag), which is a good electrical conductor and a non-reflective surface. The funnel and faceplate assembly are joined using frit (solder glass) that is approximately 70% lead oxide. The electron gun is an assembly of glass and several metal parts that are heated to embed the metal in the glass. The electron gun is then fused to the funnel neck. Finishing steps are conducted to complete the manufacturing of the CRT (or "tube") (e.g., attaching a metal implosion band for implosion protection and safety) and then the entire monitor is assembled with other necessary parts (e.g., the main and neck PWBs, power cord, casing).

1.3.3 Liquid Crystal Display

LCDs are used for various applications, with their largest market currently in notebook computers. LCDs have been gaining a presence in the desktop computer display market and are expected to continue to do so. Compared to the CRT, the LCD provides a more compact display, as well as being of higher contrast, sunlight readable, more reliable, and more durable (i.e., requiring much less maintenance) (Koch and Keoleian, 1995). In general, the major functional disadvantages have been that the resolution and quality of the image have not matched that of CRTs. However, emerging technologies are expected to meet user requirements.

The two most common types of LCDs are passive matrix (PMLCD) and active matrix (AMLCD). Brief descriptions of these and other LCD technologies are presented in Appendix A, Table A-1. In 1998, AMLCDs constituted approximately 81% and PMLCDs 19% of computer monitor LCD production (MCC, 1998). PMLCDs are used primarily for low-end products (e.g., cannot perform video applications); AMLCDs are used for high-end multimedia products and better meet the specifications for standard desktop computers. PMLCDs are forecasted to decline to less than one percent of the LCD desktop display market by 2002 (Young, 1998). Therefore, this project's focus is on AMLCDs.

1.3.3.1 LCD technology

In general, an LCD is comprised of two glass plates surrounding a liquid crystal material that filters external light. LCDs control the color and brightness of each pixel (picture element) individually, rather than from one source, such as the electron gun in the CRT.

The most common type of AMLCD, and the one that meets the functional unit specifications of this project, is the a:Si TFT AMLCD (see Appendix A, Table A-1 for descriptions of various types of AMLCDs). AMLCDs consist of driver tabs along the columns and rows of the display glass and transparent parallel electrical lines across the glass arranged to form a matrix. Each intersection of the matrix forms a pixel. The TFT AMLCD has a transistor at each pixel which functions as an electronic switch to activate an individual pixel. This active addressing technique allows for high contrast between the on and off states of a pixel.

Operation of the AMLCD is determined by how the liquid crystals are aligned when activated by an electrical current. Traditional AMLCDs use a twisted nematic (TN) operating principle of the liquid crystal, which is evaluated in this study. The orientation of the liquid crystal molecules either allows or does not allow light from a backlight source to pass through the display cell. When no electrical current is present, the liquid crystals align themselves parallel to a polyimide orientation film (alignment layer) on the glass. When a current is applied, the liquid crystals turn perpendicular to the glass. The combination of the alignment layer, electrical charge, and polarizers that are laminated to the glass panels affect an on or off state of the LCD cell (see Appendix B for further explanation; also see Castellano [1992] and OTA [1995]). The backlight supplies the light source for the display and generally has four cold cathode fluorescent tubes that contain small amounts of mercury vapor. Because the LCD technology essentially regulates passage of a backlight through the display, LCDs are considered non-emitting display technologies. CRTs, on the other hand, are emitting displays which emit electrons to illuminate appropriate phosphors.

There is a variation of the a:Si TFT AMLCD technology called in-plane switching (IPS). Compared to the traditional TN mode, IPS TFT allows for a wider viewing angle that is comparable to the CRT. The traditional TN mechanism vertically twists the liquid crystals by sending voltage through the display from electrodes that are on both the front and rear glass panels. IPS mode twists the liquid crystals horizontally in response to a voltage applied by electrodes on the rear glass only. The TN TFT uses indium-tin oxide (ITO) as the transparent electrode on the front and rear glass panels. For the IPS TFT, no ITO is needed on the front glass and the electrode on the rear glass is made of any of a number of other materials (e.g., Mo, Ta, Al/Cr, MoW). Therefore, no ITO is used for the IPS mode. However, the IPS TFT display demands an increase in the number of backlights to meet the brightness requirements for desktop applications (DisplaySearch, 1998). Although this technology may be produced for displays that meet this study's functional unit, the manufacturers of 15" AMLCDs that supplied data for this study provided data only for traditional a:Si TFT AMLCDs. IPS was forecasted to have a 35% market share of LCD desktop monitors in 2000 (Young, 1998) and therefore, studying IPS technology may be an area for future research.

Based on the disassembly of an LCD monitor conducted by MCC, a summary of the materials that are in an AMLCD are presented in Table 1-4 (MCC, 1998). The major components of the AMLCD are the glass panel (which includes the transistors, electrodes, liquid crystals, orientation film, polarizers, and row and column drivers), the backlight assembly (including the cold cathode fluorescent tube, light guide, and associated electronics), other electronics (main LCD controller), and the stand and cover. The remaining components and materials are listed in Table 1-4. In this report we will also refer to the LCD "module" as a component. This is comprised of the LCD panel, backlight unit, and main LCD controller. Module manufacturing as a process modeled in this study includes the major process in LCD manufacturing, which is panel manufacturing described below.

Table 1-4. LCD components and materials

LCD component parts				Materials
LCD assembly	LCD glass panel assembly	AMLCD cell	Glass	Soda lime or borosilicate
			Thin film transistor (TFT)	Misc. (e.g., Si, Mo, Al, etc) *
			Electrode	Indium-tin oxide (ITO)
			Polarizers	Iodine, cellulose triacetate-acrylic, etc.
			Orientation film (alignment layer)	Polyimide
			Liquid crystals	e.g., phenylcyclohexanes biphenyls
			Color filters	Resins
		Row/column driver tabs		IC chip on polyimide
		Row/column driver PWBs		Misc. (Si, Cu, etc.)
		Connection flex		Cu on film of polyimide
	Plastic frame			Polycarbonate, glass filled
	Gaskets			Silicone rubber
	Screws			Steel (Fe)
	Metal clip			BeCu
	Brightness enhancer			Polyester
	Cable assembly	Misc. wires & connectors		Misc. (Cu, plastic, etc.)
Controller (PWB)				Misc. (Si, Cu, etc.)
Power supply assembly	Housing			Steel (Fe)
	Screws			
	Insulator			Polyester
	Power switch			
	Power cord recepticle			ABS/Cu
	Heat sink			Aluminum
	Power supply PWB			Misc. (Si, Cu, etc.)

Table 1-4. LCD components and materials

LCD component parts			Materials
Backlight assembly	Metal plate		Steel (Fe)
	Screws		
	Brass threaded stand off		Brass
	Gasket		Foam rubber
	Nylon strain relief		Nylon
	Nylon clamp		
	Clear protector		Plexiglas
	Opaque diffuser		Polyester
	White reflector		
	Light pipe		Polycarbonate
	Corner tape		Aluminized mylar
	Light assembly	Cold cathode tube	Glass, phosphor, Hg
		Shock cushion	Silicone rubber
		Cable assembly	Insulated Cu
	Rear plate assembly	Rear plate	Steel (Fe)
		Screws	
		Hold-down plate	
		Cable clamp	Nylon
		Plastic tube	Polycarbonate
		Flat cable toroid	Hi-mu ferric
		Caution label	Paper
	Backlight PWB		Misc. (Si, Cu, etc.)

Table 1-4. LCD components and materials

LCD component parts		Materials
Rear cover assembly	Screws	Steel (Fe)
	Metal plate	
	BeCu fingers	BeCu
	Cloth mesh	Polyester
	Insulator	
	Rear cover	Plastic (ABS)
Base/stand assembly	Brackets & washers	Steel (Fe)
	Axle & spring	
	Base weight	
	C-clip	
	Swivel bearing 1	Stainless steel
	Swivel bearing 2	Polyoxymethylene (acetal)
	Covers	Plastic (ABS)
	Upright	unsaturated polyester, glass filled
	Bushing	Nylon
	Rubber feet	Silicone rubber
Other misc. parts	Screws	Steel (Fe)
	Power supply cover	
	Front bezel	ABS
	Knob	
	Power switch	
	LED light pipe	Polycarbonate
	Adjustment PWB	Misc. (Si, Cu, etc.)
	Cable clamp	Nylon
	Insulator	Polyester

Source: MCC, 1998.

*Example of TFT materials: gate metal (Al or Cr), S_iO_2, SiN, a-Si/SiNx, a-Si, drain metal

1.3.3.2 LCD manufacturing

LCD technology uses a glass substrate (e.g., soda lime or borosilicate glass). Once the glass is acquired, it must be cleaned, which is a critical step in reliable manufacturing. The manufacturing techniques of the LCD are similar to the production of semiconductor chips, which require energy intensive "clean rooms" for manufacturing. A conductor or semiconductor is deposited on the glass substrate. Most FPDs require a transparent conductor (electrode) such as ITO, which is usually deposited by a sputtering method. TFT devices in AMLCDs use semiconducting materials (e.g., silicon, cadmium selenide) for transistors at each pixel. These semiconducting materials can be prepared by vacuum evaporation, using either electron beam evaporation, sputtering, or chemical vapor deposition. Electrode patterns are then formed by a photolithographic process that begins with the coating of photoresist on the ITO or metal-coated substrate.

The photoresist (photosensitive organic polymer) is then "developed" using liquid organic chemicals. This is similar to the manufacture of silicon integrated circuits (ICs). The ITO or metal is then etched to form electrodes. FPD manufacturing employs etchants (e.g., H_3PO_4/HNO_3, HF/HCl, $HClO_4$, CF_4/SF_6) that differ from those used in silicon IC manufacturing. LCDs use alignment layers and iodine/dye based polarizers. AMLCDs use amorphous silicon, silicon nitride, various oxides and metals. The silicon IC manufacturing process of plasma-enhanced chemical vapor deposition (PECVD) is used for some of these layers, as are more conventional vacuum deposition techniques. Finally, various organic liquids (the liquid crystals) are injected between the top and bottom substrate of LCDs (MCC, 1993).

The general process flow of AMLCD manufacturing is presented in Figure 1-3. The photolithographic subprocess steps for the front and rear glass panels are presented in Figures 1-4 and 1-5. Various processes include sputtering, PECVD, photolithography, wet etching, reactive ion etching (RIE), in-process testing, liquid crystal processing, and lamination among others. The manufacturing process of IPS differs from traditional TN in that there are fewer photolithography steps required since no ITO is patterned onto the front or rear glass plates.

Once the photolithographic processes are completed, the polyamide orientation film is applied and rubbed on the glass. The front and rear glass substrates are merged and the liquid crystals are inserted. Polarizers are laminated to the front and rear panels, completing the "AMLCD cell" of the LCD glass panel assembly (see Table 1-4). The electronic components that operate the AMLCD cell (i.e., the column and row driver tabs and wiring boards) are then attached to the glass. This completes the LCD glass panel assembly. The other major components of the LCD are then assembled. Adding the controller PWB and the backlight assembly make up what may also be called the "LCD module." Finally, the power supply assembly and the plastic cover and stand are added to make an assembled monitor.

In total, there are six PWBs needed for the LCD: controller, row driver, column driver, backlight, power supply, and adjustment knob PWB. The major ones by size and function are the larger controller and backlight PWBs, and the smaller column and row PWBs. These are compared to the two major PWBs in the CRT: the main and neck PWBs (see Table 1-3).

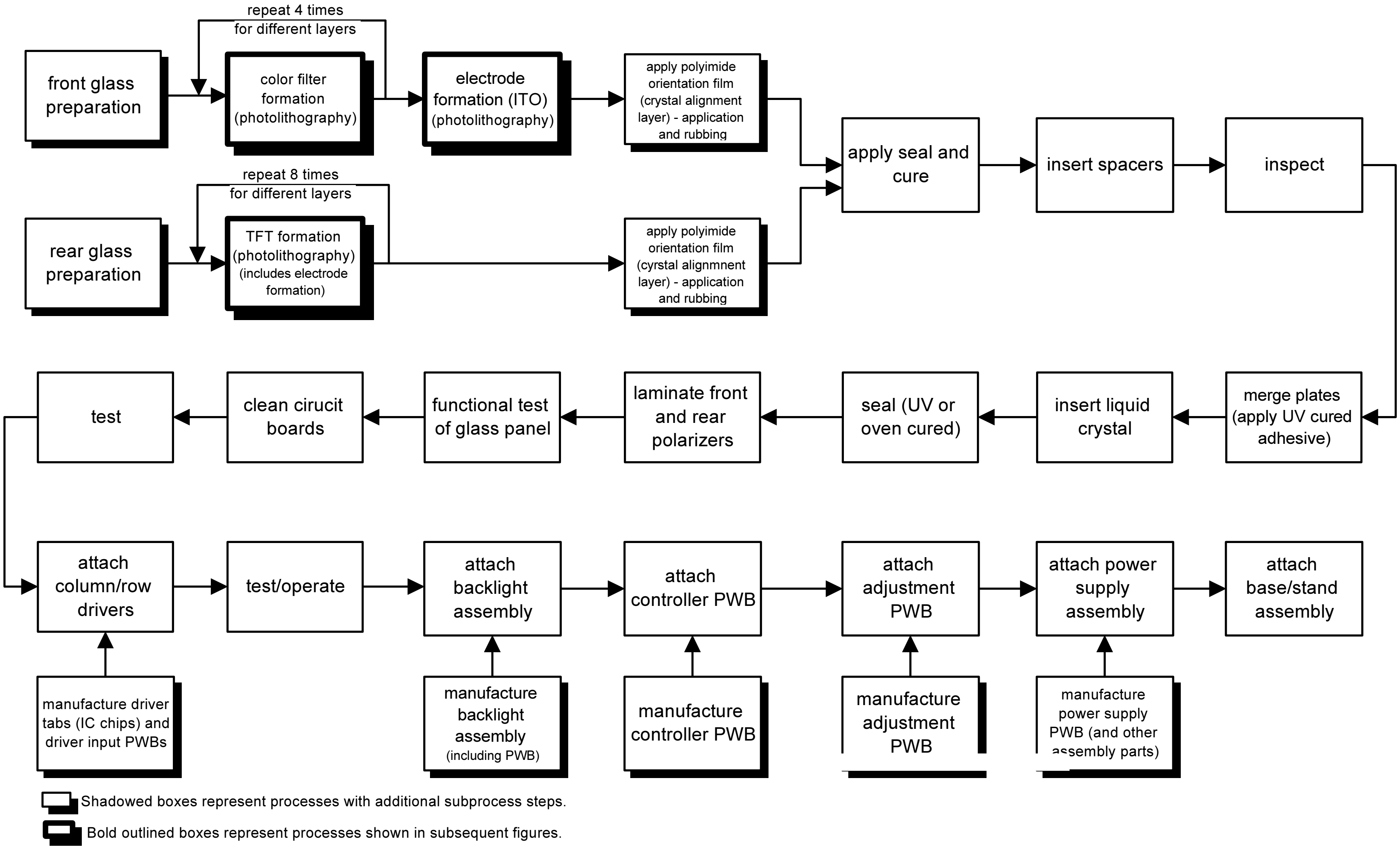


Figure 1-3. Traditional twisted nematic AMLCD manufacturing process

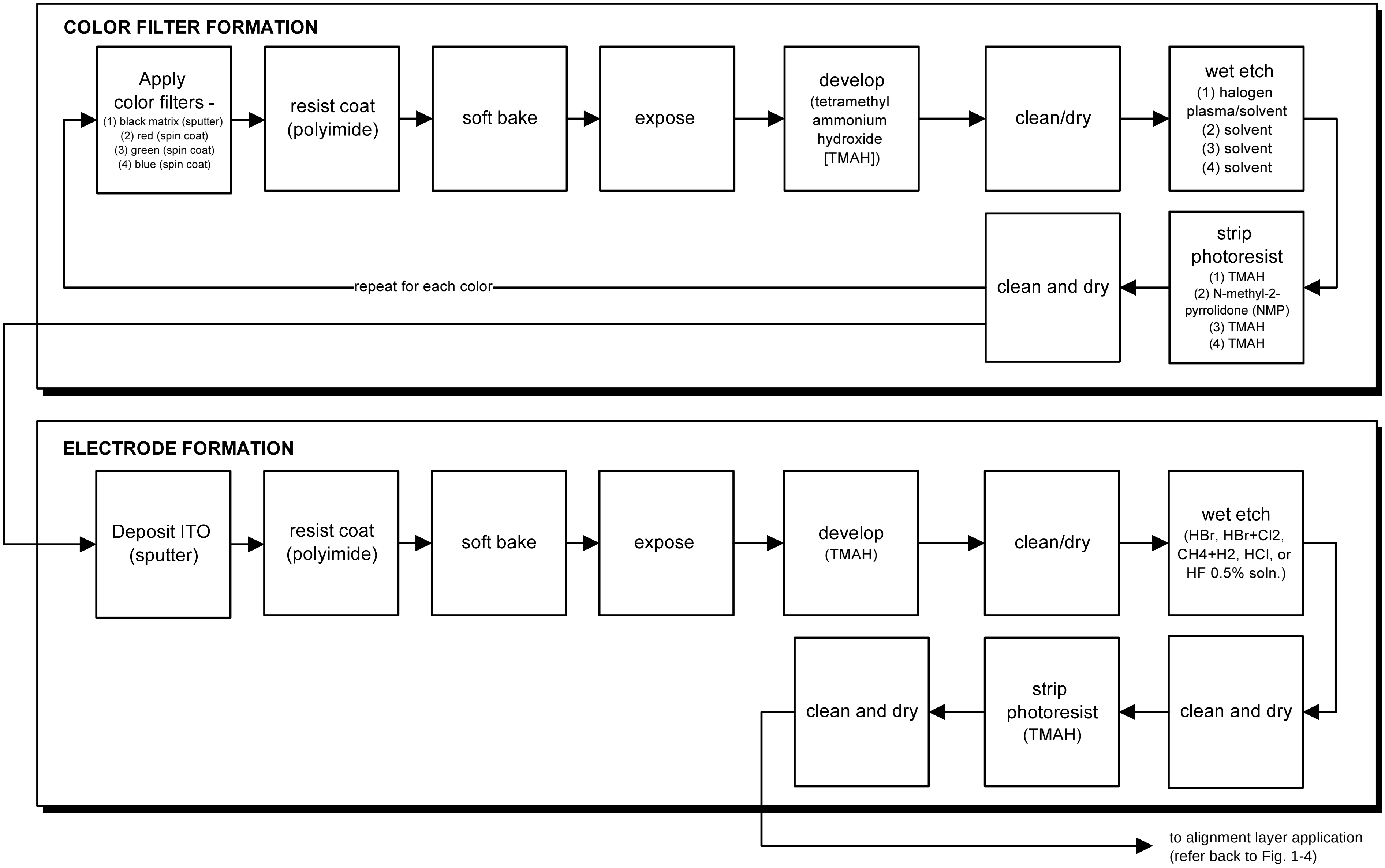


Figure 1-4. Front glass AMLCD manufacturing (photolithography)

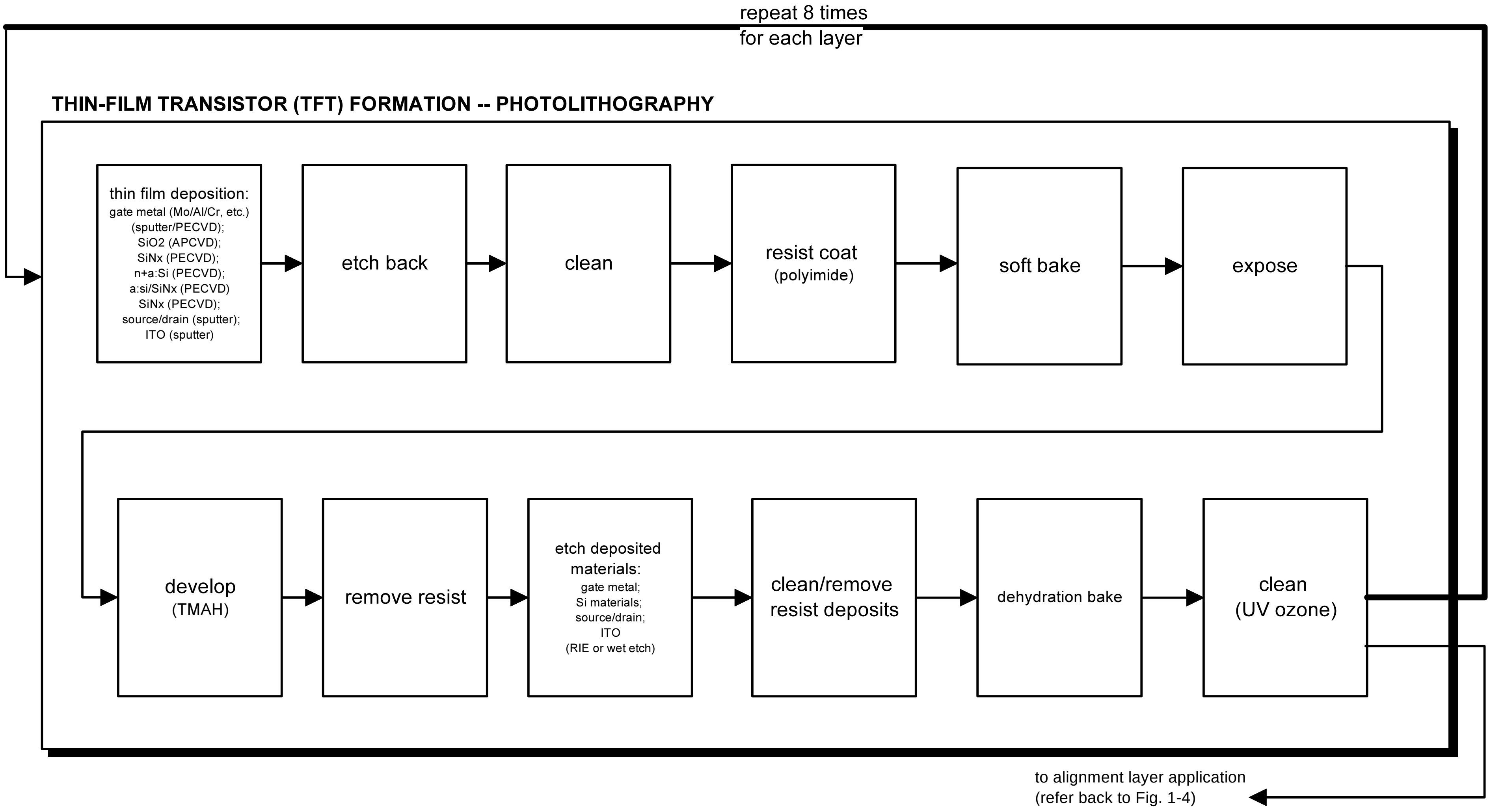


Figure 1-5. Rear glass AMLCD manufacturing (photolithography)

1.4 ASSESSMENT BOUNDARIES

1.4.1 Life-Cycle Stages and Unit Processes

In a comprehensive cradle-to-grave analysis, the display system includes five life-cycle stages: (1) raw materials acquisition; (2) materials processing; (3) product manufacture; (4) product use, maintenance and repair; and (5) final disposition/end-of-life. Also included are the activities that are required to affect movement between the stages (e.g., transportation). The major processes within the life cycles of CRTs and LCDs, which are modeled in this study, are depicted in Figures 1-6 and 1-7, respectively. Details on collecting data for these processes are presented in Chapter 2.

1.4.2 Spatial and Temporal Boundaries

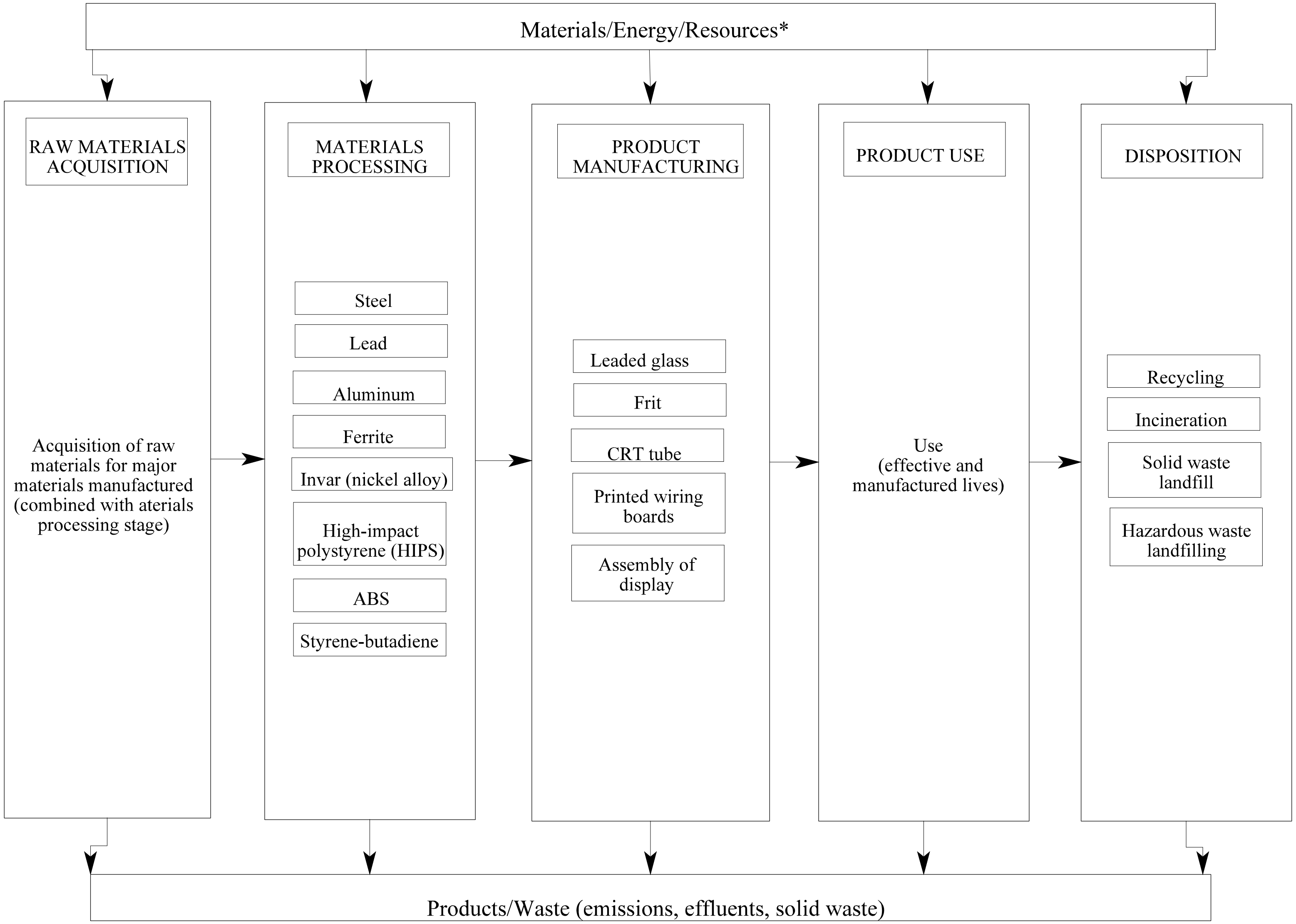
The geographic boundaries of this assessment are shown in Table 1-5. This LCA will focus on the U.S. display market; therefore, the geographic boundary for the use and disposition stages of displays is limited to the United States. Raw materials acquisition and material processing for materials used in the manufacture of computer displays are done throughout the world. Product manufacturing is done predominately in Asia, although there are foreign-owned desktop display manufacturers operating plants in the United States and other countries. Therefore, for purposes of this study, the geographic boundaries for raw material extraction, material processing, and product manufacture are worldwide.

Table 1-5. Geographic coverage for each life-cycle stage

Life-cycle stage	Geographic coverage
Raw materials acquisition	worldwide[a]
Material processing	worldwide[a]
Product manufacture	worldwide[a]
Use	United States
Disposition	United States

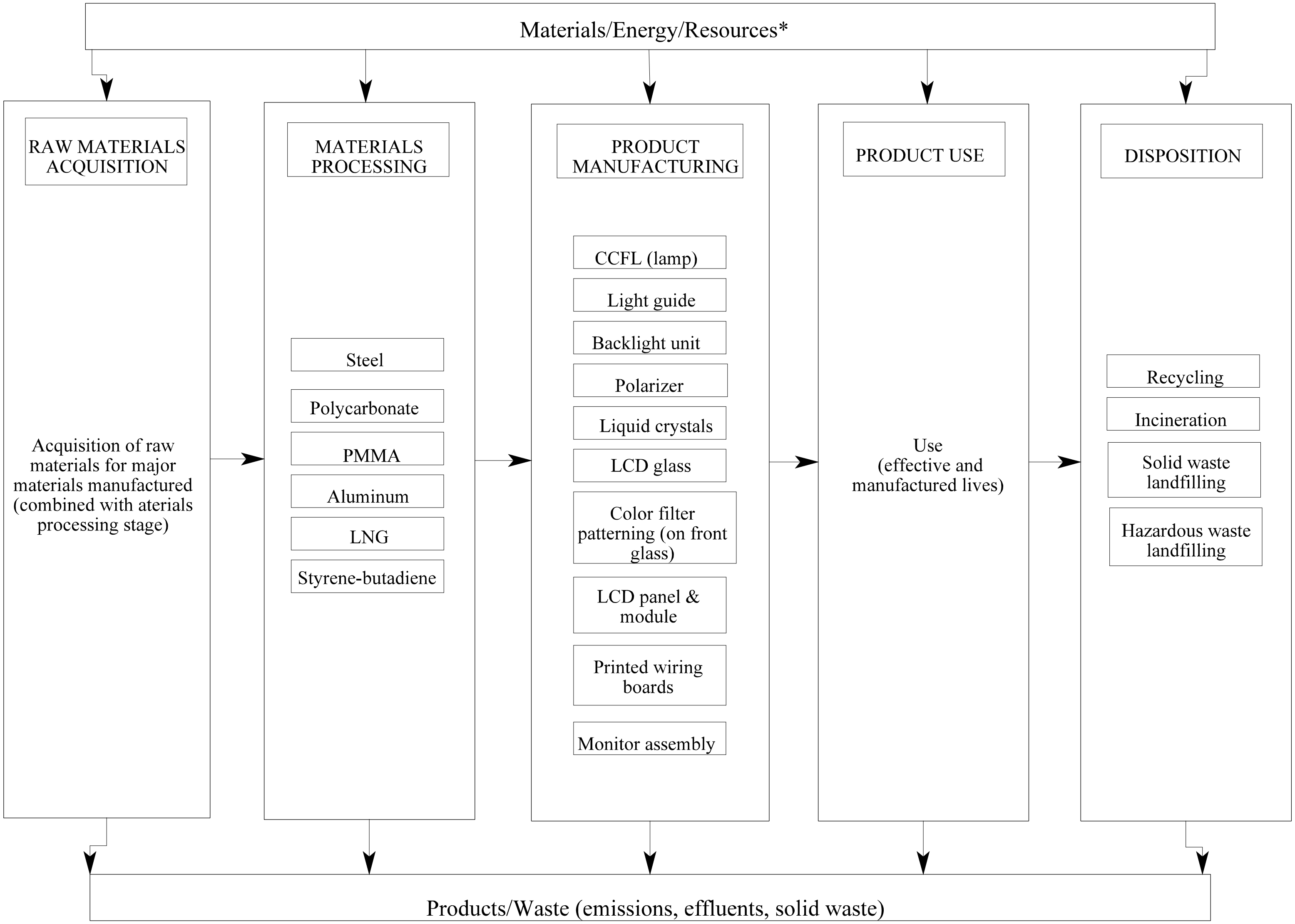
[a] In this study, worldwide boundaries were considered; however, the actual geographic locations for LC1 data are presented in Chapter 2 (Sections 2.2 and 2.3).

While the geographic boundaries show where impacts might occur for various life-cycle stages, traditional LCAs do not provide an actual spatial relationship of impacts. That is, particular impacts cannot be attributed to a specific location. Rather, impacts are generally presented on a global or regional scale.



Note: Arrows indicate flows between life-cycle stages. The arrows also represent transportation of materials required to get from one process to another.
* Electricity generation and fuel production (fuel oils, natural gas, and LPG) processes are not shown but were attached to those processes that consume energy resourcesthroughout the life-cycle

Figure 1-6. CRT Life-Cycle



Note: Arrows indicate flows between life-cycle stages. The arrows also represent transportation of materials required to get from one process to another.
* Electricity generation and fuel production (fuel oils, natural gas, and LPG) processes are not shown but were attached to those processes that consume energy resourcesthroughout the life-cycle

Figure 1-7. LCD Life-Cycle

This study addresses impacts from the life cycle of a desktop computer display manufactured using 1997-2000 technology. The use and disposition stages cover a period that represents the life of a display. Two lifespans are considered: (1) the "effective" life, defined as the period of time the display is in use by primary, secondary, or even tertiary users before reaching its final disposition; and (2) the "manufactured" life, defined as the designed durability of a display. The effective life is estimated based on past and current use patterns of displays and represents a realistic estimate of the lifespan. Because the effective life is subject to many variables, including fluctuating market trends, it is also necessary to evaluate the displays over their manufactured life. The manufactured life is estimated based on the manufacturer's estimated durability of the display. Because of quickly changing technologies in this industry, the effective life has been shorter than the manufactured life. The effective life, which is currently the more realistic scenario is used as the primary scenario in the final results presented in this study. However, the manufactured life is presented as an alternative scenario.

It is assumed that parameters that may change with time, such as available landfill space, will remain constant throughout the lifespan of the product system. If the lifespan is relatively short (i.e., within a timeframe where significant changes in landfill space would not occur), the preceding assumption is reasonable. If resources become more scarce within the lifespan, this assumption could underestimate the impacts.

1.4.3 General Exclusions

Impacts from the infrastructure needed to support the manufacturing facilities (e.g., maintenance of manufacturing plants) are beyond the scope of this study. However, maintenance of clean rooms used in the manufacturing of LCDs (and other components), which require substantial amounts of energy, are considered part of the manufacturing process.

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Chapter 2

LIFE-CYCLE INVENTORY

A life-cycle inventory (LCI) is the identification and quantification of the material and resource inputs and emission and product outputs from the unit processes in the life cycle of a product system (Figure 2-1). For the Design for the Environment (DfE) Computer Display Project (CDP), LCI inputs include materials used in the computer display product itself, ancillary materials used in processing and manufacturing of the displays, and energy and other resources consumed in the manufacturing, use, or final disposition of the displays. Outputs include primary products, co-products, air emissions, water effluents, and releases to land. Specific unit processes for CRTs and LCDs are represented by the boxes in Figures 1-6 and 1-7, and each unit process has inputs and outputs particular to that process. Figures 2-2 and 2-3 also show each unit process for both the CRT and LCD life cycles, and graphically displays how they are linked to subsequent processes. This figure will be referred to throughout this chapter in the discussion of each life-cycle stage.

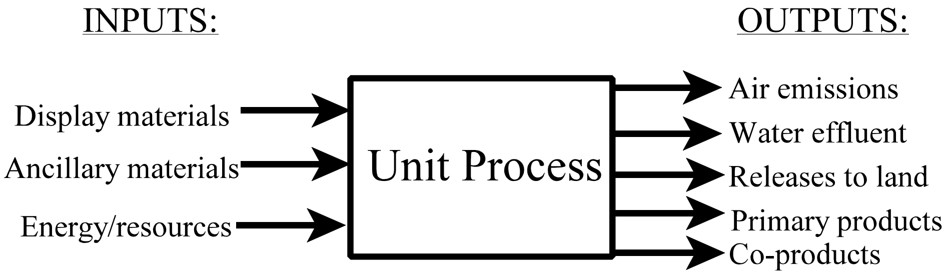
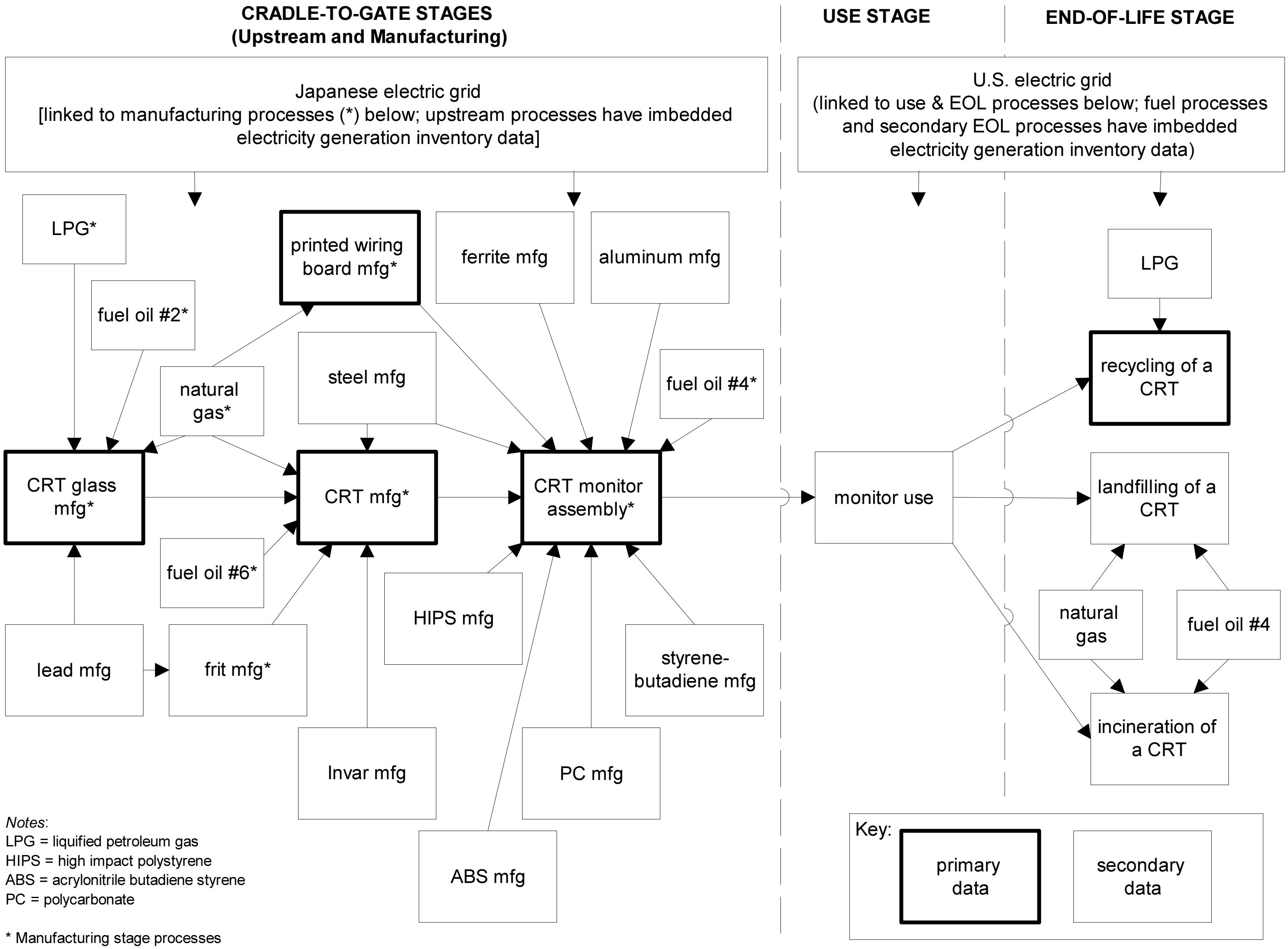


Figure 2-1. Unit process inventory conceptual diagram

This chapter describes the methods for collecting LCI data in the DfE CDP, and presents LCI results. Section 2.1 describes the general methodology for LCI data collection, while Sections 2.2 through 2.6 present the specific methodologies, data sources, data quality, limitations and uncertainties for each life-cycle stage. Section 2.7 then concludes with the combined LCI data for each monitor type.

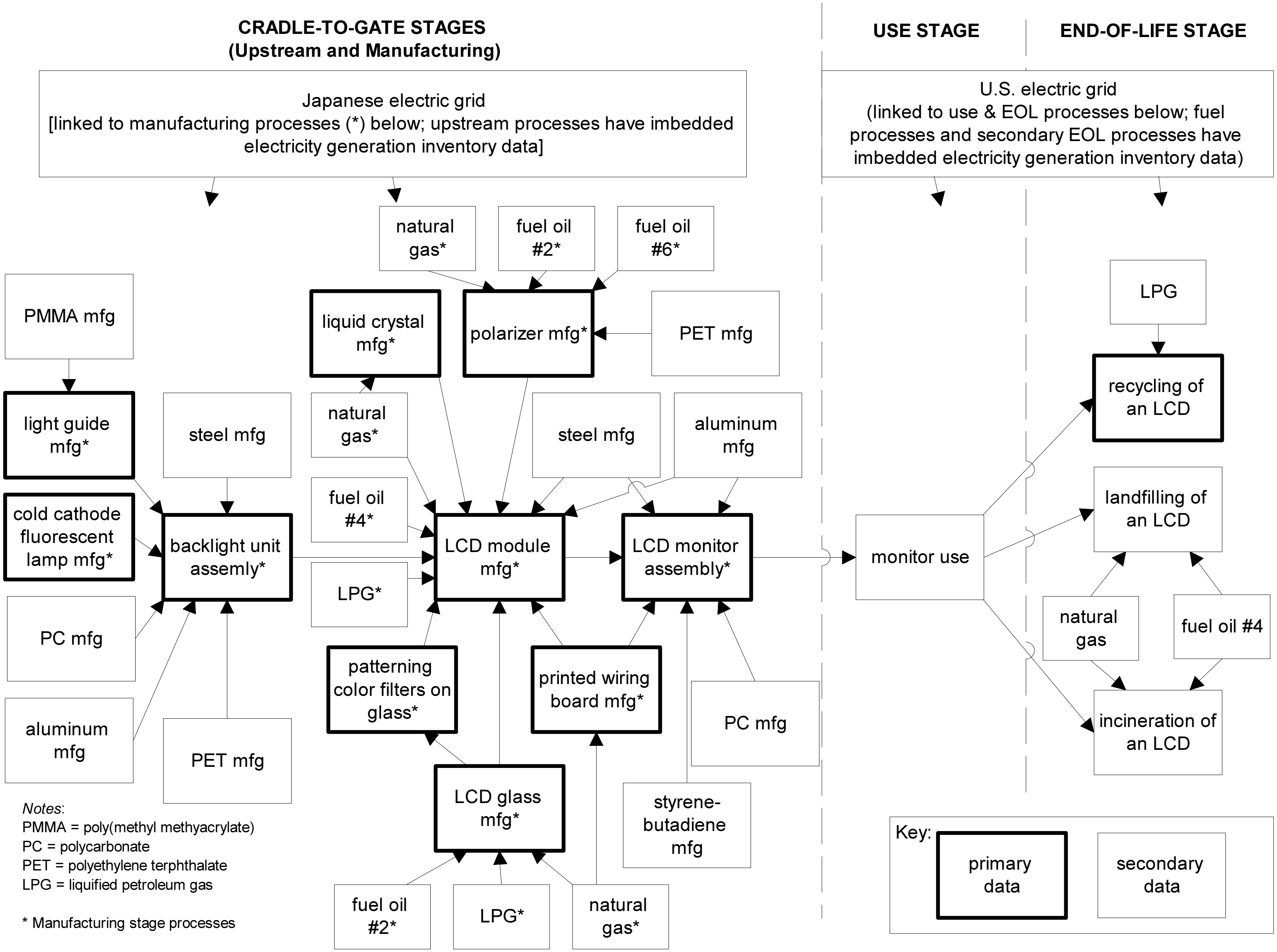
More specifically, Section 2.2 presents the LCI methodology for the materials extraction and materials processing (i.e., “upstream”) life-cycle stages, including electricity generation. Electricity is used in several processes throughout each monitor’s life-cycle, and the electricity generating process is linked to the processes that use electricity. As a consequence, the inventory results from electricity generation are reported as part of the associated life-cycle stage for the process to which it is linked. For example, electricity used in manufacturing a product component is included in the manufacturing stage inventory, while electricity used during the use stage is included in the use stage inventory.



Notes:
LPG = liquified petroleum gas
HIPS = high impact polystyrene
ABS = acrylonitrile butadiene styrene
PC = polycarbonate

* Manufacturing stage processes

Figure 2-2. CRT linked processes



Notes:
PMMA = poly(methyl methyacrylate)
PC = polycarbonate
PET = polyethylene terphthalate
LPG = liquified petroleum gas

* Manufacturing stage processes

Figure 2-3. LCD linked processes

Section 2.3 presents the LCI methods for the product manufacturing life-cycle inventory, which was developed from primary data collected through questionnaires designed and sent to manufacturers for this study. Sections 2.4 and 2.5 present the methods for developing the use and end-of-life (EOL) life-cycle stage inventories, respectively. Transportation is another important aspect of a product life-cycle that can cause environmental impacts. Information related to the transport of materials, products, and wastes is presented in Section 2.6. As the final section of Chapter 2, Section 2.7, summarizes and discusses the entire inventory data over the life-cycles of the CRT and LCD computer monitors. Sensitivity analyses are also discussed in Section 2.7.

2.1 GENERAL METHODOLOGY

This section describes the data categories evaluated in the CDP LCI, the decision rules used to determine which materials extraction and materials processing life-cycle stages (e.g., "upstream" processes) to evaluate in the study, and data collection methods. It also describes procedures for allocating inputs and outputs from a process to the product of interest (e.g., a display or display component) when the process is used in the manufacture, recycle, or disposal of more than one product type at the same facility. Finally, it describes the data management and analysis software used for the project and methods for maintaining overall data quality and critical review.

2.1.1 Data Categories

Table 2-1 describes the data categories for which inventory data were collected, including material inputs, energy inputs, natural resource inputs, emission outputs, and product outputs. Inventory data were normalized to mass per functional unit (in the case of material and resource inputs and emission or material outputs), megajoules (MJ) per functional unit (in the case of energy inputs), or the number of components per functional unit (in the case of display components). As discussed in Section 1.3, the functional unit is one desktop computer display over its lifespan.

Data that reflected production for one year of continuous processes were scaled to one functional unit. Thus, excessive material or energy associated with startups, shutdowns, and changeovers were assumed to be distributed over time. Consequently, any environmental and exposure modeling associated with the impact assessment reflects continuous emissions such that equilibrium concentrations may be assumed. If the reporting year was less than one year for any inventory item, the analysis was adjusted as appropriate.

Table 2-1. LCI data categories

Data Category	**Description**
Material inputs (kg per functional unit)	
Primary materials	Actual materials that make up the final product for a particular process. These can be individual materials or a combination of materials that comprise a component part.
Ancillary (process) materials	Materials that are used in the processing of a product for a particular process. Process materials from monitor manufacturing could include, for example, etchants used during photolithography which are washed away and not part of the final product, but are necessary to manufacture the product.
Energy inputs (MJ per functional unit)	
Process energy	Energy consumed by any process in the life-cycle.
Precombustion energy	The energy expended to extract, process, refine, and deliver a usable fuel for combustion.
Transportation energy	Energy consumed in the transportation of the materials or products in the life cycle.
Natural resource inputs (kg per functional unit)	
Non-renewable resources	Materials extracted from the ground that are non-renewable, or stock, resources (e.g., coal).
Renewable resources (e.g., water)	Water or other renewable, or flow, resources (e.g., limestone) are included in the analysis. Renewable resource data values are presented in mass of water consumed for a particular process.
Emissions outputs (kg per functional unit)	
Air	Mass of a product or material that is considered a pollutant within each life-cycle stage. Air outputs represent actual gaseous or particulate releases to the environment from a point or diffuse source, after passing through emission control devices, if applicable.
Water	Mass of a product or material that is considered a pollutant within each life-cycle stage. Water outputs represent actual discharges to either surface or groundwater from point or diffuse sources, after passing through any water treatment devices.
Solid wastes	Mass of a product or material that is deposited in a landfill or deep well. Represents actual disposal of either solids or liquids that are deposited either before or after treatment (e.g., incineration, composting), recovery, or recycling processes.
Products (kg of material or number of components per functional unit)	
Primary products	Material or component outputs from a process that are received as input by a subsequent unit process within the display life cycle.
Co-products	Material outputs from a process that can be used, either with or without further processing, that are not used as part of the final functional unit product.

Data were also collected on the final disposition of emissions outputs, such as whether outputs are recycled, treated, and/or disposed. This information helps determine what impacts will be calculated for a particular inventory item. Methods for calculating impacts are discussed in Chapter 3, Life-Cycle Impact Assessment. The dispositions used for this project are as follows:

- air,
- surface water,
- landfill,
- land (other than landfill),
- treatment,
- recycling/reuse, and
- deep well injection.

Given the enormous amount of data involved in inventorying all of the inputs and outputs for a product system, life-cycle assessment (LCA) practitioners typically employ decision rules to make the data collection manageable and representative of the product system and its impacts. Section 2.1.2 discusses the decision rules used in the CDP LCI.

2.1.2 Decision Rules

In an LCA, the materials extraction and materials processing life-cycle stages (referred to as "upstream" life-cycle stages) include processes for extracting raw materials from the earth and processing those raw materials into the materials used in the manufacture of the product of interest. Examples of upstream processes include the mining of iron ore and its processing with other materials into steel sheet or the extraction of petroleum from underground reserves and its conversion into plastic pellets. A continuing challenge for LCA practitioners is to collect all the appropriate data for a product system, including data for these upstream processes as well as data for product manufacturing, use, and disposal processes. In this project, decision rules as to what inventories should be included as upstream processes in the overall modeled life-cycle are based on the materials used to manufacture the computer monitors. Also, which component parts to include in the model depends on these decision rules. In considering upstream materials, a combination of several factors, including availability of existing data were considered. For considering which component manufacturing processes to include, the decision rules, plus manufacturers willingness to participate, factored into our overall scope of what was included in the analysis.

To help determine which upstream processes to include in the CDP LCI, first the bill of materials (BOM) of the component parts and the materials that make up those parts (Tables 1-3 and 1-4) was reviewed. The quantities of those materials identified by MCC can be found in Industry Profile Document (MCC, 1998). Using the MCC BOM allowed work to begin on selecting and collecting upstream data before the actual BOM from the manufacturing stage was obtained from the project's primary data collection effort. Final decisions on which upstream processes to include were based on the BOM developed from data collected from manufacturers. Tables 2-2 and 2-3 list the BOMs of the primary material inputs from the manufacturing of the CRT and LCD, respectively. The mass quantities given in the tables are the primary material inputs to the manufacturing process and would be equivalent to the amount of material in the final product plus excess or waste materials. While this is not exactly equivalent to the mass of each material that makes up a finished product, it does represent the mass of primary materials used to manufacture the finished product at participating facilities. Details of how these data were obtained are presented in Section 2.3, which describes the manufacturing stage inventory.

Table 2-2. Bill of primary material inputs for a 17" CRT monitor

Material/Component		**Mass (kg)** [a]		**weight % of total inputs** [a]	
	Sub-component				
Lead oxide glass		9.76		46.1%	
	Lead		0.45		2.1%
Steel		5.16		24.4%	
Plastics		3.04		14.4%	
	Polycarbonate (PC)		0.92		4.36%
	Styrene-butadiene co-polymer		0.83		3.91%
	Polyethylene ether (PEE)		0.74		3.47%
	Acrylonitrile-butadiene-styrene (ABS)		0.32		1.52%
	High-impact polystyrene (HIPS)		0.15		0.71%
	Triphenyl phosphate		0.05		0.25%
	Tricresyl phosphate		0.02		0.11%
	Phosphate ester		0.01		0.04%
Printed wiring boards (PWB) and components		0.85		4.00%	
Cables/wires		0.45		2.13%	
Aluminum (heat sink)		0.27		1.29%	
Nickel alloy (invar)		0.27		1.29%	
CRT shield assembly		0.24		1.14%	
Ferrite		0.17		0.80%	
Deflection yoke assembly		0.15		0.71%	
Demagnetic coil		0.13		0.60%	
Video cable assembly		0.11		0.54%	
Power cord assembly		0.11		0.54%	
Electron gun		0.10		0.47%	
CRT magnet assembly		0.08		0.36%	
Audio cable assembly		0.07		0.34%	
Frit		0.07		0.32%	
Solder		0.03		0.13%	
Phosphors		0.02		0.08%	
Aquadag		0.02		0.07%	
Other (misc.)		0.06		0.30%	
TOTAL		**21.16**		**100%**	

[a] Based on the primary material inputs to the manufacturing process, including material in the final product plus excess or waste materials.

Table 2-3. Bill of primary material inputs for a 15" LCD monitor

Material/Component		Mass (kg) [a]		weight % of total inputs [a]	
	Subcomponent				
Steel		2.53		44.12%	
Plastics		1.78		30.98%	
	Polycarbonate (PC)		0.52		9.00%
	Poly(methyl methacrylate) (PMMA)		0.45		7.80%
	Styrene-butadiene copolymer		0.36		6.31%
	Polyethylene ether (PEE)		0.30		5.23%
	Triphenyl phosphate		0.09		1.61%
	Polyethylene terephthalate (PET)		0.06		1.03%
Glass		0.59		10.31%	
Printed wiring boards (PWB) and components		0.37		6.52%	
Cables/wires		0.23		4.08%	
Aluminum (heat sink, transistor)		0.13		2.34%	
Solder (60% tin, 40% lead)		0.04		0.66%	
Color filter pigment		0.04		0.65%	
Polyvinyl alcohol (PVA) (for polarizer)		0.01		0.15%	
Liquid crystals, for 15" LCD, unspecified [b]		0.0023		0.04%	
Backlight lamp (cold cathode fluorescent lamp, CCFL)		0.0019		0.03%	
	Mercury		3.99E-06		0.0001%
Transistor metals, other (e.g., Mo, Ti, MoW)		0.0019		0.03%	
Indium tin oxide (ITO) (electrode)		0.0005		0.01%	
Polyimide alignment layer		0.0005		0.01%	
Other (e.g., adhesives, spacers, misc.)		0.0031		0.05%	
TOTAL		5.73		100%	

[a] Based on the primary material inputs to the manufacturing process, including material in the final product plus excess or waste materials.

[b] This does not include all liquid crystals, as those specified as individual chemicals are in very small amounts and included in the "other" category.

The decision rule process begins by assessing the materials and components in Tables 2-2 and 2-3 for the following attributes:

1. *The mass (M) contribution of each component and material in the display.* The mass is important in order to account for the majority of materials and components that make up a display, but also because the more significant the material or component by mass, the more materials and resources may be required to manufacture the material or component and thus it may have a significant environmental impact.

2. *Materials that are of known or suspected environmental (Env) significance (e.g., toxic).* As this is an environmental life-cycle assessment, consideration of materials or components that are known to or are suspected to exhibit an environmental hazard are also included to the extent feasible.

3. *Materials that are known or suspected to have a large energy (E) contribution to the systems energy requirements.* Energy impacts are of great interest to the use and manufacture of display monitors and, therefore, priorities were given to including materials or components that are known to or suspected to consume large amounts of energy.

4. *Materials or components that are functionally (F) significant to the display.* "Functionally significant" is defined as important to the technically successful operation of the display. For example, the liquid crystals in an AMLCD would be "functionally significant" while screws, gaskets, or the plastic cover would not be.

5. *Materials or components that are physically (P) unique in the CRT as compared to the LCD and vice versa.* The physical uniqueness of a material or component could be identified by chemical makeup or by size. An example of the latter would be if the plastic casing for the CRT and LCDs were made of the same material, but the CRT casing had substantially more material by weight.

The priority scheme depicted in Figure 2-4 provides guidelines for applying the CDP decision rules. Material or component inputs that account for more than five percent of the total mass of a display technology were given top priority for data collection, as were those of known or suspected environmental or energy significance and those that are functionally significant or physically unique. Of less emphasis in trying to obtain data, but still included if possible, were materials or components that are functionally significant but physically similar to those in the other technologies, and those that were between 1 and 5% of the total mass of the display. Recognizing the limitations of project resources, materials or components that account for less than one percent of total mass or are not otherwise significant or unique were excluded *a priori*.

Based on this hierarchy and on review of the preliminary BOMs, Tables 2-4 and 2-5 present how components were rated based on the priority scheme, and which ones were included in the analysis. If a material or component was included in the analysis as a separate process, it is listed in the last column of Tables 2-4 and 2-5 by what life-cycle stage that process is in (i.e., upstream or manufacturing process). If a material or component was only included as part of another process, and not as a separate process in the profile, the process in which that material or component is found is provided in the last column.

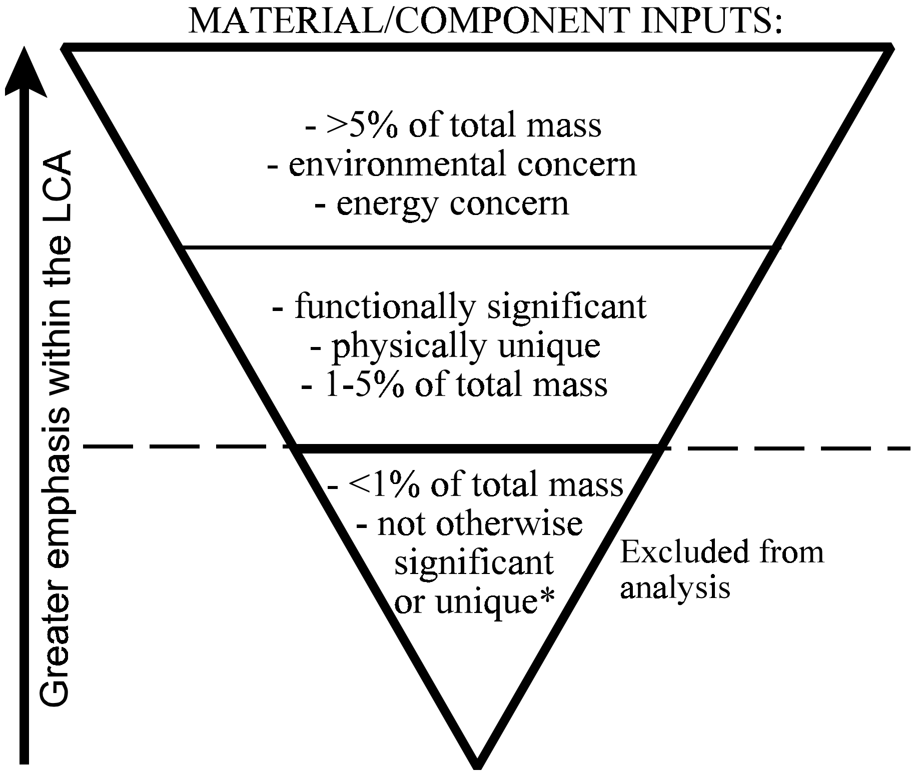


Figure 2-4. Decision rule guidelines

*e.g., materials are excluded if they are not of known environmental significance (for example, toxic) or are not physically unique.

Table 2-4. Decision rule priorities and scope of analysis for the primary material inputs of the 17" CRT monitor

Material/Component	**Sub-component**	**Decision rule**	**Included in analysis as:**
Lead oxide glass		M, F, P, E, Env	manufacturing process
	Lead	P, Env	upstream process
Steel		M	upstream process
Plastics		---	-----
	Polycarbonate (PC)	M	upstream process
	Styrene-butadiene co-polymer	M	upstream process
	Polyethylene ether (PEE)	M	part of monitor assy. process
	Acrylonitrile-butadiene-styrene (ABS)	M	upstream process
	High-impact polystyrene (HIPS)	none	upstream process
	Triphenyl phosphate	none	part of monitor assy. process
	Tricresyl phosphate	P	part of monitor assy. process
	Phosphate ester	P	part of monitor assy. process
Printed wiring boards (PWB) and components		M, E, Env	manufacturing process
Cables/wires		none	part of monitor assy. process
Aluminum (heat sink)		M (<5%), E	upstream process
Nickel alloy (invar)		M (<5%), P	upstream process
CRT shield assembly		none	part of monitor assy. process
Ferrite		P	upstream process
Deflection yoke assembly		F, P	part of monitor assy. process
Demagnetic coil		F, P	part of monitor assy. process
Video cable assembly		none	part of monitor assy. process
Power cord assembly		none	part of monitor assy. process
Electron gun		F, P	part of tube mfg. process
CRT magnet assembly		P	part of monitor assy. process
Audio cable assembly		none	part of monitor assy. process
Frit		F, P, E, Env	manufacturing process
Solder		Env	part of monitor assy. process
Phosphors		F, P	part of tube mfg. process
Aquadag		F, P	part of tube mfg. process
Other (misc.)			miscellaneous

M = mass is greater than 1% of the total display weight; **Env** = environmental/toxic concern; **E** = energy concern;
F = functional (technological) importance; **P** = physically unique.
Note: The CRT processes included in the CDP LCA were presented in Figures 1-6 and 2-2.

Table 2-5. Decision rule priorities and scope of analysis for the primary material inputs of the 15" LCD monitor

Material/Component		**Decision rule**	**Included in analysis as:**
	Sub-component		
Steel		M	upstream process
Plastics		---	-----
	Polycarbonate (PC)	M	upstream process
	Poly(methyl methacrylate) (PMMA)	M, P	upstream process
	Styrene-butadiene co-polymer	M	upstream process
	Polyethylene ether (PEE)	M	part of monitor assy. process
	Triphenyl phosphate	M (<5%)	part of monitor assy. process
	Polyethylene terephthalate (PET)	M (<5%), P	upstream process
Glass		M	manufacturing process
Printed wiring boards (PWB) and components		M, E, Env	manufacturing process
Cables/wires			part of monitor assy. process
Aluminum (heat sink, transistor)		M (<5%), E	upstream process
Solder (60% tin, 40% lead)		Env	part of monitor assy. & module mfg. processes
Color filter pigment		P	part of color filter patterning
Polyvinyl alcohol (PVA) (for polarizer)		none	part of polarizer mfg. process
Liquid crystals, for 15" LCD		F, P, Env	manufacturing process
Backlight lamp (cold cathode fluorescent lamp)		F, P, Env	manufacturing process
	Mercury	Env	part of backlight lamp process
Transistor metals, other (e.g., Mo, Ti, MoW)		F, P	part of module mfg. process
Indium tin oxide (ITO) (electrode)		F, P	part of module mfg. process
Polyimide alignment layer		F, P	part of module mfg. process
Other (e.g., adhesives, spacers, misc.)			miscellaneous

M = mass is greater than 1% of the total display weight; **Env** = environmental/toxic concern; **E** = energy concern;
F = functional (technological) importance; **P** = physically unique.
Note: The LCD processes included in the CDP LCA were presented in Figures 1-7 and 2-3.

2.1.3 Data Collection and Data Sources

Data were collected from both primary and secondary sources. Primary data are directly accessible, plant-specific, measured, modeled, or estimated data generated for the particular project at hand. Secondary data are from literature sources or other LCAs, but are specific to either a product, material, or process used in the manufacture of the product of interest.

Table 2-6 lists the types of data (primary or secondary) used for each life-cycle stage in the CDP LCI. In general, greater emphasis was placed on collecting data and/or developing models for product manufacturing, use, and end-of-life. Primary data were collected from product and component manufacturers (in the U.S., Japan, and Korea), and CRT recyclers who voluntarily agreed to participate in the project. When proprietary data were involved, the University of Tennessee (UT) Center for Clean Products and Clean Technologies entered into confidentiality agreements with the affected company. In addition, to both protect confidentiality and better represent the various manufacturing processes, data for particular processes that were collected from more than one company, where possible, and aggregated. Attempts were made to get at least two companies to contribute data for each particular process in the manufacturing life-cycle stage, which resulted in some process datasets being the aggregate of multiple (2-7) companies data. However, this was not feasible in every case and some datasets were simply the data of one company. Details of the data aggregation methods are provided in Section 2.3.

Data for the use stage were modeled specifically for this project by UT researchers, but were based on secondary data (i.e., secondary data were built upon to create the data used in the inventory for the use life-cycle stage). Data associated with the electricity generation were also based on secondary data, but modeled for this project. Transportation information (e.g., transportation mode and distances) were collected from the manufacturers that provided primary data. These data were linked to secondary data inventories of fuel inputs and emissions outputs for various types of transport vessels. Transportation data cover movement of materials and components both into and out of a facility, but do not include transportation of packaging or distribution of the finished display to the consumer. Finally, secondary data were used for upstream processes. More details on each of these data collection efforts are provided in subsequent sections of this chapter.

Table 2-6. Data types by life-cycle stage

Life-cycle stage	Data types
Upstream (materials extraction and processing)	Secondary data.
Product and component manufacturing	Primary data, except secondary data used for frit.
Use	Modeled using secondary data; maintenance and repair are not included in the analysis.
Final disposition (recycling and/or disposal)	Modeled using secondary data plus primary data from CRT recycling facilities.
Packaging, transportation, distribution	Primary data from product and component manufacturers for transport mode and distance; secondary data for fuel inputs and emissions outputs for the transport vessel. Packaging and distribution not included.

In some instances, neither primary nor secondary data were available. For example, CRTs are a much more mature technology than the LCD, and end-of-life (EOL) data are much less prevalent for the LCD than for the CRT. Where primary and secondary data are lacking, various assumptions and modeling serve as defaults.

2.1.4 Allocation Procedures

An allocation procedure is required when a process within a system shares a common management structure, or where multiple products or co-products are produced. In the CDP LCI allocation procedures are used when processes or services associated with the functional unit (e.g., a desktop computer display over its lifetime) are used in more than one product line at the same facility (e.g., notebook computers, televisions). For example, transistors are used in LCD desktop computer displays, but also in other LCD technologies, such as notebook computer displays. If a facility uses a single process to manufacture transistors for both desktop and notebook computer display, inputs and outputs are allocated among the product lines to avoid over-estimating the environmental burdens associated with the product under evaluation.

The International Standards Organization (ISO, 1996) recommends that wherever possible, allocation should be avoided or minimized. This may be achieved by sub-dividing the unit process into two or more sub-processes, some of which can be excluded from the system under study. In the example above, if a manufacturer of transistors supplied only desktop computer LCD manufacturers, no allocation would be necessary from that manufacturer. However, it is more likely that the transistor manufacturer would have a larger customer base, including manufacturers of various products other than liquid crystal desktop computer displays. This requires allocation of flows from the manufacturing of transistors for several products to those associated only with desktop computer displays. As suggested by ISO, if sub-processes within the transistor facility can be identified that distinguish between transistors manufactured for LCDs and for other products, the latter sub-processes can be eliminated from the analysis, thus reducing allocation procedures.

In this study allocation procedures are used as follows:

- *Inventory data for utilities and services common to several processes are allocated to reflect the relative use of the service.* For example, fuel inputs and emission outputs from electric utility generation are allocated to a display or display component according to the actual or estimated electricity consumed during the manufacture, use, or final disposition of the product. Similarly, fuel inputs and emission outputs from commercial transport of a display component to a display assembler are allocated to the display component according to the mass of the component, the distance traveled, and the fraction of the transport vehicle's capacity occupied by the number of components shipped.
- *Where a unit process produces co-products, the burdens associated with the unit process are allocated to the co-product on a mass basis.* In the transistor example above, burdens are allocated according to the total mass of transistors used in desktop displays and the mass used in notebook computers. Total mass can be calculated from sales records which document the number of transistors delivered to different customers and measured mass of a set number of transistors.

Allocation is also necessary when a single process produces both energy and products. In this case, the inputs are partitioned among the energy and products, as appropriate, to avoid allocating inapplicable chemical burdens to energy production. However, this scenario was not encountered in the CDP LCI.

2.1.5 Data Management and Analysis Software

The data that were collected for this study were either obtained from questionnaires developed for this project, from existing databases, or from primary or secondary data collected by the UT Center for Clean Products and Clean Technologies. All these data were transferred to spreadsheets, which were then imported into a Life-Cycle Design Software Tool developed by the Center for Clean Products and Clean Technologies with funding from the EPA Office of

Research and Development and Saturn Corporation. The software tool was developed to store and organize life-cycle inventory data and to calculate life-cycle impacts for a product profile. Written using Microsoft FoxPro programming software, the tool is designed to allow flexibility in conducting life-cycle design and life-cycle assessment functions. It provides the means to organize inventory data, investigate alternative scenarios, evaluate impacts, and assess data quality.

The UT Life-Cycle Design Software Tool organizes data in such a way that each process inventory is independent. Customized “profiles” (e.g., the manufacture of a CRT or the whole life-cycle of an LCD) can be developed by linking processes together. The tool has the flexibility to modify or replace any particular process within a profile to evaluate potential alternatives. The data provided in this study may serve as a baseline to compare alternatives or modifications to particular processes. The models developed for the life-cycles of the CRT and LCD in this study can remain useful as many of the individual processes in the CRT and LCD life-cycles will likely remain constant (e.g., steel manufacturing, plastics manufacturing). Changes to specific processes can be made to conduct analyses of current or emerging process or technology changes. Relatively quick life-cycle analyses can be conducted on future product or process improvements, given the baseline data already available through this study.

2.1.6 Data Quality

LCI data quality can be evaluated based on the following data quality indicators (DQIs): (1) the source type (i.e., primary or secondary data sources); (2) the method in which the data were obtained (i.e., measured, calculated, estimated); and (3) the time period for which the data are representative. LCI DQIs are discussed further in *Life-Cycle Assessment Data Quality: A Conceptual Framework* (SETAC, 1994). CDP data quality for each life-cycle stage is discussed in detail in Sections 2.3 through 2.6 and summarized below.

For the primary data collected in this project, participating companies reported the method in which the data were obtained and the time period for which the data are representative. Data from the 1997-2000 time period were sought, with the most recent data preferred. Similarly, the time period of secondary data and method in which the data were originally obtained was also recorded, where available. Secondary data cover a broader time period, with data for most materials from the 1997 to 1998 time period, and data for most fuels from the 1983 to 1993 time period.

Anomalies and missing data are common hurdles in any data collecting exercise. Anomalies are extreme values within a given data set. Any anomaly identified during the course of this project that is germane to project results was highlighted for the project team and investigated to determine its source (e.g., mis-reported values). If the anomaly could be traced to an event inherently related to the process, it was left in the data set. If, however, the anomaly could not be accounted for, it was removed from the data set. Specific anomalies highlighted by the project team are discussed in Section 2.7, Summary of Life-Cycle Inventory Results.

We attempted to account for missing data by replacing it hierarchically. That is, if specific primary data were missing, secondary data were used. Where neither primary nor secondary data were available, such as data on the percent of LCD desktop displays recycled or remanufactured, assumptions were made and a sensitivity analysis was performed. In the cases where no data were found or reasonable assumptions could not be made, these deficiencies are reported.

Any proprietary information required for the assessment was subject to confidentiality agreements between the Center for Clean Products and Clean Technologies and the participating company. Proprietary data are presented as aggregated data to avoid revealing the source. Further, any averaged process data obtained from fewer than three companies are also aggregated to avoid revealing individual inventory items from individual companies.

2.1.7 Critical Review

Critical review is a technique to verify whether an LCA has met the requirements of the study for methodology, data, and reporting, as defined in the goal definition and scoping phase. A critical review process was maintained in the CDP LCA to help ensure that the following criteria were met:

- the methods used to carry out assessments are consistent with the EPA, SETAC, and ISO assessment guidelines;
- the methods used to carry out assessments are scientifically and technically valid within the LCA framework;
- the data used are appropriate and reasonable in relation to the goals of the study;
- the interpretations reflect the limitations identified and the goals of the study; and
- the study results are transparent and consistent.

A project Core Group and Technical Work Group, both consisting of representatives from industry, academia, and government, and EPA's DfE Work Group provided critical reviews of the assessment. Members of these groups are listed in Appendix C, Critical Review. The Core Group served as the project steering committee and was responsible for approving all major scoping assumptions and decisions. The Technical Work Group and the DfE Work Group provided technical guidance and reviews of all major project deliverables including the final LCA report.

In addition to the critical review process, primary data collected were double-checked with the original source to ensure that their data are presented accurately. Additional details on the data verification process for primary data are presented in Sections 2.3 and 2.5.

2.2 MATERIALS EXTRACTION AND MATERIALS PROCESSING (UPSTREAM LIFE-CYCLE STAGES)

2.2.1 Methodology

The inventories included in the materials extraction and materials processing (upstream) life-cycle stages are those of the major primary materials found in the CRT or LCD monitor, as well as major ancillary materials required to manufacture the monitors. Inventories for electricity generation and fuels, which may be used in several life-cycle stages (e.g., to manufacture the products or to use the products), are also presented.

The inventories for extraction and processing of major materials were obtained from existing LCI databases. Electricity generation inventories were developed for this project from secondary sources that describe the distribution of fuels for different electric grids and the fuel inputs and emission outputs associated with different fuel types. The methodologies for developing these inventories are summarized below.

2.2.1.1 Upstream materials processes

Materials for which upstream processes were included in the CRT and LCD life-cycles were selected based on the decision rules described in Section 2.1.2, as well as the availability of secondary data for those materials. An attempt was made to include materials with a mass greater than or equal to one percent of the overall inputs to the product manufacture, or materials that may contribute to a large amount of energy use or have environmental concern. Tables 2-4 and 2-5 in Section 2.1.2 listed the decision criteria for primary materials/components that are included either as separate processes or as part of another process. The upstream materials processes for which inventory data were obtained for this project are presented in Table 2-7.

To determine which source or sources of secondary data to use, nine LCI databases were evaluated against 11 selection criteria in a technical memorandum presented to the project review teams (see Appendix D). Based on this analysis the project team chose the Environmental Information and Management Explorer (EIME) database and the Database for Environmental Analysis and Management (DEAM), two life-cycle inventory databases developed by the *Ecobilan* (Ecobalance) Group (*Ecobilan,* 1999). EIME was developed by *Ecobilan* specifically for electronics and the electronics industry and covers many of the materials specific to the CDP, while the DEAM database includes materials not covered by EIME. Combined, these databases contain detailed inventories of materials extraction and processing activities for most of the materials of interest in this project.

In the *Ecobilan* inventory for a particular material, the functional unit is a set mass of the material. Inputs and outputs are therefore given in terms of mass or other appropriate unit per unit mass of material. These data were imported into the UT Life-Cycle Design Software Tool discussed in Section 2.1.5, where they were linked to the mass of material used in the manufacture of a display monitor to develop inventories specific to the CDP. The associated amounts of each material were presented in Tables 2-2 and 2-3 in Section 2.1.2. How these materials are linked to other processes in the CRT and LCD profiles are shown in Figures 2-2 and 2-3 at the beginning of this chapter.

The materials inventories from *Ecobilan* also contain data for electricity generation, as appropriate, and in some cases, for transportation. Electricity generation and transportation data that were included in the *Ecobilan* inventories could not be separated from the inventory data for materials extraction and conversion processes. Therefore, when electricity generation and transport data were included in the *Ecobilan* inventories, the electricity and transport data collected specifically for this project were not used with the upstream process data.

Table 2-7. Materials having upstream processes included in the CDP LCA

Material	**CRT**	**LCD**
METALS		
aluminum	✓	✓
ferrite	✓	
lead	✓	
nickel alloy (invar)	✓	
steel	✓	✓
POLYMERS		
acrylonitrile-butadiene styrene (ABS)	✓	
high impact polystyrene (HIPS)	✓	
polycarbonate (PC)	✓	✓
polyethylene terphthalate (PET)		✓
poly(methyl methacrylate) (PMMA)		✓
styrene-butadiene co-polymer	✓	✓
ANCILLARY MATERIALS		
natural gas (used to represent LNG)		✓

2.2.1.2 Electric grids

Electricity is used in several processes throughout the life-cycle of the CRT and LCD monitors, and in some instances in large amounts. Therefore, the inventory for electricity generation is included in the scope of this project.

As described in Chapter 1, Section 1.4.2, the geographic boundaries of this project are worldwide for upstream and product manufacturing processes and limited to the United States for the use and end-of-life stages. In addition, most CRT and LCD manufacturing is done in Asia and most product manufacturing data collected in this study were from the United States or Japan, except for two LCD manufacturing data sets collected from Korean manufacturers. Therefore, the inventory associated with electricity generation during manufacturing was based on either the Japanese or U.S. electric grids, depending on the particular process or component being manufactured. Where data were obtained from more than one country for the same process, only one electric grid inventory could be used for a single process. In these cases, the Japanese electric grid was used since the majority of manufacturing data are from Japanese companies. The inventory for electricity generated during use and EOL processing was based on the U.S. electric grid.

The methodology and results for the electricity generation inventories are detailed in Appendix E, which presents the electric grid technical memorandum prepared for this project. The inventories were developed by first compiling U.S. inventory data for each of the major generation categories or fuel types, including electricity generated from coal, gas, petroleum, and nuclear fuels. These inventories were then combined with data on net electricity generation by fuel type in the U.S. and Japanese electric grids (Table 2-8) to develop the country-wide electric generation inventories. The inputs and outputs for the electricity generation inventories are presented in terms of mass or radioactivity per kWh of electricity generated. Inventories were not included for hydroelectric and renewable energy generation categories due to the scarcity of data on inputs and outputs for these categories. In addition, renewables account for only a small fraction of total U.S. electricity generation.

Table 2-8. Net electricity generation by fuel type

Fuel	Net electricity generation	
	United States (percent)	Japan (percent)
Coal	57	18
Gas	9	20
Petroleum	3	21
Nuclear	20	31
Hydro	11	9
Other	<1	1

Sources: U.S.: EIA, 1999a; Japan: EIA, 1997; FEPC, 1996.

Note that the Japanese grid inventory is based on the same fuel-specific inventories developed for the U.S. grid, but uses the average distribution of fuels for the Japanese grid (EIA, 1997, FEPC, 1996). This introduces some uncertainty into the Japanese electric grid since Japanese technologies, efficiencies, and pollution control techniques are likely to differ somewhat from their U.S. counterparts. However, the U.S. fuel-specific inventories were used to conserve project resources, rather than expending considerable effort on collecting inventory data from Japanese utilities.

The electricity generation inventories presented in Appendix E are shown as separate process inventories. However, in the overall analysis, they are linked to the manufacturing, use and EOL life-cycle stages, as appropriate. That is, where electricity is used in a process in any of those life-cycle stages, the inputs and outputs from generating the amount of electricity needed is allocated to that process. Note that the U.S. and Japanese electricity generation inventories developed for this project are not linked to the upstream life-cycle stages for materials used to manufacture CRT and LCD desktop computer displays. Electricity generation data were already included in the upstream material inventories received from *Ecobilan*.

2.2.1.3 Fuels

Several fuels are used in manufacturing and end-of-life processes during the life-cycle of the CRT and LCD monitors, and in some instances in large amounts.[1] Therefore, fuel production inventories are included in the scope of this project. These inventories are included in the life-cycle stage in which the fuels are actually consumed (e.g., product manufacturing or end-of-life) instead of in the upstream (materials processing) life-cycle stage. The following fuel inventories are included in both the CRT and LCD LCIs:

- natural gas (also used to represent LNG),
- liquified petroleum gas (LPG),
- fuel oil #2 (distillate),
- fuel oil #6 (residual), and
- fuel oil #4 (average of residual and distillate).

Fuel inventories were obtained from *Ecobilan*. In the *Ecobilan* inventories, the functional unit is a set mass of the material, with inputs and outputs given in terms of mass or other appropriate unit per mass of material (product) produced. These data were imported into the UT Life-Cycle Design software tool where they were linked to the mass of fuel used in different processes in the life-cycle of a display. How the fuel processes are linked to other processes in the CRT and LCD profiles was shown in Figures 2-2 and 2-3.

2.2.2 Data Sources and Data Quality

2.2.2.1 Upstream material and fuel processes

Table 2-9 summarizes data source and data quality information for the data received from *Ecobilan*, which are all secondary data for the purposes of the CDP. In addition to information about CDP data quality indicators (e.g., original source of data, year of data, method in which data were obtained, and geographic boundaries), the table lists whether or not electricity generation or transport data were included in the inventories. This information is important because: (1) electricity generation and transportation data are not from the same sources and therefore are not necessarily consistent among data sets; and (2) transportation data are not included in several of the upstream processes, and are thus a data gap for those processes.

As revealed in Table 2-9, the *Ecobilan* data were derived from various sources, including European data sources and U.S. data sources. In addition, the temporal boundaries of the data vary, with some data being as recent as 1998 but others being from as early as 1975. Electricity generation data are included in all of the inventories, but transportation data are only included in six of 16 data sets. All of these factors create some inconsistencies among the data sets and reduce the data quality when used for the purposes of the CDP. However, this is a common difficulty with LCA, which often uses data from secondary sources for upstream processes to avoid the tremendous amount of time and resources required to collect all the needed data.

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[1] Fuels are also used in the materials processing life-cycle stage, but fuel production processes should already be accounted for in the materials inventories obtained from *Ecobilan*.

Table 2-9. Data sources and data quality for the *Ecobilan* inventories [a]

Material	Electricity generation included?	Transport included?	Year of data	Original source [b]
METALS				
aluminum	Y	--	--	ETH
ferrite	Y	--	--	not provided
lead	Y	--	Unknown	ETH
nickel-alloy (invar) [c]	Y	Y (nickel)	1991 (nickel)	ETH
steel	Y	--	1975-1990 [d]	FOEFL, others [d]
POLYMERS				
acrylonitrile-butadiene styrene (ABS)	Y	Y [e]	1997	Boustead
high impact polystyrene (HIPS)	Y	Y [e]	1997	Boustead
polycarbonate (PC)	Y	Y [e]	1997	Boustead
polyethylene terphthalate (PET)	Y	Y [e]	1998	Boustead
poly(methyl methacrylate) (PMMA)	Y	Y [e]	1997	Boustead
styrene-butadiene co-polymer [f]	Y	Y [e]	1997	Boustead
FUELS				
natural gas	Y	Y	1987-98	six sources cited
liquified petroleum gas (LPG)	Y	Y	1983-93	seven sources cited
fuel oil #2	Y	Y	1983-93	seven sources cited
fuel oil #6	Y	Y	1983-93	seven sources cited
fuel oil #4 [g]	Y	Y	1983-93	seven sources cited

Y: yes, included in inventory.

-- : not included in inventory.

[a] In general, the *Ecobilan* inventories provide descriptions of data quality but often do not report how data were collected (e.g., measured, estimated, etc.). Therefore, information on the data collection method is not presented here.

[b] *Sources*: ETH (EidgenÖssische Technische Hochschule): Data from the ETH (Swiss Federal Institute of Technology) (*Ecobilan,* 1999). FOEFL (Swiss Federal Office of Environment, Forests and Landscape): Data from the Eco-inventory of Packaging published by the Swiss FOEFL; FOEFL is also known as BUWAL, the acronym in German (*Ecobilan,* 1999). Boustead: LCI database developed by Boustead Consulting (*Ecobilan,* 1999).

In general, the geographic boundaries for different sources are as follows: (1) ETH and FOEFL data are from Europe; (2) Boustead data are from Europe and/or the United States; and (3) miscellaneous sources may be European or U.S. data.

[c] The invar inventory is a combination of 36% of the nickel inventory and 64% of the ferrite inventory.

[d] The steel inventory was originally provided by *Ecobilan* without detailed documentation; however, DEAM data that were received later have inventories for several steel production processes. The sources listed here are for the DEAM data.

[e] Boustead addresses transportation; however, the extent to which it is included in a particular process inventory is uncertain.

[f] The styrene-butadiene process is the 50/50 average of the styrene and butadiene processes.

[g] The fuel oil #4 process is the 50/50 average of the fuel oil #2 and fuel oil #6 processes.

2.2.2.2 Electric grids

Several sources of data were consulted to generate the fuel-specific inventories that were used to create the overall electricity generation inventories. Table 2-10 summarizes the data sources and some of the data quality indicators for these inventories. Appendix E discusses the data sources and data quality in detail.

As shown in Table 2-10, the electricity generation data were obtained primarily from secondary sources and include data from the mid-1990s as well as data from an unknown time frame. Most are based on measured data collected by the original source, although some are estimated or the data collection method is unknown. Finally, most of the fuel-specific inventories are based on U.S. data, indicating these data are probably less representative and thus of lower quality when applied to the Japanese electric grid.

Table 2-10. Data sources and data quality indicators for the electric generation inventories

Type of data	Source	Year of publication	Data collection method	Geographic boundaries
Net electricity generation by fuel	U.S. Energy Information Administration (EIA)	1997	Measured	U.S. and Japan
Primary inputs (Fuel)	EIA	1997	Measured	U.S.
Ancillary inputs	EIA, California Energy Commission, utility contacts	Varies	Varies [a]	U.S.
Air emissions	Primarily AP-42 plus other sources [b]	Varies, but mostly AP-42 data from 1995	Varies [a]	U.S.
Water releases	Oak Ridge National Laboratory (ORNL) [c]	1994	Unknown	U.S.
Radioactive air and water releases	ORNL [d]	1995	Measured	U.S.
Solid wastes	ORNL [e]	1994	Unknown	U.S.

[a] Includes emission factors from measured and estimated data, plus data where data collection methods were not reported.
[b] AP-42 is the U.S. EPA's compilation of Air Pollutant Emissions Factors (EPA, 1996).
[c] Coal-fired water release data from ORNL report addressing the externalities of coal fuel cycles (ORNL, 1994).
[d] From ORNL report addressing the externalities of nuclear fuel cycles (ORNL, 1995).
[e] Coal-fired solid waste data from ORNL report addressing the externalities of coal fuel cycles (ORNL, 1994); radioactive solid waste data from ORNL report addressing the externalities of nuclear fuel cycles (ORNL, 1995).

2.2.3 Limitations And Uncertainties

The limitations and uncertainties associated with the upstream materials, fuels, and electricity generation inventories are primarily due to the fact that these inventories were derived from secondary sources and thus are not tailored to the specific goals and boundaries of the CDP. Because the data are based on a limited number of facilities and have different geographic and temporal boundaries, they are not necessarily representative of current industry practices or of industry practices in the geographic and temporal boundaries defined for the CDP (see

Section 1.4). These are common limitations and uncertainties of LCA, which strives to evaluate the life-cycle environmental impacts of entire product systems and is therefore limited by resource constraints which do not allow the collection of original, measured data for every unit process within a product life cycle. Despite these limitations and uncertainties inherent in LCA methodology itself, LCA remains useful and, indeed is increasingly used by industry, governments, and other stakeholders as part of a comprehensive decision-making process or to understand broad or general environmental trade-offs.

2.2.3.1 Upstream material and fuel processes

Because they are derived from secondary sources, the upstream materials and fuels inventories used in the CDP do not precisely meet the geographic and temporal boundaries outlined for the CDP. Some data are from Europe, some from the United States, and some a combination of both. The manufacturing data for this project were collected from companies in the United States, Japan, and Korea (see Section 2.3), and the available upstream data may not represent the exact location or type of processing represented in the upstream data inventories. This is a limitation to using secondary data; however, the upstream data are only one portion of the overall inventory of the product systems being evaluated, and the project partners chose to focus on collecting primary data for the product manufacturing life-cycle stage, since those data had not been previously compiled.

Another limitation of the upstream inventory data is the lack of transportation data for some processes. These data become particularly important when, for example, raw materials are uncommon and must be transported long distances for processing or when the particular transport mode used for a particular material tends to have high environmental impacts. However, the original data sources used in the *Ecobilan* inventories (see Table 2-9) are among the most used LCI databases in the world (*Ecobilan,* 1999), which suggests the lack of transportation data for upstream processes is not unique to the CDP LCI, but a common limitation of other LCIs as well.

2.2.3.2 Electricity generation data

The limitations to the electricity generation inventory data are provided in Appendix E, Section 6. As another limitation, the Japanese grid was chosen when manufacturing data were from more than one country. Appendix E also describes how the U.S. fuel-specific inventories are applied to the Japanese grid, although technologies, efficiencies, etc. used in Japan are likely to differ from those in the United States. Furthermore, U.S. fuel-specific inventories were derived from secondary sources which did not necessarily meet our temporal boundaries, but did meet geographic boundaries for the U.S. inventory.

2.3 PRODUCT MANUFACTURING

2.3.1 Methodology

2.3.1.1 Identification of processes and manufacturers

Through literature research and contacts with industry experts, the manufacturing processes and the component parts of a CRT and an LCD computer monitor were identified. The major manufacturing processes and components, in terms of resources used, and potential importance to environmental impacts, were selected for inclusion in our primary data collection effort.

Once the components and processes were chosen, companies who might supply manufacturing data for the project needed to be identified. In order to identify those manufacturers, the DfE project's Core and Technical Work Groups were consulted. These groups consist of parties interested in the project results and willing to provide technical assistance throughout the project, including identifying contacts in manufacturing facilities. Manufacturing of CRTs, LCDs, and their component parts is done all over the world. Some manufacturers are in the United States; however, most manufacturers of desktop computer monitors and their components are in Asia. Where available, U.S. industry partners provided contacts at U.S. as well as some Japanese manufacturing facilities and questionnaires were sent to those contacts.

To assist in the collection of data in Asia, UT subcontracted with the Asian Technology Information Program (ATIP) to identify company contacts, and to distribute and collect questionnaires from Asian manufacturers. ATIP acted as a liaison between UT and Japanese and Korean companies that participated in the study.

Participation in the study was completely voluntary. Companies were provided with the goals of the study and the potential benefits of their participation. Once a company chose to participate, they were sent data collection questionnaires to complete information about their manufacturing process and to provide their inventory of process inputs and outputs. A copy of the manufacturing data collection questionnaire that was developed for and used in this study is provided in Appendix F.

The manufacturing processes for which primary data were collected are listed below. In parenthesis are the number of individual data sets collected for each process:

CRT monitor:

- CRT monitor assembly (3)
- CRT (tube) manufacturing (3)
- CRT leaded glass manufacturing (3)

LCD monitor:

- LCD monitor assembly (2)
- LCD panel and module manufacturing (7)
- LCD glass manufacturing (1)[2]
- color filter patterning on front glass (1)
- liquid crystal manufacturing (2)
- polarizer manufacturing (1)
- backlight unit assembly (3)
- backlight light guide manufacturing (1)
- cold cathode fluorescent lamp (CCFL) manufacturing (1)

How these processes are linked to one another in the CRT and LCD life-cycles is presented in Figures 2-2 and 2-3, respectively. The companies that provided data for the foregoing processes are listed in Table 2-11.

Table 2-11. Companies that provided primary manufacturing data for the CRT and/or LCD

Company	Technology	Company	Technology
American Video Glass Company	CRT	Nippon Denyo Co., Ltd.	LCD
T. Chatani and Co., Ltd.	LCD	Nippon Electric Glass Co., Ltd.	CRT
Chisso Corporation	LCD	Polaroid Corporation	LCD
Eizo Nanao Corporation	CRT, LCD	Samsung Electronics	LCD
Harison Electric Co., Ltd.	LCD	Sharp Corporation	LCD
Hoshiden and Philips Display Corporation	LCD	Sony Corporation (Japan)	CRT
Hyundai Electronics Industries Co., Ltd.	LCD	Sony Electronics Inc. (U.S.)	CRT
Iiyama Electric Co., Ltd.	CRT, LCD	Stanley Electric Co., Ltd.	LCD
Matsushita Electric Industrial Co., Ltd.	LCD	Techneglas	CRT
Merck Japan Ltd.	LCD	Toppan Printing Co., Ltd.	LCD
Mitsubishi Electronic Co., Ltd.	LCD	Toshiba Display Technology Co., Ltd.	CRT, LCD

Another process that was included in the CRT manufacturing stage data was frit manufacturing. We were not able to obtain primary data for this process; therefore, secondary data were collected from EPA documentation and personal contacts (see Appendix G). An inventory for printed wiring boards (PWBs) was also developed and included in the manufacturing stage analysis. The PWB inventory is based on manufacturing of the electronic boards, and does not include the components on the PWBs. The PWB data were obtained from an industry representative who was able to provide general data not necessarily from one facility, but from a combination of facilities, based on his experience (Sharp, 2000). More details about PWB data collection are provided in Appendix G.

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[2] LCD glass manufacturing data were derived from the three sets of CRT leaded glass manufacturing data (modified to remove lead from the inventory).

The manufacture of some components were not included in the scope of this study because they were either deemed to be of less significance to the overall product inventories, or data could not be obtained. However, all components were included as part of the final assembled monitor even when individual manufacturing inventories were not. For the CRT, the manufacture of the electron gun, deflection yoke, and phosphors were not included as separate processes, and for the LCD, the transistor metals/materials, spacers, drivers/driver ICs, and color filters were not included.

2.3.1.2 Data collection questionnaires

Data collection questionnaires were developed by the UT research team and approved by the Technical Work Group to most efficiently collect inventory data needed for the LCA. Appendix F provides a copy of the questionnaire given to product and component manufacturers. The data that were collected include brief process descriptions; primary and ancillary material inputs; utility inputs (e.g., electricity, fuels, water); air, water and waste outputs; product outputs; and associated transportation. Quantities of inputs and outputs provided by companies were converted to mass per unit of product. Transport of materials to and products or wastes from the manufacturing facility were also reported. Details of the transportation analysis for this project are presented in Section 2.6.

A total of 27 product manufacturing questionnaires were collected for 11 different processes. The corresponding countries and the number of data sets from each country are listed in Table 2-12.

Table 2-12. Location of companies and number of process data sets

Process	**Country of origin of data (# of data sets)**
CRT monitor assembly	Japan (2), U.S. (1)
CRT (tube) manufacturing	Japan (2), U.S. (1)
CRT leaded glass manufacturing	Japan (1), U.S. (2)
CRT frit manufacturing	generic secondary data from the U.S.
LCD monitor assembly	Japan (2)
LCD panel and module manufacturing	Japan (5), Korea (2)
LCD - glass manufacturing	Japan and U.S. (1)*
LCD - color filter patterning on front glass	Japan (1)
LCD - liquid crystal manufacturing	Japan (2)
LCD - polarizer manufacturing	Japan (1)
LCD - backlight unit assembly	Japan (3)
LCD - backlight light guide manufacturing	Japan (1)
LCD - cold cathode fluorescent lamp (CCFL) manufacturing	Japan (1)
PWB manufacturing (for CRT and LCD monitors)	generic secondary data from the U.S.

* Average of three data sets for CRT leaded glass manufacturing modified to remove lead from the inventory.

2.3.1.3 Allocation

Data provided by manufacturers may need to be allocated to the products of interest (i.e., 17" CRT or 15" LCD) in three situations:

- data are provided for more than the defined functional unit;
- data are provided on a rate basis instead of per functional unit (product); and
- data are provided for monitors/components of more than one size (i.e., not only 17" CRTs or 15" LCDs).

In some cases, allocation was not required, as the inventory data collected were for one unit of the product, defined as the functional unit. The three cases where allocation was necessary are briefly described below.

In the first case, simple scaling was required when data were provided for all 17" CRT or 15" LCD monitors produced at a plant, as opposed to only one monitor. This simply requires dividing the inventory mass by the number of monitors produced.

In the second case, data were provided over a certain amount of time. The inventory data were then scaled to represent the functional unit. For example, if it was reported that x kilograms of a material are used *per year* to produce one 17" or 15" monitor, and y number of products are produced per year, then the amount of that material per functional unit is x/y.

In the third situation, allocation was also necessary for a company that manufactured more than just the product or component of interest for this study. For example, a monitor manufacturer may assemble various sized monitors, in addition to 15" LCDs or 17" CRTs. Therefore it was necessary to allocate the process inventory to only our product of interest. We used the difference in mass between the product of interest and other co-products and the difference in the number of each product produced to allocate the inventory to the functional unit.

2.3.1.4 Aggregating manufacturing data

After one set of data from one company is allocated to one monitor, processes for which we collected more than one company's data were averaged together. Once the inventory data for a process were averaged, the electricity consumption from that process was linked to the appropriate electric grid inventory (i.e., Japanese or U.S.). All the manufacturing processes were linked to the Japanese grid, with the exception of frit and PWB manufacturing, both of which were based on data collected in the United States. Where process data were represented by companies in more than one country, the countries in which the majority of facilities were located was used for the basis of which electric grid to use. An exception is the polarizer data, which was from the United States, but the manufacturing was only a pilot plant and not producing a product in the open market. Therefore, it was assumed that polarizer manufacturing, as with most other LCD components, was done in Japan. Once each manufacturing process inventory for each monitor type was complete (i.e., an averaged inventory with an associated electric grid), each was aggregated with the rest of the manufacturing stage processes to comprise the inventory for the manufacturing stage for a monitor. This manufacturing stage inventory was then combined with the other life-cycle stages to represent the full LCI for each monitor type.

2.3.2 Data Sources and Data Quality

While manufacturers worldwide were offered the opportunity to participate in this project, only manufacturing data from Japan, Korea, and the United States were collected. The quality of the data can be evaluated against two factors: (1) the date of the data; and (2) the type of data (i.e., measured, calculated or estimated). An understanding of how data were collected and data verification steps should also be considered when evaluating the data quality. The data collection phase of this project began in 1997 and extended through 2000. Some processes are more sensitive to production dates than others. Most processes included in this analysis are mature technologies and are not expected to differ significantly between the years 1997 and 2000. However, an exception is LCD panel manufacturing, which is an evolving and rapidly advancing process and has seen changes between these years. The countries and dates from which data for each process were obtained are presented in Table 2-13. For the LCD panel and module manufacturing process, most data were from 1998 and 1999.

In the data collection questionnaires, companies identified whether the quantity of each inventory item was a measured, calculated, or estimated value. These identifiers were referred to as the “data quality indicator” (DQI) in the manufacturing questionnaire. The breakdown of DQIs for the inventory items in the CRT and LCD processes are presented in Tables 2-14 and 2-15, respectively. The last line in each table shows overall averages weighted by the number of inventory items in each data set. For the CRT, 43% of the data were measured, 34% calculated, 13% estimated, and 10% were not classified. For the LCD, a similar distribution shows 33% measured, 30% calculated, 23% estimated, and 14% not classified.

Table 2-13. Applicable years of primary data sets

Process	# of data sets	Dates of inventory for each data set
CRT monitor assembly	3	1997, 1998-9, 1999
CRT (tube) manufacturing	3	1997, 1998, 1998
CRT leaded glass manufacturing	3	1998, 2000, 2000
LCD monitor assembly	2	1998, 1999
LCD panel and module manufacturing	7	1997-8, 1998, 1998, 1998-9, 1999, 1999, 1999-2000
LCD - color filter patterning on front glass	1	1998
LCD - glass manufacturing*	1	1998-2000
LCD - liquid crystal manufacturing	2	1998, 1998
LCD - polarizer manufacturing	1	1997
LCD - backlight unit assembly	3	1998, 1999, 1999
LCD - backlight light guide manufacturing	1	1999
LCD - cold cathode fluorescent lamp (CCFL) manufacturing	1	1998-9

* Primary data, but developed from the CRT glass manufacturing data.

Data quality can also be reviewed in terms of data collection methods. Much effort was given to collecting primary data from manufacturers in this study. Questionnaires were sent out and follow-up communication was conducted to verify data gaps or discrepancies. Twelve companies were visited directly to clarify data and telephone or electronic communication followed-up those and the remaining companies that were providing data for the study. Where data could not be confirmed, additional literature research and discussions with other industry experts were conducted.

Table 2-14. Data quality indicator percentages for the CRT processes

Process	**% of inventory items that are:**			
	Measured	**Calculated**	**Estimated**	**Not reported**
CRT monitor assembly				
Data set 1 (22 inventory items)	9%	64%	27%	0%
Data set 2 (11 inventory items)	9%	83%	0%	9%
Data set 3 (33 inventory items)	3%	0%	0%	97%
total inventory items = 66	wt. avg = 6%	wt. avg = 35%	wt. avg = 9%	wt. avg = 50%
CRT (tube) manufacturing				
Data set 1 (69 inventory items)	91%	1%	4%	3%
Data set 2 (51 inventory items)	45%	55%	0%	0%
Data set 3 (83 inventory items)	21%	78%	1%	0%
total inventory items = 203	wt. avg = 51%	wt. avg = 46%	wt. avg = 2%	wt. avg = 1%
CRT leaded glass manufacturing				
Data set 1 (43 inventory items)	9%	3%	86%	2%
Data set 2 (45 inventory items)	91%	7%	0%	2%
Data set 3 (2 inventory items)	100%	0%	0%	0%
total inventory items = 90	wt. avg = 52%	wt. avg = 5%	wt. avg = 41%	wt. avg = 2%
Overall weighted average for CRT (359 items)	**43%**	**34%**	**13%**	**10%**

Table 2-15. Data quality indicator percentages for the LCD processes

Process	**% of inventory items that are:**			
	Measured	**Calculated**	**Estimated**	**Not reported**
LCD monitor assembly				
Data set 1 (36 inventory items)	5%	78%	17%	0%
Data set 2 (10 inventory items)	10%	80%	10%	0%
total inventory items = 46	wt. avg = 6%	wt. avg = 78%	wt. avg = 16%	wt. avg = 0%
LCD panel and module manufacturing				
Data set 1 (71 inventory items)	80%	17%	0%	3%
Data set 2 (39 inventory items)	0%	100%	0%	0%
Data set 3 (45 inventory items)	40%	32%	17%	11%
Data set 4 (139 inventory items)	55%	38%	0%	7%
Data set 5 (53 inventory items)	43%	0%	36%	21%
Data set 6 (86 inventory items)	0%	0%	24%	76%
Data set 7 (32 inventory items)	0%	0%	97%	3%
total inventory items = 465	wt. avg = 37%	wt. avg = 26%	wt. avg = 17%	wt. avg = 20%
LCD - glass manufacturing* (83 inventory items)	0%	0%	100%	0%
LCD - color filter patterning on front glass (29 inventory items)	97%	0%	3%	0%
LCD - liquid crystal manufacturing				
Data set 1 (41 inventory items)	22%	64%	7%	7%
Data set 2 (6 inventory items)	0%	0%	0%	100%
total inventory items = 47	wt. avg = 19%	wt. avg = 56%	wt. avg = 6%	wt. avg = 19%
LCD - polarizer manufacturing (30 inventory items)	57%	17%	20%	6%
LCD - backlight unit assembly				
Data set 1 (20 inventory items)	0%	90%	0%	10%
Data set 2 (12 inventory items)	50%	0%	8%	42%
Data set 3 (12 inventory items)	0%	92%	8%	0%
total inventory items = 44	wt. avg = 14%	wt. avg = 66%	wt. avg = 4%	wt. avg = 16%
LCD - backlight light guide manufacturing (5 inventory items)	40%	40%	20%	0%
LCD - cold cathode fluorescent lamp (CCFL) manufacturing (36 inventory items)	58%	39%	0%	3%
Overall average for LCD (785 items)	**33%**	**30%**	**23%**	**14%**

* Data based on CRT leaded glass manufacturing data.

2.3.3 Limitations and Uncertainties

The limitations and uncertainties associated with the manufacturing stage are related to the following categories:

- the product system boundaries (scope),
- the data collection process, and
- the data.

Specific limitations/uncertainties for each of these categories are briefly described below.

2.3.3.1 Product system boundary uncertainties

The scope of the analysis included the major monitor components; however, it excluded certain components, such as column and row driver ICs for the LCD and the electron gun for the CRT. The components that were thought to possibly have an effect on the inventory were the column and row drivers, as IC manufacturing is known to be energy intensive and use various process chemicals. Based on some back-of-the-envelope calculations, the exclusion of the manufacturing of the column and row driver ICs is not expected to have a large impact on the inventory or impact results due to the small size of the drivers. Therefore, it is assumed that the exclusion of the column and row drivers will not have a significant impact on the study results.

The scope of the analysis in this study was also dependent on whether companies were willing to provide data. LCD glass manufacturing data from a primary source are not included in the inventory because no companies were willing to supply the data. For example, one manufacturer chose not to provide data because LCD glass manufacturing technology is still developing and is expected to improve from current low yields and high waste generation. However, because glass is an important component by weight of the LCD, we chose to modify the CRT glass manufacturing data to represent LCD glass manufacturing.

Both CRT and LCD glass are considered to be “specialty glasses” in the glass industry and a limited number of companies produce these products. Consequently, there are limited public data available on the production of these glasses. (One major difference between the CRT glass and the LCD glass is that CRT glass contains lead oxide while LCD glass does not.) Therefore, the primary data collected for this study for CRT glass manufacturing was modified by removing inputs and outputs containing lead, and used to represent LCD glass manufacturing. The remaining inputs and outputs were assumed to be the same per kilogram of glass produced. Further research was conducted to confirm whether this was a valid assumption for the energy used in production. Consultation with experts in the field revealed differing estimates between energy used to produce a kilogram of CRT glass and a kilogram of LCD glass. Estimates ranged from an equal amount of energy per kilogram for CRT and LCD glass production, to twice as much energy per kilogram of LCD glass compared to CRT glass. With an assumption of equal or greater energy use for the LCD (call that quantity of energy X), the proportion of that energy (X) that is electrical energy and fuel energy was assumed to be the same as that given in the primary data for CRT glass production (if the portion of energy X for the CRT was 30% electrical and 70% fuel energy, those same proportions were used for the LCD’s breakdown of energy X).

Uncertainty in the differences between energy used for CRT versus LCD glass production are related to production yield and melting point. The melting point of LCD glass is greater than that of CRT glass; however, the difference in the production yield is uncertain compared to the difference in melting point. The production yield for CRT and LCD depends on whether one considers the surface area or the volume of the glass. LCD glass is a flat glass product and excess glass is cut off the ends to obtain the final product. CRT glass manufacturing drops molten glass into a mold and glass is not cut off of a flat piece of glass as in LCD production, but excess glass may be produced during the molding process. Another factor in the difference in energy used for CRT and LCD glass is that the LCD glass must meet high specification standards for use as a substrate for the transistors to be patterned on the glass. Additional finishing steps are required and the process is conducted in clean rooms (described in Section 1.3.3.2, LCD manufacturing). The assumption that the same amount of energy is used for CRT glass and LCD glass production takes into account each of these factors. The baseline analysis in this study assumes the energy use per kilogram of LCD glass is equivalent to that of CRT glass. The uncertainty associated with the glass manufacturing data is a limitation to the manufacturing inventory data set. Additional limitations from the glass manufacturing data are discussed below with other "data uncertainties" in Section 2.3.3.3.

2.3.3.2 Data collection process uncertainties

Limitations and uncertainties related to the data collection process include the fact that companies were self-selected, which could lead to selection bias (e.g., those companies that are more advanced in terms of environmental protection might be more willing to supply data than those that are less progressive). Also, the data were supplied by companies whose vested interest is to have their product look more desirable, which could result in biased data being provided. However, multiple sets of data were obtained for this project, where possible, so that average processes could be developed in an attempt to avoid biased data. The peer review process and employment of the Core and Technical Work Groups as reviewers in this project is intended to help reduce or identify any such bias. Further, several companies were visited and contacted for verification of data.

Other data collection-process limitations resulted from the difficulty in obtaining and verifying data over long distances (i.e., Japan and Korea to United States) as well as from the language barrier. The use of ATIP as the Asian Liaison aided in reducing this limitation; however, there were still language barriers that had to be overcome with ATIP, as well as through direct communication with several companies.

2.3.3.3 Data uncertainties

Additional limitations to the manufacturing stage inventory are related to the data themselves. Several attempts were made to verify or eliminate outliers in the data; however, uncertainty in some data remained due to large data ranges and outliers. Specific data with the greatest uncertainty include: (1) CRT glass manufacturing energy inputs (mentioned above in Section 2.3.3.1); (2) the distribution of fuel/electricity inputs for LCD module manufacturing; and (3) the use of a large amount of liquified natural gas (LNG) as an "ancillary material" and not a fuel.

In addition to the uncertainty in the difference between energy used to manufacture CRT glass and LCD glass, the energy reported to produce a kilogram of CRT glass varied greatly between the data sets. Consultation with experts in the glass industry confirmed that the average energy consumption derived from the primary data sets, although it appeared to be high, could be possible. The total energy inputs per kilogram of glass from the primary data sets used in the analysis, ranged over a factor of approximately 150 (i.e., the largest total energy value in the data was about 150 times that of the smallest value). Due to this large discrepancy, the glass energy data is the subject of sensitivity analyses in this study. The high energy use values were mostly a function of liquified petroleum gas (LPG) used as a fuel.

Other data for which large ranges were found, and which could be important to the results, are the energy use from LCD panel/module manufacturing. Energy data were provided by six of the seven companies supplying LCD panel/module data. The percent of energy from electricity ranged from approximately 3% to 87%. Three of the companies had the electrical energy component contributing greater than 50% of the total energy use, and the other three companies listed other fuels [e.g., LPG, LNG] as contributing greater than 50% to the total energy use. Another large discrepancy was the total energy use for panel/module manufacturing. Four of the six companies had energy use per panel between approximately 440 MJ/panel and 940 MJ/panel, while the two remaining companies had approximately 4,100 and 7,000 MJ/panel. The average per panel was approximately 2,270 MJ/panel and the standard deviation was about 2,910 MJ/panel.

Given the wide variability in the data and large standard deviation, CDP researchers evaluated the data for outliers by breaking the total energy data points into quartile ranges. Minor outliers are then those within a certain range of multipliers beyond the middle 50% of the distribution. That is, the interquartile range (IQR) (i.e., the range of values representing the middle 50%) multiplied by 1.5 is the lower bound of the minor outlier and the IQR multiplied by three is the upper bound. Anything beyond the IQR times three is a major outlier. Using this approach, one data set was found to be a minor outlier and another was found to be a major outlier. These outliers were excluded from the averages used in the baseline analysis, but included in the averages used in a sensitivity analysis (see Section 2.7.3.3).

Finally, the average amount of LNG used as an ancillary material (not a fuel) in LCD panel/module manufacturing was reported as 194 kg per functional unit. This data point remained in the inventory data set for LCD manufacturing, and was assumed to indeed be an ancillary material, and not a fuel. LNG was also reported as a fuel as a separate input (approximately 3.22 kg/functional unit). Keeping the LNG ancillary material in the inventory will not affect the energy impact results, since LNG used as an ancillary material is only linked to the production of that material, and not to the use of it as a fuel. It will, however, affect upstream impacts from the production of the material. Note that the natural gas process was used as a surrogate for the production of LNG, as inventory data was not available for the latter.

2.4 PRODUCT USE

2.4.1 Methodology

The methods for developing the use stage inventory are presented in Appendix H and summarized here. CRTs and LCDs use different mechanisms to produce images on screen, which result in different energy use rates. These energy use rates (e.g., kW) can be combined with the time a desktop monitor is on during its lifespan (hours/life) to calculate the total quantity of electrical energy consumed during the use life-cycle stage (e.g., kWh/life). In this project, two lifespan scenarios are considered:

- *Effective life* - the actual amount of time a monitor is used, by one or multiple users, before it is disposed of, recycled, or re-manufactured. Reuse of a monitor by a subsequent user is considered part of its effective life. Recycling, on the other hand, is the reuse of parts or materials that require additional processing after disassembly, and it is not considered part of the use stage.
- *Manufactured life* - the amount of time either an entire monitor or a single component will last before reaching a point where the equipment no longer functions, independent of user choices.

These two scenarios are considered in this project in order to account for potential differences between how consumers *currently* use the equipment and how consumers could use the equipment. Currently, consumers often replace monitors before they physically break down. This behavior results in a lifespan that is not solely dependent on the monitor technology itself. The manufactured life, on the other hand, is based on the technology and represents how consumers could potentially use the equipment. If the lifespans are significantly different, the difference could have a large impact on how the use stage compares to the other life-cycle stages in this study. The baseline analyses in this project use the effective life scenario and the manufactured life will be part of the sensitivity analyses.

2.4.1.1 Energy use rate

Most desktop monitors manufactured today are built to use several different power consumption modes during normal operation. There are often up to four different power consumption modes that can be used by a monitor in going from a state of active use to a state of almost complete shut-down. These four modes, from greatest power consumption to least, are typically entitled “full-on” or active use, “standby,” “suspend,” and “active-off.” For this report, manufacturers’ data on these power modes were collected from company contacts and Internet sites for 35 different 17" CRT monitors and 12 different 15" LCD monitors. The complete list of these data is presented in Appendix H, Attachment A, Table A1.

For the purposes of this study, the power consumption modes have been categorized into two modes: “full-on” and “low.” The “low” power mode is an average of the three low power modes typically provided by the manufacturers (i.e., standby, suspend, and active-off). These three categories were averaged to create one “low” power consumption mode because hours per use data (needed for calculations in this study) are only available for a “full-on” and a reduced power mode. The low mode value for the CRT is the average of the three modal averages of standby, suspend, and active-off. For the LCD, data on only two low-power modes (standby and active-off) were provided by manufacturers (see Appendix H, Attachment A, Table A2), and therefore, the low mode value is an average of those two modal averages. Table 2-16 presents the average values for full-on and low power modes that were used for subsequent calculations in this analysis.

Table 2-16. Average energy use rates [a]

Monitor type	Full-on power mode [kilowatts (std. dev.)]	Low power mode [b] [kilowatts (std. dev.)]
17" CRT	0.113 (0.015 SD)	0.013 (0.005 SD)
15" LCD	0.040 (0.007 SD)	0.006 (0.003 SD)

[a] See Appendix H, Attachment A, Table A1 for source data.
[b] An average of company-reported values for standby, suspend and active-off (see Appendix H, Attachment A, Table A1).
Note: 1 kW = 1000 Watts = 1000 J/sec.

2.4.1.2 Effective life (baseline lifespan calculation)

The effective life scenario attempts to model the actual quantity of hours that an average monitor spends in each of the two primary power consumption modes (full-on and a lower power state) during its lifetime. The effective life of an average monitor is based on the following information:

- the proportion of computers that are used in an office environment versus a home environment, to account for different use rates in these two basic user environments;
- the amount of time in a year a typical monitor spends in full-on power mode and in a lower power-consuming mode for both office and home environments; and
- the number of years a typical monitor is used during its lifespan for both office and home environments, not including years in storage before a monitor is replaced or discarded (as it is not consuming power during storage).

Under the effective life scenario, we assume there is no difference in the amount of time a CRT or LCD monitor is operating. That is, the hours per life for the effective life calculation is not technology-dependent. Therefore, the same set of hours-per-life values are used to calculate the kWhs used per effective lifetime for a CRT and an LCD. The remainder of this section discusses the data and methods used to calculate the hours-per-life values used in the effective life scenario. More details are also provided in Appendix H.

Percentages of Office- and Home-Environment Users

Home and office users of computer equipment do not follow the same use patterns. Thus, data are needed on the percent of users in each environment to determine the use pattern of an "average" computer monitor. It is assumed that 65% of computers are in office environments and 35% in home environments, based on data available through the Computer Industry Almanac (CIA, 1997) and the Energy Information Administration (EIA, 1999b) (see Appendix H, Section 2.2.2.1 for more details).

Note that an "office" environment may be a school, hospital, or other commercial environment, and the computers they use may follow widely varying degrees of use. For example, computers (and thus monitors) in a school may only be used a few hours in a day, while hospitals might operate theirs nearly constantly. For this study, it is assumed that on average, typical office use patterns (to be presented below, and in Appendix H, Section 2.2.2.2) are representative of all non-home environment users.

Operating Pattern (average hours in use per year)

In order to determine the amount of electricity consumed during a monitor's effective life, we need to know the use operating patterns for both the office and home environments. The "operating pattern" is defined here as the number of hours per year spent in each power mode. The average number of hours per mode per year will be the weighted average of the two user environments (i.e., 65% office, 35% home).

A literature search for computer monitor operating patterns was conducted for both office and home environments and a summary of literature reviewed is presented in Appendix H, Attachment A, Table A3. Based on the literature (Nordman *et al.,* 1996, Fanara, 1999, EIA, 1999b) and other assumptions presented in Appendix H, Section 2.2.2.2, we assume the number of hours per year that office and home monitors are used in each mode are as follows:

- Office:

Full-on power mode:	1,095 hrs/yr
Low power mode:	2,263 hrs/yr
Total:	3,358 hrs/yr

- Home:

Full-on power mode:	522 hrs/hr
Low power mode:	793 hrs/yr
Total:	1,315 hrs/yr

Average Years Per Life

The number of years per life, multiplied by the operating patterns in hours per year (listed above), will result in the hours per effective life. A monitor may be reused in multiple "lives" before reaching its end-of-life. The end-of-life is defined as the point at which the monitor is no longer used for its intended purpose in the physical form in which it was originally manufactured. End-of-life options include indefinite storage (in which case it is not reused after storage), de-manufacturing, recycling, or disposal. A monitor may be stored before being reused; however, this storage time will not affect our use calculations since no electricity is required to operate the monitor during this storage. After its first life as used by the original owner, a monitor might be used by different people and with different PC systems in subsequent lives.

For data on the number of years of use that are in a monitor's lifetime, several sources of information were reviewed (see Appendix H). Based on a recent study by the National Safety Council (NSC, 1999), we assumed that a monitor is used for 4 years in its first life and 2.5 years for its second or subsequent lives. The operating patterns (in hours/year) presented above are assumed to be the same for all of the 6.5 years of the total effective life. However, in the lives subsequent to the first life, the hours per year values are reduced by the fraction of monitors assumed to be reused. Matthews *et al.* (1997) estimated that 45% of PCs are reused after a first life; thus, the effective life operating pattern values in years of life after the first life are 45% of the values in the first life.

Lifespan estimates from the National Safety Council (NSC, 1999) were specific to CRT monitors; however, they were not specific to LCD desktop monitors. The NSC data did contain estimates of a "Notebook PC," which were two to three years for the first life and one to two years for the remaining lives; however, we expect that desktop LCD monitors will more closely mirror the lifetime estimates of a desktop CRT monitor than that of a notebook PC. Consequently, it was assumed that LCD desktop monitors also spend four years in their first life and 2.5 years in their subsequent lives. Additionally, the NSC document did not attempt to separate those computer systems or monitors that are used in an office versus a home environment. Thus, it was assumed that the same years per life are realized for office and home environments.

Effective Life Estimates (hours per life)

The data presented above are summarized in Table 2-17 and used to estimate the total hours per effective life. The values for hours per year per power mode are assumed to be the operating pattern throughout the first life (first four years). In the remaining lives, the annual operating hours decrease to 45% of the hours in operation during each year in the first life, with the remaining lives lasting a total of 2.5 years. Table 2-17 also presents the total hours per effective life per mode, based on percentage in office and home environments. These values are in bold in Table 2-17 (4,586 and 8,961 hrs per effective life) and will be multiplied by the energy use rates per mode (presented in Table 2-16), to calculate the total energy consumption per effective life for each monitor type.

Table 2-17. Effective life values

User environment	Power mode	First life (4 years)		Remaining lives (2.5 years)		Model totals [b] (hr/effective life)
		Operating pattern (hr/yr)	Total (hr/4 yrs)	Operating pattern (hr/yr) [a]	Total (hrs/2.5 yrs)	
Office (65%)	Full-on	1,095	4,380	493	1,233	5,613
	Low	2,263	9,052	1,018	2,545	11,597
Home (35%)	Full-on	523	2,092	235	588	2,680
	Low	793	3,172	357	893	4,065
Weighted average [c]	Full-on	---	---	---	---	**4,586**
	Low	---	---	---	---	**8,961**

[a] The remaining lives operating pattern is 45% of first life operating pattern, based on 45% of monitors that are reused (Matthews *et al.*, 1997).

[b] Modal totals calculated as [(Total for first 4 years) + (Total for remaining 2.5 years)].

[c] The weighted averages shown for full-on and low power modes are based on the assumption that 65% of users operate in an office environment and 35% operate in a home environment.

Effective Life Total Energy Consumption (kWh/life)

In order to calculate the total kWhs consumed, first, the energy use rates (kW) were multiplied by the lifespans (hours per life) for each mode and each monitor type. They were then summed for the two power modes to obtain a total kWh/life for each monitor type (Table 2-18).

Table 2-18. Effective life electricity consumption

Monitor type	Power mode	Energy use rate (kW)	EL calculated lifespan (hours/life)	EL energy consumption (kWh/life)
17" CRT	Full-on	0.113	4,586	518
	Low	0.013	8,961	116
	Total	----	13,547	634
15" LCD	Full-on	0.040	4,586	183
	Low	0.006	8,961	54
	Total	----	13,547	237

2.4.1.3 Manufactured life (alternative lifespan calculation)

Due to the uncertainty and assumptions associated with the effective life scenario, an alternative scenario is also considered. The manufactured life is defined here as the length of time a monitor is designed to operate effectively for the user. It is the number of hours a monitor would function as manufactured, and is independent of user choices or actions. One way to estimate this manufactured life is to use the mean-time-before-failure (MTBF) specification of a monitor or its components. The CRT MTBF specification dictates the amount of time the display must operate before it reaches its brightness “half-life,” or the ability to produce 50% of its initial, maximum brightness. The MTBF value, generally provided in total hours per life of a monitor, is what most final manufacturers or assemblers of personal computer (PC) equipment, including monitor assemblers, typically specify for a component. To meet the specification, suppliers typically calculate the MTBF (a military-based specification) based on component data. Suppliers’ test results are usually called the “calculated” MTBF. The MTBF value also depends on which combination of power modes are used during testing, which is referred to as the “duty cycle” and each supplier may use a different duty cycle to test their component.

Additionally, monitor assemblers will often perform their own testing, typically entitled “demonstrated” MTBF. The testing includes sequences where the monitor is “stressed” by quickly switching back and forth from an all black picture to an all white one, or quickly switching individual pixels either on and off or through multiple colors or black and white. Manufacturers typically find that their demonstrated MTBF is on the order of twice as long as the calculated MTBF (McConnaughey, 1999; Douglas, 1999). However, it should be noted that the demonstrated MTBF is not a real-time testing method, as the testing data is used in a complex equation to calculate that “demonstrated” value.

From review of the information obtained on CRT-based monitors (see Appendix H, Attachment A, Table A2), it appears that the CRT (the tube) itself is the limiting component, or the component that 99% of the time determines whether the entire monitor has reached its end-of-life. Thus, from the limited information that was obtained on CRTs, and the limited confidence that can be instilled in those data, an average of the two ranges obtained on the estimated lifetime of CRTs (10,000 and 15,000 hours) was used as the CRT manufactured lifetime (12,500 hours) (Goldwassar, 1999; Douglas, 1999).

For active matrix LCDs, the components that have the greatest potential to fail first are the display panel itself (including the liquid crystals and thin-film transistors), backlights, driver integrated circuit (IC) tabs, and other smaller components. The backlights and driver IC tabs can be field-replaced, thus their failure does not necessarily represent the end of the monitor's life. However, failure of the liquid crystals or transistors, which would require replacement of the display panel itself, would most likely mean that the monitor cannot be cost-effectively repaired. The MTBFs of all these components appear to have a broad range. For example, different backlight manufacturers reported from as few as 15,000 hours to as many as 50,000 hours (Douglas, 1999; Tsuda, 1999; VP150, 1999). However, it appears that those components that are not field-replaceable (e.g., the LCD panel) have MTBFs in the range of 40,000 to 50,000 hours (Tsuda, 1999; Young, 1999). Thus in this study, the amount of time an LCD monitor would operate during its manufactured life is assumed to be the average of the two non field-replaceable values, or 45,000 hours. In order for a monitor to operate for 45,000 hours, any major field-replaceable parts that have MTBFs less than 45,000 hours will need to be accounted for in this LCA project. For example, assuming the backlights last on average 32,500 hours (the average of the values obtained for backlights), more than one (approximately 1.4, on average) would be needed for every panel during its lifetime. Therefore, in the final CDP LCA, the manufacturing of extra backlights would need to be included in the inventory.

Little information is available on the duty cycles that component manufacturers use to test components. Thus, it is assumed that the average duty cycle used in testing components is 50% of the time tested in full-on mode and 50% in a lower power mode. Table 2-19 shows the values that are used in this study for the hours per manufactured life for the CRT and LCD. Some sensitivity analyses were done and presented in Socolof *et al.* (2000).

Table 2-19. Manufactured life values

Monitor type	Total hours (hours/life)	Mode	Duty cycle (% time spent in each mode during testing)	Hours per mode (hours/life)
17" CRT	12,500	Full-on	50%	6,250
		Low	50%	6,250
15" LCD	45,000	Full-on	50%	22,500
		Low	50%	22,500

To calculate the manufactured life electricity consumption (kWh/life), the energy use rate (kW) is multiplied by the lifespan (hours/life) for each monitor in each power mode (Table 2-20). The LCD manufactured life (45,000 hours) is 3.6 times greater than the CRT manufactured life (12,500 hours). In an LCA, comparisons are made based on functional equivalency. Therefore, if one monitor will operate for a longer period of time than another, impacts should be based on an equivalent use. Therefore, based on equivalent use periods, 3.6 CRTs would need to be manufactured for every LCD. This will be incorporated into the profile analysis for the comparative manufactured life LCA.

Table 2-20. Manufactured life electricity consumption

Monitor type	Power mode	Energy use rate (kW)	ML calculated lifespan (hours/life)	ML energy consumption (kWh/life)
17" CRT	Full-on	0.113	6,250	706
	Low	0.013	6,250	81
	Total	----	12,500	787
15" LCD	Full-on	0.040	22,500	900
	Low	0.006	22,500	135
	Total	----	45,000	1,035

2.4.1.4 Effective life versus manufactured life

For the CRT monitor, the effective life total hours are 13,547 versus the manufactured life total of 12,500. While this suggests that a CRT can be used longer than is physically possible, it simply reveals our low confidence in these numbers and some of their supporting values, with less confidence in the manufactured life data than the effective life estimates. A more complete discussion of the data quality is presented in Section 2.4.2 and Appendix H.

Assumptions were required several times that could bias these numbers in either direction; however, it is thought that the manufactured life estimate is most likely low based on the other estimates for the overall CRT monitor (see Appendix H, Attachment A, Table A2). However, there was no sound basis for assuming a lower value and thus the above hours per life values were used. It should also be stated that while these numbers are different, they are within an 8% error range of one another, and can be taken to be a near 1:1 ratio, indicating a similar potential lifespan.

For LCDs, the comparison across lifespan scenarios is more consistent with what one would expect, with the manufactured life value of 45,000 hours per life being much greater than the effective life value of 13,547 hours per life. The effective life value reflects the assumption that a user’s use habits are not technology-dependent, and would seem to reveal that LCDs are not being used as long as they can physically be (less than a third as long).

The difference between the effective and manufactured lives are important when evaluating all the life-cycle stages for a particular monitor type. If the manufactured life is significantly greater than the effective life, the use stage will have greater impacts, as compared to other life-cycle stages. Therefore, it is important to focus on the lifetime scenario that is most realistic, while still recognizing the potential impacts from another feasible lifespan scenario.

In this project, we will use the effective life as the primary basis for the use stage inventory due to the fact that the effective life data are attempting to obtain a more realistic value for electricity consumed per lifetime, and that we currently have greater confidence in those data versus the manufactured life data. The manufactured life data will be used in one sense as a sensitivity analysis and to discuss potential differences in the use stage impacts based on this alternative lifetime scenario.

2.4.2 Data Sources and Data Quality

Source and quality information for the use stage data are detailed in Appendix H, Table 11. We assigned four categories of data quality ratings: excellent, average, poor, and unknown. In general, data assigned higher quality ratings were directly measured and represent 1998 data. As data required more calculation or estimation, or were found from a previous year, the data quality rating was reduced.

The overall level of use stage data quality is between average and excellent (Appendix H, Table 11). However, a distinct difference can be seen in the average data quality ratings given to manufactured life data (average) and the effective life data (excellent). This implies that greater confidence can be placed in the effective life data than in the manufactured life data. Additionally, the energy use rate data appears to be of average quality.

2.4.3 Limitations and Uncertainties

Details of the limitations and uncertainties associated with the energy use rate, the effective life, and the manufactured life estimates are presented in Appendix H, Section 5.

2.5 END-OF-LIFE

2.5.1 Methodology

A Technical Memorandum, attached as Appendix I, was prepared for this project that provides background on the EOL issues for the CRT and LCD. It also provides details on the methodology used in this project for the EOL life-cycle inventory. This section summarizes the salient points from that memorandum needed to understand the EOL methodology and results. For the EOL analysis, a monitor is assumed to have reached EOL status when:

- it has served its useful life;
- is no longer functional; and/or
- is rendered unusable due to technological obsolescence.

Each of these situations is addressed by either the manufactured or effective lives (defined in Section 2.4).

2.5.1.1 EOL disposition options

The major EOL dispositions considered in this analysis are as follows:

- recycling - including disassembly and materials recovery;
- landfilling - including hazardous (Subtitle C) and non-hazardous (Subtitle D) landfills;
- remanufacturing - including refurbishing or reconditioning (to make usable again); and
- incineration - waste to energy incineration.

See Appendix I for further descriptions of these dispositions. Note that reuse is considered part of the use stage and not included as an EOL disposition.

The functional unit in this analysis is one monitor; therefore, the different EOL dispositions were allocated as a probability of one monitor going to a certain EOL disposition. Data were somewhat scarce on the percent of monitors going to each disposition, especially for the LCD monitors. After literature research and consultation with the project's Technical Work Group, as well as various other industry experts, project partners chose best estimates of disposition distributions. Table 2-21 presents the assumptions used for the EOL life-cycle stage dispositions for the CRT and LCD, respectively. An explanation of the assumptions and the sources of the data are presented in Appendix I.

The values in Table 2-21 have been used in the baseline scenarios for the CRT and LCD LCIs. To address the uncertainty in the LCD estimates, a sensitivity analysis was conducted (which is discussed in Section 2.7.3).

Table 2-21. Distribution of EOL disposition assumptions for the CRT and LCD

Disposition	CRT	LCD
Incineration	15%	15%
Recycling	11%	15%
Remanufacturing	3%	15%
Hazardous waste landfill	46%	5%
Solid waste landfill	25%	50%

Sources: NSC, 1999; EPA, 1998; Vorhees, 2000; CIA, 1997; EIA, 1999b

2.5.1.2 Data collection

Inventory data were needed for each of the EOL dispositions to be included in the life-cycle profiles. Primary data were collected for CRT recycling from three companies. Hazardous/solid waste landfilling and incineration were developed from secondary data obtained from *Ecobilan*. In attempts made to obtain remanufacturing data, it was found that remanufacturing processes span a wide range of activities, from as little as replacing button tops to as extensive as testing and replacing PWBs or transformers. Given the broad range of possibilities, no single set of operations could be identified to adequately represent remanufacturing activities that could be incorporated in our model. Remanufacturing data were, therefore, excluded from the assessment.

Recycling

Companies willing to provide CRT recycling data were given EOL questionnaires, which are similar to the manufacturing questionnaires, but modified as appropriate for the EOL life-cycle stage (see Appendix I). The questionnaires were used as a guide for collecting inventory data. The companies agreed to provide inventory data through personal meetings and telephone conversations rather than completing the detailed questionnaire. As a result, the most critical data were identified by the research team to prioritize data needs, and all the details in the questionnaire may not have been provided.

The three companies contacted were: (1) DMC Recycling; (2) A & B Recycling; and (3) The Oak Ridge National Recycle Center (TORNRC). DMC shreds the complete monitor up and separates the recovered materials into three major material streams: ferrous, silica-based, and copper-based. The ferrous metals are sent to steel mills for recycling, while the other streams are sent to lead and copper smelters, respectively. A & B Recycling performs a partial disassembly of the casing and other materials outside the CRT. These materials (namely, HIPS, steel, aluminum, and copper wiring) are sent for recycling, while the CRT itself is shipped to Envirocycle (a CRT recycler in Pennsylvania), where the glass is recovered and sent for recycling back into CRT glass, and the other materials are also recovered for recycling. TORNRC conducts complete monitor disassembly (which includes the CRT recycling process similar to the one performed at Envirocycle), and recovers the individual materials for subsequent recycling.

None of the recycling companies contacted have yet encountered end-of-life LCDs in any appreciable quantities that would justify the development of a separate recycling process for them. Whatever sporadic quantities of LCDs that they do receive (mainly notebook computer displays) are either sent for refurbishing/resale or are processed along with other electronic equipment, by recovering different materials from them, such as metals, glass, plastics, etc. In the absence of actual data for LCD recycling, the shredding-and-materials-recovery process followed by DMC Recycling for CRTs was assumed to be suitable for recovering materials from LCDs as well, and was therefore used to model LCD recycling.

Landfilling and Incineration

Generic secondary data were used for the incineration and landfilling processes because when monitors are disposed of, they are combined with multiple waste streams, and data for monitors alone are not readily available. Although data specific to landfilling and incineration operations for monitors alone were not available, DEAM inventories from *Ecobilan* were available for landfilling and incinerating the following major monitor materials (by weight): steel, glass, plastic, and aluminum. These inventories were combined, based on the approximate proportion of each material in a CRT and an LCD, to create individual processes for landfilling and for incineration (for each monitor type). The proportions of these materials in a CRT and an LCD, presented in Table 2-22, are estimates of the final assembled monitor based on the manufacturing inventory data. Note that these proportions are slightly different from the proportion of total inputs per functional unit presented in Section 2.1.2, Tables 2-2 and 2-3 because materials efficiency during production is not accounted for here (in Table 2-22). The majority of the assembled monitors by weight is accounted for in the overall incineration and landfilling processes, as seen in the totals in Table 2-22.

It should be noted that some of the DEAM inventories associated with incineration or landfilling are for generic materials (i.e., glass, plastic), and may not accurately represent the makeup of the material used in the monitors. For example, the glass is not leaded glass, and the plastics may not represent the exact breakdown of plastics in the monitors being modeled in this study (see Section 2.5.3, Limitations and Uncertainties for further discussion).

Table 2-22. Percent contribution of major materials in the final product

Material	CRT	LCD
Glass	43% (9.48 kg)	9% (0.585 kg)
Steel	30% (6.61 kg)	47% (3.055 kg)
Plastic	17% (3.75 kg)	40% (2.60 kg)
Aluminum	2% (0.441 kg)	1% (0.065 kg)
Total	**92% (22.043 kg)**	**97% (6.5 kg)**

2.5.1.3 Assumptions

The assumptions used in the EOL life-cycle stage include the percentage breakdown of each EOL disposition option (see Table 2-21), the breakdown of materials for the incineration and landfilling inventories (Table 2-22), as well as those listed in Section 2.2 of Appendix I.

2.5.2 Data Sources and Data Quality

Primary CRT recycling data collected were collected from three companies: A & B Recycling, DMC Recycling, and TORNRC. Efforts were made to collect all data in the questionnaires; however, priority was given to obtaining the inventory data. The companies, preferring to provide data over the phone or during personal meetings, were able to provide the inventory data required for the analyses in this study.

Specific DQIs, such as those reported for the manufacturing data (see Section 2.3.2, Tables 2-14 and 2-15), were not obtained. The data from these companies represent facility operations ranging from October 1999 to February 2000. Also, while the data obtained are from three recycling facilities that may have different operations, the averaged inventory data are intended to be representative of various recycling activities in the industry.

Data for the EOL life-cycle stage are a combination of primary data, for which we do not have specific DQI, and secondary data, with limited data quality information. The overall data quality for this life-cycle stage may therefore be limited, and in relative terms, is lower quality than the manufacturing stage data.

Sources of data for EOL distribution assumptions include the National Safety Council (NSC, 1999), EPA (1998), CIA (1997), EIA (1999b) and Vorhees (2000). These are discussed in Appendix I.

2.5.3 Limitations and Uncertainties

Assumptions of the disposition percentages for CRTs and LCDs may not be truly representative of actual dispositions. Recycling technologies are not yet standardized for the sorting, separation, and processing of different types of CRT glass, metals, and plastics. The methods currently employed by a few large-volume recyclers who have been in the CRT recycling business for some years were used in this study and represent “state-of-the-art” in the CRT recycling industry. The LCD recycling process used was based on a CRT recycling process employed by one of the recycling companies contacted, as it was considered general enough to be applicable to LCDs. In the future, when greater numbers of LCDs begin to arrive at recycling facilities, more standardized processes for handling LCDs specifically might be developed.

Limitations for the incineration and landfilling inventories are that incineration and landfilling of the materials were for generic materials and not specific to actually incinerating or landfilling a CRT or LCD monitor. For the CRT, the glass incineration portion of the monitor is for generic, non-leaded glass. The plastics are also generic plastics (mainly those used for packaging that ultimately end up in municipal solid waste, such as HDPE, LDPE, and PET) and may not account for the flame retardants that might be in the plastics, for example. Also, only a few of the major materials by weight are included in the modeled CRT and LCD that are incinerated (listed in Table 2-22).

2.6 TRANSPORTATION

2.6.1 Methodology

Transportation of materials, products, and wastes throughout a product's life-cycle has environmental impacts and should be included in a comprehensive LCA. However, complete transportation data for all life-cycle stages is often difficult to obtain. Only six of the 16 upstream data sets used for this study explicitly stated that transportation was included. An additional six upstream processes are assumed to have considered transportation (Table 2-9). In the manufacturing stage, transportation data were collected in the questionnaires that were distributed to manufacturers. Some transportation data were provided by manufacturers on materials received by their facility and products and wastes shipped from their facility. Data were not obtained on transportation during the use stage because distributing questionnaires and collecting primary data for the use stage were not within the boundaries and scope of the LCA. Consequently, individual consumer transport to pick up purchased monitors and to send to a secondary user or to a recycling/disposal facility were not accounted for. Similarly, EOL data, either from CRT recyclers, or secondary data for incineration and recycling did not include transportation data. Therefore, the transportation data collected in this study may only represent a small portion of the overall transport in the life of a monitor.

The manufacturing data collection questionnaires (Appendix F) provided space for companies to identify transportation information for each material input, product output, or waste output. The questionnaire asked for the distance traveled, mode of transport (i.e., vehicle type), number of trips per year, and percent capacity of the vehicle containing a particular material of interest. Given this information, the project researchers calculated the total distance traveled for a transportation mode per functional unit.

In order to determine the environmental effects of transport, the total distance traveled must be linked to an inventory associated with a transport mode on a per-distance-traveled basis. *Ecobilan's* DEAM data provided inventories for several vehicles either on a per-distance-traveled basis or a per mass-load, per-distance-traveled basis. Given the maximum load of the vehicle, the latter figures can also be used with the transportation data collected in the manufacturing questionnaires to estimate the total distance traveled per mode per functional unit.

2.6.2 Questionnaire Results

In many cases, companies completing the questionnaires provided partial transportation data. For the CRT processes, manufacturers supplied adequate transportation data for 66% of the materials that are expected to have transportation data. For the LCD processes, 73% of the materials had adequate transportation data to determine the total distance traveled per mode per functional unit. Of the transportation data that were provided, Table 2-23 lists the distribution of transport modes for the CRT and LCD manufacturers. To complete the LCI, transport data from the questionnaires would have to be linked to vehicle inventories, which were available through the DEAM data. However, the vehicle inventories were not linked to the questionnaire data because the questionnaire asked for percent capacity, but did not couple that with the load capacity of the vehicle. As a result, the data were inconsistent and could not accurately be used in the overall product LCI.

Table 2-23. Distribution of transport modes and total distances per mode

Transport mode	CRT		LCD	
	Distribution of modes	Approx. normalized [a] distance traveled per functional unit	Distribution of modes	Approx. normalized* distance traveled per functional unit
Large diesel truck	61%	3 km	58%	3 km
Small diesel or gas truck	21%	<1 km	35%	<1 km
Ocean	16%	37 km	3%	<1 km
Rail	2%	<1 km	2%	<1 km
Air	0%	0	2%	52 km
Total	100%	40 km	100%	56 km

[a] Normalized by the percent capacity of a vehicle carrying the material of interest.
Note: 1 km = 0.6215 miles.

In order to use the vehicle inventory data, it would have to be assumed that the load capacity assumed by manufacturers when providing the percent capacity was consistent with that in the DEAM vehicle inventory data. However, conducting a review of the DEAM data versus the questionnaire data showed that this was not consistent. The greatest difference (based on relatively crude averages of all the transport data provided) appeared to be for the ocean transport, where the discrepancy was on the order of tens of millions of times different. The other modes appeared to be between 22,000 to 660,000 times. These huge discrepancies puts the linked transportation data into question, making it unreliable for use in this study. When the transportation impacts were run in the analysis, and these factors applied, the transportation impacts appeared to be small compared to the other life-cycle stages, but no real reliable information can be gleaned from these data. Further work is needed in this area to understand the true transportation impacts. For this report, the transportation-related inventories are not included.

Transportation data that can be used from the questionnaires include the modes of transport used and the total distances traveled per functional unit (by mode). These are presented in Table 2-23. The “normalized” distance is the total distance traveled for each material multiplied by the percent capacity of the vehicle that was carrying the particular material of interest. This was done to allocate a portion of the vehicle (and thus a portion of the associated inputs and outputs for transport in a particular vehicle) to the transport of the material of interest. It should be noted that these percent capacities were assumptions made by the manufacturers who completed the questionnaires and the percent capacity assumptions could have been inconsistently interpreted. Not only are the distances modified to represent only the product of interest, they are scaled to represent one functional unit (i.e., the material, product, or waste associated with one monitor). Thus, the total normalized distance for the CRT is 40 kilometers (km) per functional unit and 56 km per functional unit for the LCD. These numbers are normalized with the intention of linking them to the individual vehicle inventories, but as stated above, this has not been done due to data inconsistencies.

The most frequently used mode of transport for both the CRT and LCD is the large diesel truck, followed by the small gas or diesel truck. However, the largest normalized distance traveled for the CRT is via ocean transport and for the LCD is via air transport. Worth noting again is that these distances were calculated by normalizing the capacity of the vehicle, as assumed by the manufacturer. Although the transport data represent transport of several materials, products, and wastes into and out of manufacturing facilities, the majority of the distances traveled are from the transport of the final assembled monitors. Of all the reported transportation for the manufacturing stage, the distance traveled of a final assembled CRT monitor via the ocean represents 80% of the total distance traveled. For the LCD, 90% of all reported kilometers traveled are for transport of the final assembled LCD monitor via airplane. Transport of the final assembled CRT monitor for all transport modes is 86% of all kilometers traveled per functional unit. Similarly, for the final assembled LCD monitor, approximately 92% of all manufacturing transportation reported is for the final assembled monitor.

2.6.3 Data Sources and Data Quality

Primary data were derived from manufacturing questionnaires and inventory data for transport vehicles were available through DEAM data. However, inconsistencies between the data made it impossible to accurately apply the DEAM inventories to the questionnaire data. Therefore, the data quality is very low and complete transportation inventory data are excluded from the analysis results.

2.6.4 Limitations and Uncertainties

Inconsistencies between data collected in questionnaires and DEAM data made it impossible to use the transportation inventory data as part of the overall life-cycle. From rough estimates based on data received, it is possible that the transportation impacts are not driving overall life-cycle impacts, however, this would need to be investigated further to confirm such a conclusion.

2.7 SUMMARY OF LIFE-CYCLE INVENTORY RESULTS

2.7.1 Baseline LCI

This section presents the baseline inventory data for the life-cycles of the CRT and LCD monitors. The baseline scenario meets the following conditions:

- uses the effective life use stage scenario;
- uses the average value of all the energy inputs from the primary data for glass manufacturing;
- assumes LCD glass manufacturing processes use the same amounts of energy as CRT glass manufacturing per kilogram of glass produced;
- excludes two outliers from the average of the energy inputs in the LCD panel/module manufacturing inventory;
- excludes transportation in the manufacturing stage, but includes any transportation embedded in upstream data sets; and,
- includes the manufacturing process of materials used as fuels (e.g., natural gas, fuel oils) in the life-cycle stage in which they are consumed instead of in the materials processing stage. In cases where materials normally considered to be fuels are used as ancillary materials their manufacturing processes are included with other upstream processes.

Inventory data presented here are used to calculate impacts in the impact assessment (Chapter 3), which translates inventory items into impacts. Note that only limited conclusions can be made based on the inventory alone.

Table 2-24 presents the total quantity of inputs and outputs for the entire life-cycles of the CRT and LCD based on input and output types. Definitions of the input and output types were presented in Table 2-1 in Section 2.1.1. Graphs depicting selected input and output types, derived from the values in Table 2-24, are in Figures 2-5, 2-6, and 2-7. Complete inventory tables for each input and output type by life-cycle stage for the CRT and LCD are provided in Appendix J. The inventories presented in Appendix J list each individual input or output alphabetically for a particular input or output type. The individual inputs or outputs may be the sum of that material for several processes.

The total inventory results for life-cycle inputs reveal that more primary materials,[3] water, fuels, electricity, and total energy (i.e., fuel energy plus electricity) are used throughout the CRT life-cycle while more ancillary materials are used throughout the LCD life-cycle. For the life-cycle outputs, the CRT releases more air emissions; water pollutants; hazardous, solid, and radioactive waste; and radioactivity than the LCD. The LCD releases more total wastewater than the CRT. The data that comprise the inventory totals presented in Table 2-24 are listed in Appendix J and broken down by life-cycle stage. Further details on the inventory are provided for each monitor type below.

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[3] Note that the total mass of primary materials includes the inputs to each process, which may duplicate materials used in processes subsequent to other processes. For example, the primary materials used in steel production are added to the steel used as a primary material for monitor assembly.

Table 2-24. Total life-cycle inventory summary - baseline analysis

Inputs	CRT	LCD	Units
Primary materials	**6.53e+02**	3.63e+02	kg/functional unit
Ancillary materials	1.98e+01	**2.08e+02**	kg/functional unit
Water	**1.31e+04**	2.82e+03	kg (or L)/functional unit
Fuels	**4.33e+02**	3.86e+01	kg/functional unit
Electricity	**2.49e+03**	1.20e+03	MJ*/functional unit
Total energy	**2.08e+04**	2.84e+03	MJ*/functional unit
Outputs			
Air pollutants	**6.64e+02**	3.46e+02	kg/functional unit
Wastewater	1.52E+03	**3.13e+03**	kg (or L)/functional unit
Water pollutants	**2.09E+01**	1.68e+00	kg/functional unit
Hazardous waste	**9.46e+00**	6.29e+00	kg/functional unit
Solid waste	**1.72e+02**	5.23e+01	kg/functional unit
Radioactive waste	**2.90e-03**	1.48e-03	kg/functional unit
Radioactivity	**8.98e+07**	4.01e+07	Bq/functional unit

* 3.6 MJ = 1 kWh

Note: Bold indicates the larger value when comparing the CRT and LCD.

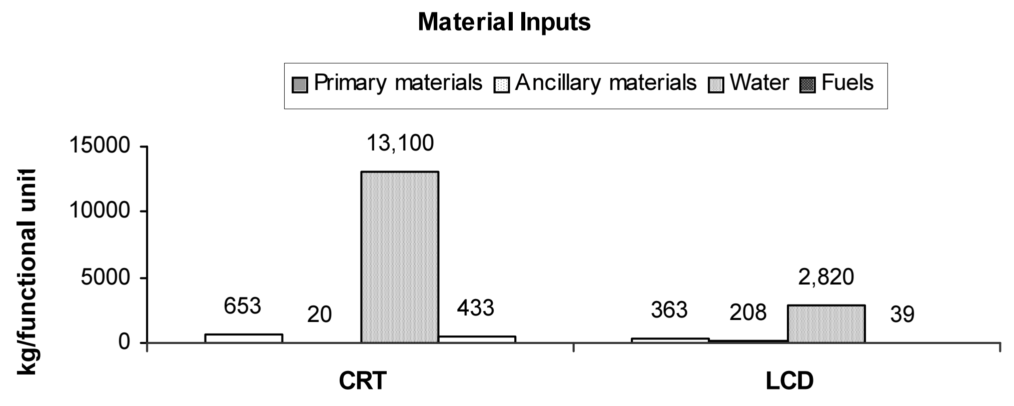


Figure 2-5. Mass-based life-cycle inputs

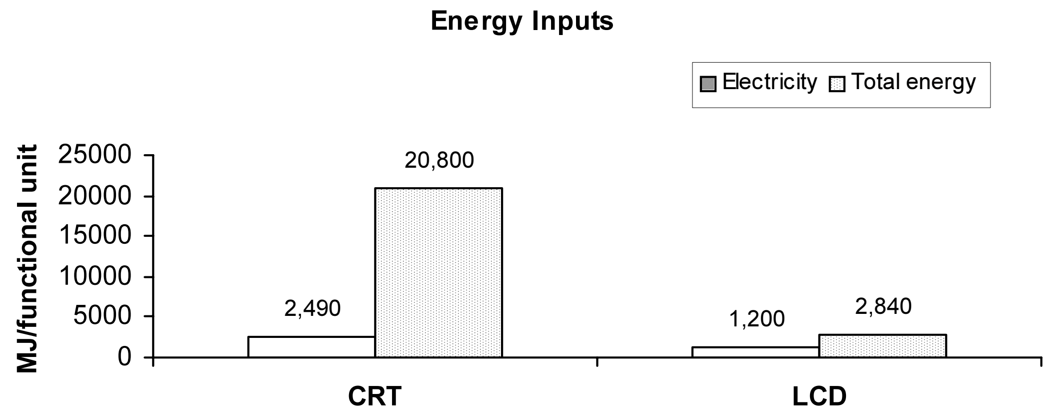


Figure 2-6. Energy-based life-cycle inputs

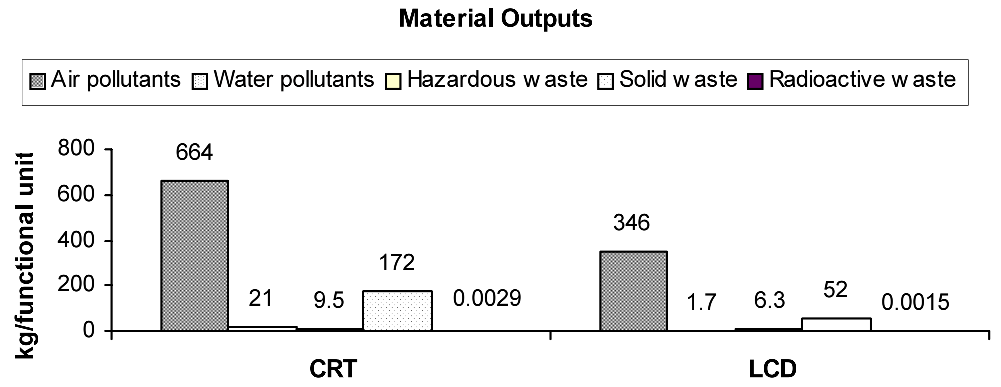


Figure 2-7. Mass-based life-cycle outputs (excluding total wastewater)

2.7.1.1 CRT inventory results

The total CRT inventory presented in Table 2-24 and Figures 2-5, 2-6, and 2-7 show the inventory from all life-cycle stages combined. The totals by life-cycle stage are presented in Table 2-25, Figures 2-8, 2-9, and 2-10.

Table 2-25. CRT inventory by life-cycle stage

Inventory type	Upstream	Mfg	Use	EOL	Total	Units [a]
Inputs						
Primary materials	1.58e+01	4.21e+02	2.19e+02	-3.32e+00	6.53e+02	kg
Ancillary materials	2.11e+00	3.54e+00	3.47e+00	1.07e+01	1.98e+01	kg
Water	5.54e+02	1.14e+04	1.14e+03	-2.73e+01	1.31e+04	kg (or L)
Fuels	??	??	??	??	0.00e+00	kg
Electricity	7.32e+01	1.29e+02	2.29e+03	2.29e-01	2.49e+03	MJ
Total energy	3.66e+02	1.83e+04	2.29e+03	-1.28e+02	2.08e+04	MJ
Outputs						
Air pollutants	3.00e+01	1.83e+02	4.49e+02	2.47e+00	6.64e+02	kg
Wastewater	1.70e+01	1.51e+03	0	-3.65e+00	1.52e+03	kg (or L)
Water pollutants	8.12e-01	2.01e+01	7.02e-02	-6.18e-02	2.09e+01	kg
Hazardous waste	??	??	0	??	9.46e+00	kg
Solid waste	9.55e+00	8.12e+01	8.33e+01	-1.66e+00	1.72e+02	kg
Radioactive waste	4.39e-04	1.80e-04	2.28e-03	2.29e-07	2.90e-03	kg
Radioactivity	3.80e+07	3.78e+06	4.80e+07	4.80e+03	8.98e+07	Bq

[a] Per functional unit (i.e., one CRT monitor over its effective life).

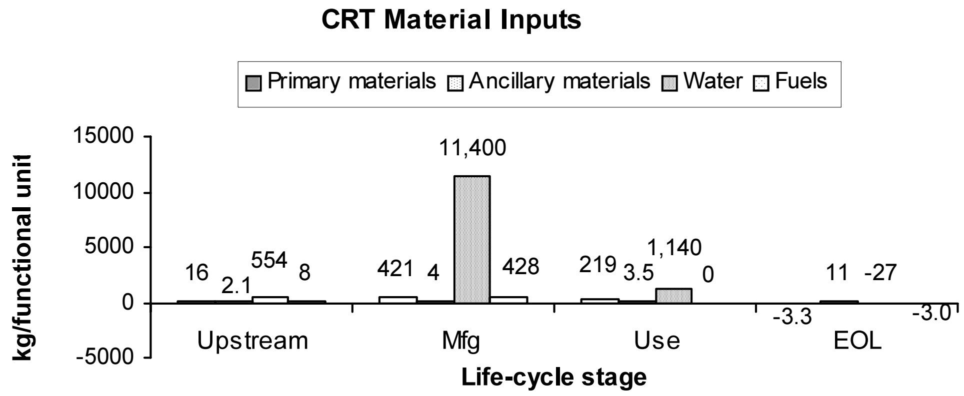
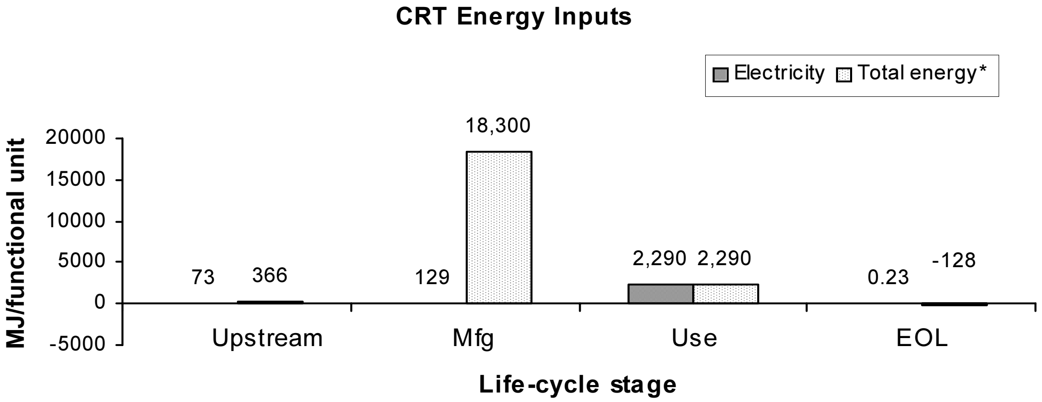


Figure 2-8. CRT Mass-based material inputs by life-cycle stage



*Total energy is the sum of electricity and fuel energy

Figure 2-9. CRT Energy-based inputs by life-cycle stage

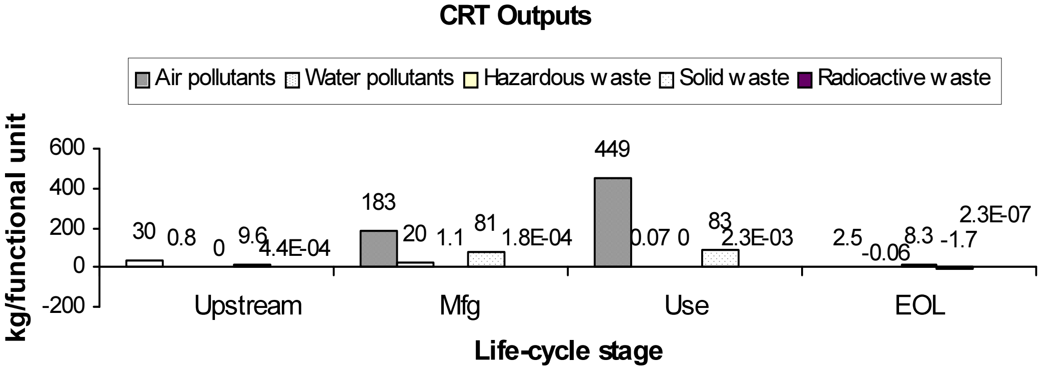


Figure 2-10. CRT mass-based outputs by life-cycle stage

Considering inputs, Figure 2-8 shows that of the inputs measured in mass, the water inputs in the manufacturing life-cycle stage constitute the majority of the inputs by mass for the entire life cycle. Water inputs from the LPG production process constitute almost 80% of the water inputs for all life-cycle stages. In this inventory, the LPG is used in large quantities as a fuel in CRT glass manufacturing. When considering which life-cycle stage contributes most to an inventory category, the manufacturing stage has the largest inventory by mass for primary materials, ancillary materials, water inputs, and fuel inputs. This is also due to the production of LPG as needed for CRT glass production. Fuel inputs are dominated by the manufacturing stage and electricity inputs are dominated by the use stage. The total energy (which is calculated by converting the mass of the fuel into units of energy and combining the fuel energy with the electrical energy[4]) is dominated by the manufacturing life-cycle stage, again mostly due to the large LPG fuel energy used in CRT glass production (Figure 2-9).

Outputs measured in mass include air emissions, wastewater, water pollutants and hazardous, solid, and radioactive waste. Wastewater, by mass (or volume), constitutes the greatest output; however, wastewater alone will not be used to calculate water-related impacts. Water pollutants are also used to calculate water-related impacts. Of the remaining outputs measured in mass (i.e., air emissions, and hazardous, solid and radioactive waste), which are shown on Figure 2-10, air emissions are the greatest contributor to outputs in mass. Note that radioactivity is measured in Bequerels (Bq) and cannot be compared on the same scale.

Considering each inventory type and their contributions by life-cycle stage, the mass of wastewater and water pollutants are greatest in the manufacturing life-cycle stage (again due to LPG consumption). The outputs of air emissions, hazardous waste, solid waste, radioactive waste, and radioactivity all have the greatest contribution from the use stage.

For the outputs, all the totals represented in Table 2-25 include outputs to all dispositions. For example, water outputs sent offsite to treatment as well as those directly discharged to surface waters are all included. Similarly, hazardous, solid and radioactive waste outputs may be landfilled, treated or recycled. The inventory shows these as totals; however, when impacts are calculated, the dispositions dictate which inventory items will be used to calculate impacts (Chapter 3).

The tables and figures discussed above show the total inventories for particular input or output types by life-cycle stage. Tables in Appendix J list each material that contributes to those totals. Figures 2-11 through 2-23 show the total contribution by life-cycle stage, based on the entire input/output type-specific tables in Appendix J. Summary tables for the CRT (Tables 2-26 through 2-34), developed from the Tables in Appendix J, show the top contributing inventory items to each input or output type. Note that Table 2-28 includes input/output types that are classified together as utilities: water, fuel, electricity and total energy.

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[4] Conversions and calculations of energy impacts are described in the LCIA methodology discussion in Chapter 3.

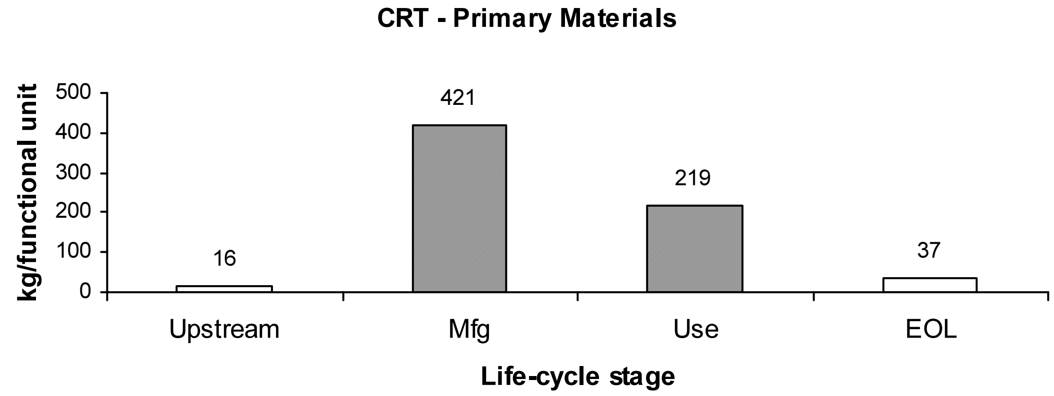

Figure 2-11. CRT primary material inputs by life-cycle stage

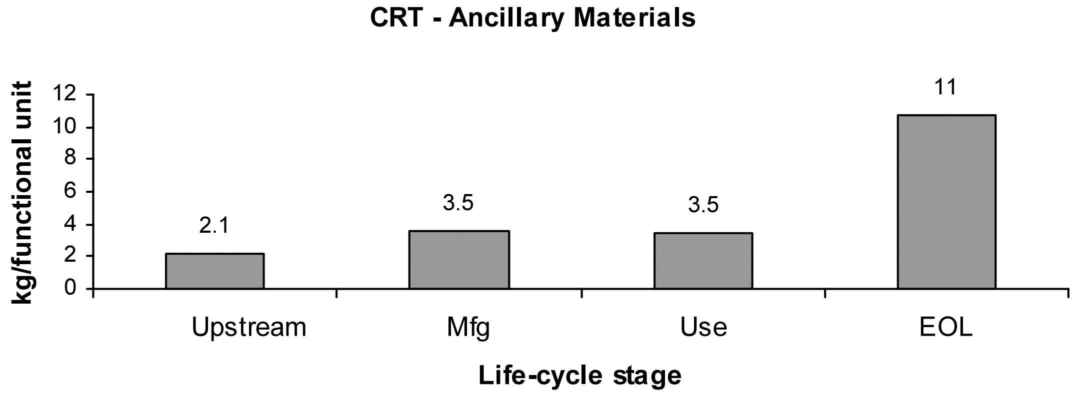

Figure 2-12. CRT ancillary material inputs by life-cycle stage

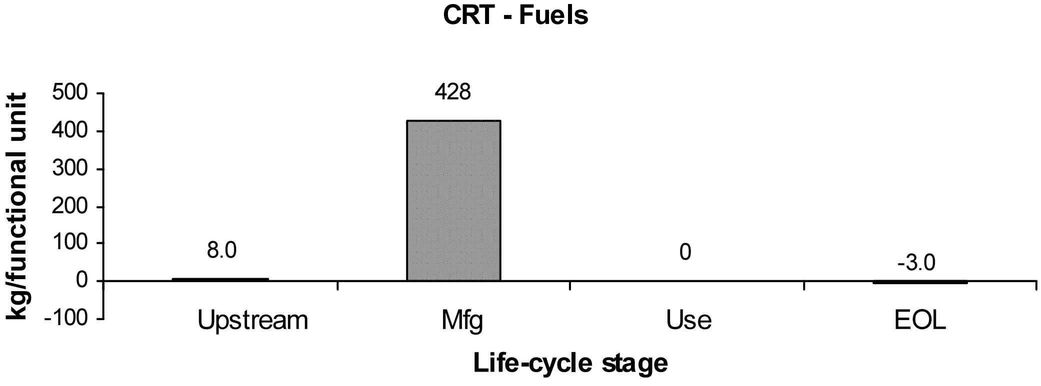

Figure 2-13. CRT fuel inputs by life-cycle stage

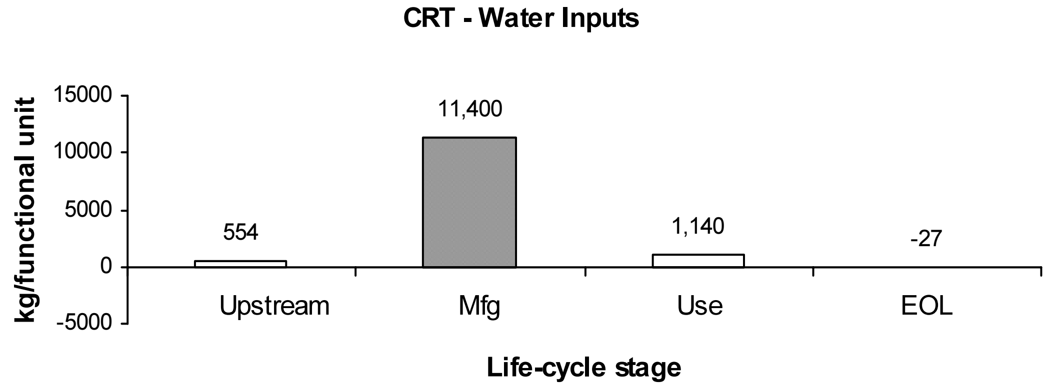

Figure 2-14. CRT water inputs by life-cycle stage

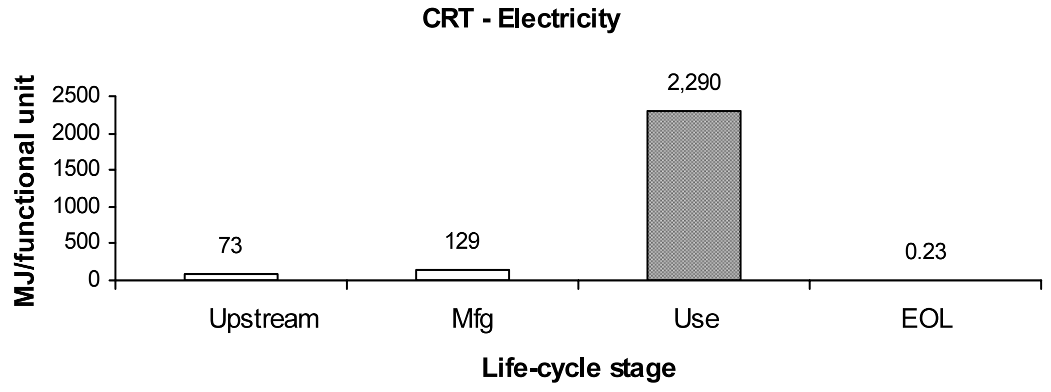

Figure 2-15. CRT electricity inputs by life-cycle stage

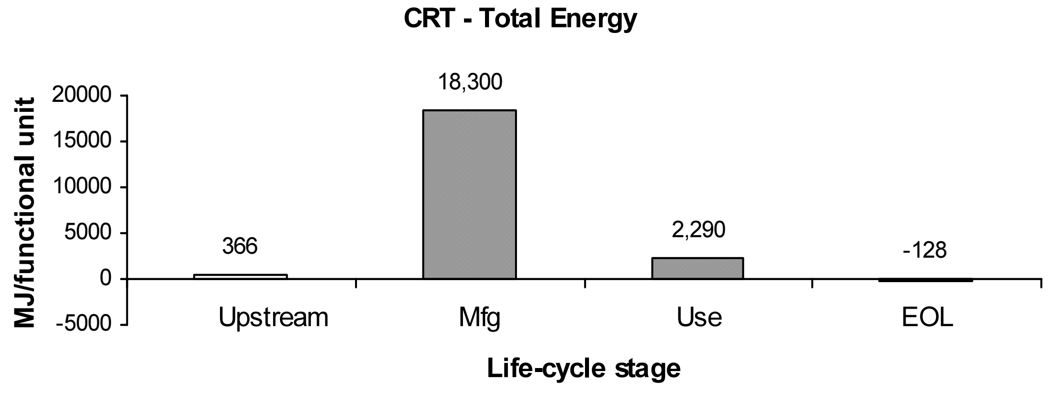

Figure 2-16. CRT energy inputs by life-cycle stage

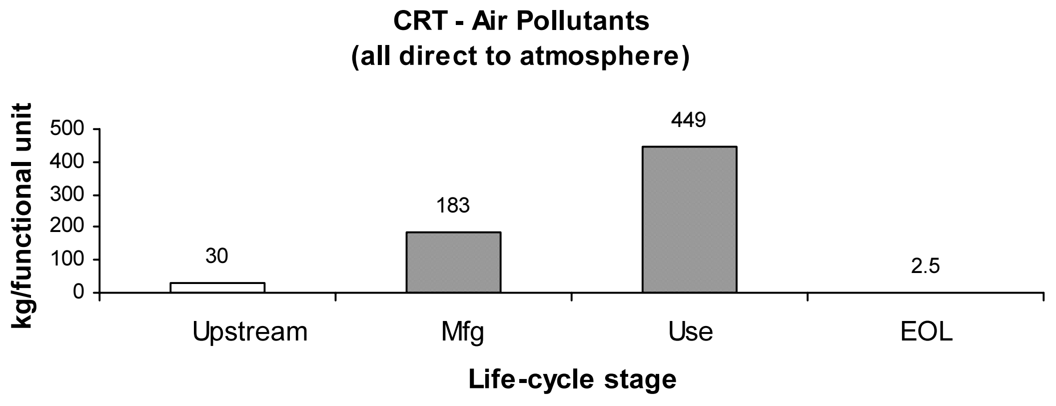

Figure 2-17. CRT air outputs by life-cycle stage

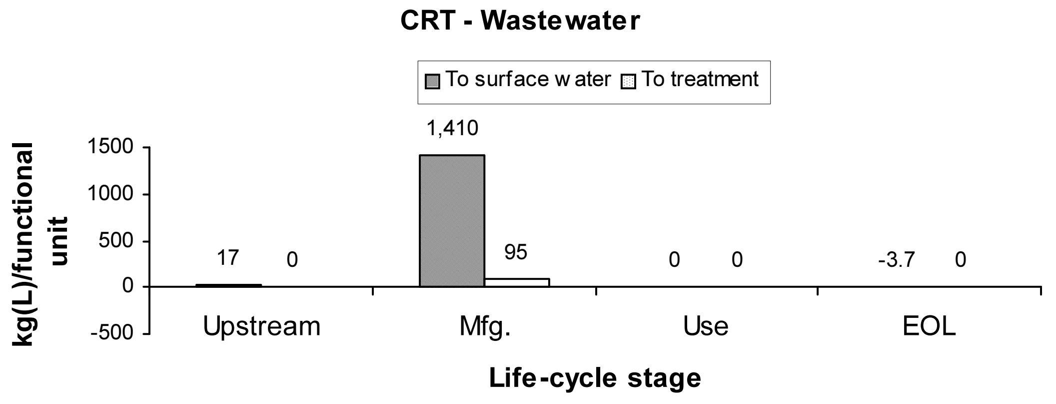

Figure 2-18. CRT wastewater outputs by life-cycle stage

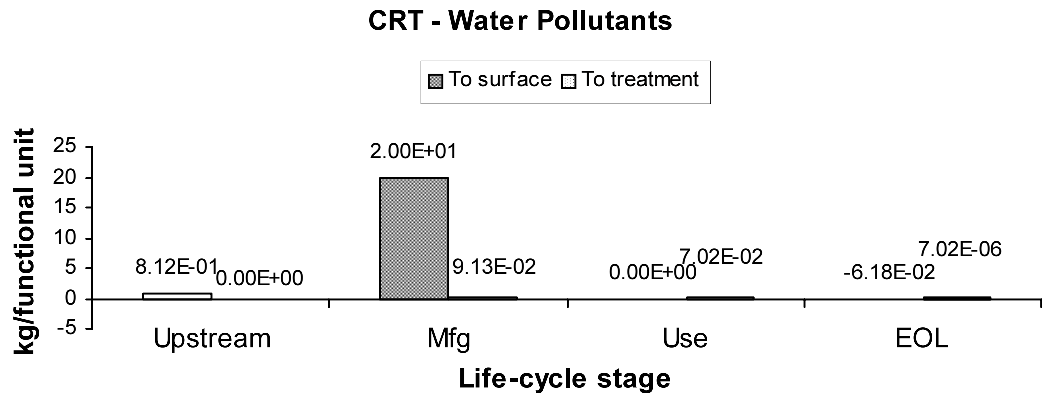

Figure 2-19. CRT waste pollutant outputs by life-cycle stage

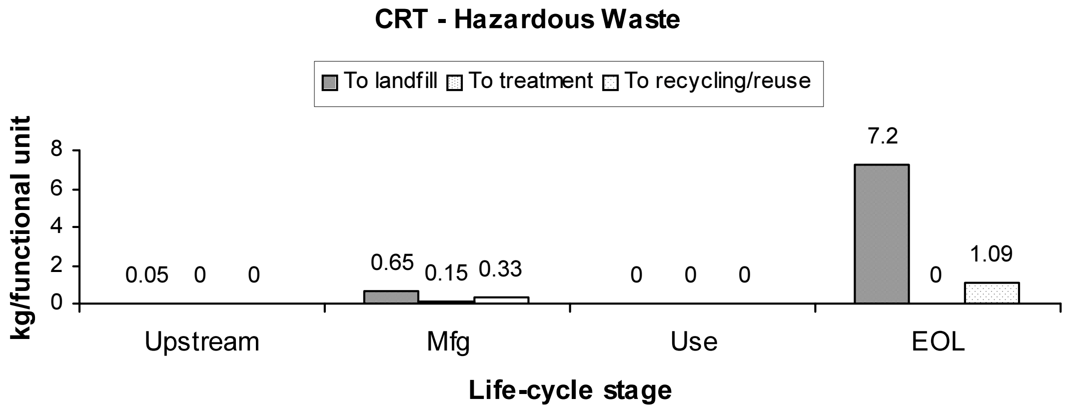

Figure 2-20. CRT hazardous waste outputs by life-cycle stage

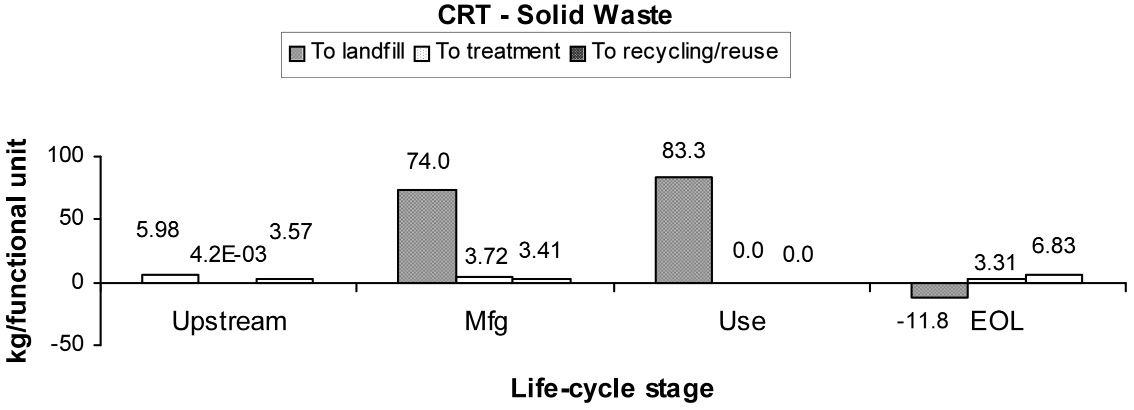

Figure 2-21. CRT solid waste outputs by life-cycle stage

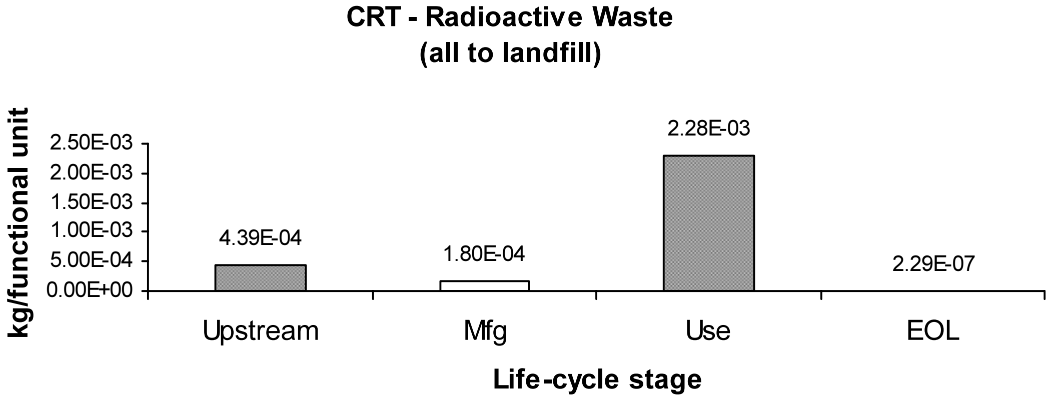

Figure 2-22. CRT radioactive waste outputs by life-cycle stage

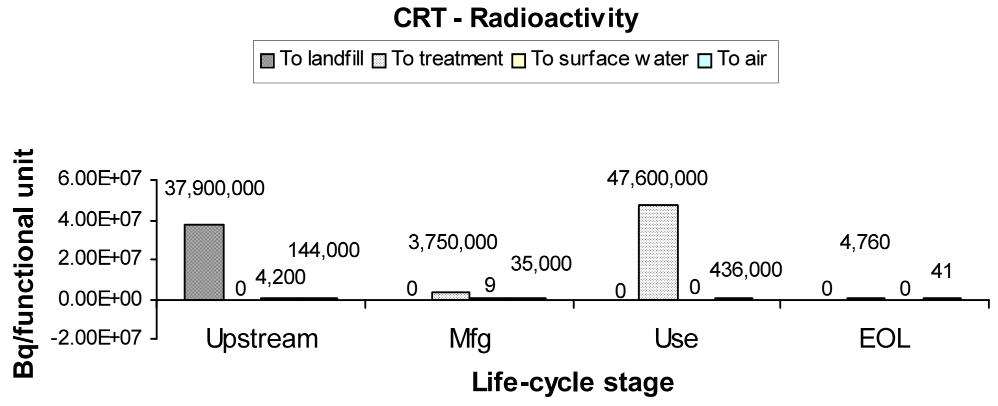

Figure 2-23. CRT radioactivity outputs by life-cycle stage

CRT Primary Inputs

Beginning with the primary data inputs, Figure 2-11 shows that most primary materials are from the manufacturing and use life-cycle stages. To better understand what some of the top contributing materials are to those life-cycle stage totals, Table 2-26 shows the top 99% of the materials contributing to the total CRT primary input inventory. As shown in Table 2-26, the largest material contributor is petroleum, which is about 54% of all the primary CRT inputs. The petroleum is mostly (>98%) from the LPG production process, which relates back to the LPG needed as a fuel in glass production. The other major contributor to primary material inputs is coal (~27%) which is used to produce electricity consumed in the use stage. More detail on the processes that contribute greatest within the manufacturing stage will be presented below after brief discussions of the life-cycle stage breakdowns for each inventory type. For the complete list of primary materials in the CRT inventory, the total mass, and the mass contribution of each life-cycle stage, see Appendix J-1, Table J-1.

CRT Ancillary Inputs

Observing Figure 2-12, the mass of ancillary CRT inputs in the EOL life-cycle stage was greatest (11 kg/functional unit). The upstream stages had the lowest mass of ancillary inputs compared to the other life-cycle stages. To better understand the materials contributing to those totals, Table 2-27 shows that clay is the greatest contributor by mass at 41% of the total CRT ancillary inputs. Clay is used predominately during EOL incineration and landfilling. See Table J-2 in Appendix J for the complete list of ancillary materials in the CRT inventory.

Table 2-26. Top 99% of CRT primary materials inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% of total
Petroleum (in ground)	1.32E+00	3.72E+02	3.80E+00	-1.52E+00	3.75E+02	54.17%
Coal, average (in ground)	3.57E+00	5.15E+00	1.79E+02	1.79E-02	1.88E+02	27.15%
Assembled CRT monitor	0	0	2.20E+01	0	2.20E+01	3.38%
Natural gas	0	1.47E+00	1.40E+01	-8.88E-02	1.54E+01	2.36%
Cathode ray tube (CRT)	0	1.07E+01	0	0	1.07E+01	1.64%
CRT glass, unspecified	0	9.76E+00	0	0	9.76E+00	1.50%
Iron (Fe, ore)	6.90E+00	0	0	0	6.90E+00	1.06%
Steel	2.48E-06	5.16E+00	0	0	5.16E+00	0.79%
Natural gas (in ground)	8.41E-01	3.27E+00	0	-1.64E+00	2.47E+00	0.38%
Sand	0	2.40E+00	0	0	2.40E+00	0.37%
Recycled CRT Glass	0	2.06E+00	0	0	2.06E+00	0.32%
Bauxite (Al2O3, ore)	1.37E+00	0	0	0	1.37E+00	0.21%
Iron scrap	9.46E-01	0	0	0	9.46E-01	0.14%
Polycarbonate resin	0	9.23E-01	0	0	9.23E-01	0.14%
PWB-laminate	0	8.47E-01	0	0	8.47E-01	0.13%
Printed wiring board (PWB)	0	8.47E-01	0	0	8.47E-01	0.13%
Styrene-butadiene copolymers	0	8.27E-01	0	0	8.27E-01	0.13%
PPE	0	7.35E-01	0	0	7.35E-01	0.11%

See Appendix J for complete inventory table.

Table 2-27. Top 99% of CRT ancillary materials inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% of total
Clay (in ground)	4.49e-03	0	0	8.19e+00	8.19e+00	41.35%
Sand (in ground)	5.85e-02	2.74e-02	0	2.71e+00	2.80e+00	14.13%
Limestone	0	6.91e-02	2.41e+00	2.41e-04	2.48e+00	12.51%
Limestone (CaCO3, in ground)	8.60e-01	1.08e+00	0	-2.39e-01	1.70e+00	8.58%
Lime	0	3.04e-02	1.06e+00	1.06e-04	1.09e+00	5.49%
Sodium chloride (NaCl, in ground or in sea)	7.61e-01	1.26e-02	0	-3.07e-05	7.73e-01	3.90%
Sulfuric acid	0	2.38e-01	0	0	2.38e-01	1.20%
Hydrochloric acid	0	2.36e-01	0	0	2.36e-01	1.19%
Sodium hydroxide	0	1.98e-01	0	0	1.98e-01	1.00%
Pyrite (FeS2, ore)	1.94e-01	0	0	0	1.94e-01	0.98%
Nitric acid	0	1.44e-01	0	0	1.44e-01	0.73%
Ferric chloride	0	1.37e-01	0	0	1.37e-01	0.69%
Calcium Chloride	0	1.27e-01	0	0	1.27e-01	0.64%
Calcium hydroxide	0	9.54e-02	0	0	9.54e-02	0.48%
Hydrofluoric acid	0	8.65e-02	0	0	8.65e-02	0.44%
Hydrogen peroxide	0	8.45e-02	0	0	8.45e-02	0.43%
Ammonium hydroxide	0	7.90e-02	0	0	7.90e-02	0.40%
Pumice	0	7.86e-02	0	0	7.86e-02	0.40%
Ammonium chloride	0	7.76e-02	0	0	7.76e-02	0.39%

Table 2-27. Top 99% of CRT ancillary materials inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% of total
Alkali cleaning agent	0	7.72e-02	0	0	7.72e-02	0.39%
Iron (Fe, ore)	7.23e-02	0	0	3.41e-03	7.57e-02	0.38%
Potassium peroxymonosulfate	0	7.06e-02	0	0	7.06e-02	0.36%
Sulfuric acid, aluminum salt	0	6.75e-02	0	0	6.75e-02	0.34%
Alkali soda (to neutralize acid waste water)	0	5.45e-02	0	0	5.45e-02	0.28%
Polyethylene glycol	0	5.04e-02	0	0	5.04e-02	0.25%
Bauxite (Al2O3, ore)	1.10e-03	4.47e-02	0	-1.14e-04	4.57e-02	0.23%
Nitrogen	0	4.57e-02	0	0	4.57e-02	0.23%
PWB-solder mask solids	0	4.37e-02	0	0	4.37e-02	0.22%
Potassium hydroxide	0	4.27e-02	0	0	4.27e-02	0.22%
Lubricant (unspecified)	4.11e-02	0	0	0	4.11e-02	0.21%
Chlorine	0	4.03e-02	0	0	4.03e-02	0.20%
Zinc (Zn, ore)	3.79e-02	0	0	0	3.79e-02	0.19%
Aluminum Oxide	0	3.37e-02	0	0	3.37e-02	0.17%
Oil (in ground)	0	0	0	3.35e-02	3.35e-02	0.17%
Sodium Carbonate	0	3.22e-02	0	0	3.22e-02	0.16%
Tin (Sn, ore)	2.43e-02	0	0	0	2.43e-02	0.12%

See Appendix J for complete inventory table.

CRT Utility Inputs

Utility inputs in the CRT life-cycle are presented in the inventory in Table 2-28 and include fuel (kg/functional unit), electricity (MJ/functional unit), and water (kg or L/functional unit) inputs. Figures 2-13, 2-14, and 2-15 show the total fuels, water, and electricity inputs, respectively. The fuel and electricity inputs have also been combined into a total energy input category, shown in Figure 2-16. This is also considered one of the impact categories of the LCIA that will be presented in Chapter 3. Therefore, more details on how it is calculated are available in Chapter 3. Briefly, the mass of the fuels are converted to units of energy and added to the electrical energy quantities (in units of MJ).

Table 2-28. CRT utility inputs

Material	Upstream	Mfg	Use	EOL	Total	% of total
Fuels (kg/functional unit):						
LPG	0	3.51E+02	0	3.03E-03	3.51E+02	81.10%
Natural gas (in ground)	2.76E+00	4.56E+01	0	-2.09E-01	4.82E+01	11.14%
Coal, average (in ground)	2.25E+00	1.36E+01	0	-1.16E-02	1.58E+01	3.66%
Petroleum (in ground)	2.02E+00	9.71E+00	0	-5.77E-02	1.17E+01	2.70%
Fuel oil #6	0	3.68E+00	0	0	3.68E+00	0.85%
Fuel Oil #2	0	1.16E+00	0	0	1.16E+00	0.27%
Natural gas	0	2.44E+00	0	-1.30E+00	1.14E+00	0.26%
Coal, lignite (in ground)	9.73E-01	0	0	0	9.73E-01	0.22%
LNG	0	3.35E-01	0	0	3.35E-01	0.08%
Uranium (U, ore)	1.21E-04	2.29E-04	0	-1.99E-07	3.49E-04	<0.01%
Fuel oil #4	0	1.37E-01	0	-1.38E+00	-1.24E+00	-0.29%
Total fuels	8.00E+00	4.28E+02	0	-2.95E+00	4.33E+02	100.00%
Electricity (MJ/functional unit):						
Electricity	7.32E+01	1.29E+02	2.29E+03	2.29E-01	2.49E+03	
Water (kg or L/functional unit):						
Water	5.54E+02	1.14E+04	1.14E+03	-2.73E+01	1.31E+04	
Total energy (fuels and electricity, MJ/functional unit):						
Energy	3.66E+02	1.83E+04	2.29E+03	-1.28E+02	2.08E+04	

Table 2-28 shows that LPG used in the manufacturing stage dominates the fuel inputs. LPG from the manufacturing stage is equal to about 81% of all the fuel inputs in the CRT life-cycle. More detail into the process-specific contributions within the manufacturing stage will be presented below at the end of this section. Electricity inputs, however, are dominated by the use stage (~92% of all electricity throughout the CRT life-cycle). When fuel energy and electrical energy are combined into a total energy input value, the overall energy from manufacturing greatly exceeds that from the use stage (18,300 MJ/functional unit versus 2,290 MJ/functional unit). This is depicted in Figure 2-16.

The other utility listed in Table 2-28 is water. Nearly 87% of the water inputs in the CRT life-cycle are from the manufacturing processes; and nearly 80% are from LPG production alone. The life-cycle stage contributing the next most is the use stage at 8.7%. This is from the water used to generate electricity used during the use stage. The upstream stages only contribute about 4% to the total water inputs for the CRT life-cycle. Table J-3 in Appendix J provides the complete list of inventory items for the CRT.

CRT Air Outputs

Air emissions from the CRT life cycle are dominated from the use stage as seen in Figure 2-17. This indicates that most air emissions by mass are from the generation of electricity used by consumers of the monitors. Nearly 68% of the total life-cycle air emissions by mass (or 450 kg/functional unit) are from the use stage. Carbon dioxide (CO_2) alone constitutes 445 kg/functional unit (or about 66% of all air emissions by mass in the life-cycle and nearly 99% of the use stage air emissions). Table 2-29 reveals the individual contribution of CO_2 and other inventory items that contribute to the top 99.99% of air emissions. (See Appendix J for complete inventory table.) These are organized from the air emissions that are the largest contributors to those that are the smaller contributors. Table J-4 in Appendix J shows the contribution of every air emission in the inventory, organized alphabetically. The next largest air emissions, by life-cycle stage, are emitted during the manufacturing stage, which contribute about 28% to the total life-cycle air emissions. Almost 85% of that is air emissions from the LPG production process. All the air emissions in the CRT inventory are designated as direct emissions to the ambient environment.[5]

Table 2-29. Top 99.99% of CRT air pollutant emissions (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% of total
Carbon dioxide	2.92e+01	1.79e+02	4.45e+02	2.59e+00	6.55e+02	98.68%
Sulfur dioxide	3.37e-01	1.26e-01	2.49e+00	8.30e-04	2.96e+00	0.45%
Nitrogen oxides	6.99e-03	6.95e-01	1.18e+00	-1.90e-02	1.86e+00	0.28%
Methane	6.40e-02	9.08e-01	6.45e-01	-4.30e-02	1.57e+00	0.24%
Sulfur oxides	5.71e-03	8.20e-01	0	-2.97e-02	7.96e-01	0.12%
Carbon monoxide	4.18e-02	4.58e-01	8.09e-02	-4.17e-03	5.76e-01	0.09%
PM	1.28e-01	1.31e-01	0	-1.88e-02	2.40e-01	0.04%
Nonmethane hydrocarbons, remaining unspeciated	9.97e-02	1.10e-01	0	-1.91e-03	2.08e-01	0.03%
Hydrocarbons, remaining unspeciated	1.28e-02	1.58e-01	0	-6.12e-04	1.70e-01	0.03%
Hydrochloric acid	2.39e-03	1.12e-02	1.08e-01	-1.04e-03	1.20e-01	0.02%
Other organics	5.60e-04	7.83e-02	0	-3.65e-03	7.52e-02	0.01%
PM-10	0	3.15e-03	5.78e-02	4.78e-06	6.09e-02	0.01%
Nitrogen dioxide	5.76e-02	0	0	1.85e-03	5.95e-02	0.01%

CRT Water Outputs

The volume (or mass) of wastewater released throughout the CRT life-cycle is approximately 1,520 L (kg) per functional unit. Approximately 6% of that is sent to treatment as opposed to direct discharge to surface water (Figure 2-18). The mass of chemical pollutants within the wastewater streams was calculated separately. The total mass of these water pollutants released, presented by life-cycle stage, is shown in Figure 2-19. The manufacturing life-cycle stage contributes the greatest mass of water pollutants with approximately 20 kg per functional unit. This is about 96% of all the water pollutants for the entire life-cycle. The upstream stages have the second greatest mass of water pollutants at nearly 1 kg/functional unit (just under 4%). The use and EOL stages are small contributors, with the EOL being negative due to recovery processes within the EOL stage. Table 2-30 shows the major contributors to the

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[5] Note that some companies may not have reported inventory items associated with all output dispositions, as only some dispositions are used for impact calculations. For example, outputs that are treated or recycled and not directly released to the environment are not used in calculating impacts and may not have been reported. This could be applicable to all output inventories.

water pollutant quantities, and reveals that sodium ion, chloride ions and dissolved solids contribute nearly 85% of all the water pollutants to the entire life-cycle. Greater than 95% of the sodium ion outputs are from LPG production and greater than 78% of the chloride ions are from LPG production. As with other input/output types, LPG production used in glass manufacturing has a large impact on the CRT inventory. For the complete inventory, listing water pollutants alphabetically and subtotaled for each life-cycle stage, see Appendix J, Table J-5. Further details on the manufacturing stage will be provided later.

Table 2-30. Top 99.9% of CRT water pollutant outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg.	Use	EOL	Total	% of total
Sodium (+1)	surface water	2.90e-01	7.04e+00	0	-3.08e-02	7.30e+00	34.94%
Chloride ions	surface water	4.29e-01	6.48e+00	0	-2.39e-02	6.88e+00	32.95%
Dissolved solids	surface water	5.30e-03	3.62e+00	0	-8.77e-05	3.62e+00	17.36%
COD	surface water	1.00e-02	1.60e+00	0	-3.94e-03	1.61e+00	7.71%
Suspended solids	surface water	7.72e-03	8.69e-01	0	-2.11e-03	8.74e-01	4.19%
BOD	surface water	3.93e-04	1.95e-01	0	-4.65e-04	1.95e-01	0.93%
Waste oil	surface water	3.65e-03	1.01e-01	0	-3.13e-04	1.04e-01	0.50%
Dissolved solids	treatment	0	8.01e-02	0	0	8.01e-02	0.38%
Sulfate ion (-4)	treatment	0	1.09e-03	6.84e-02	6.84e-06	6.95e-02	0.33%
Sulfate ion (-4)	surface water	3.75e-02	9.61e-04	0	-1.85e-06	3.84e-02	0.18%
Ammonia ions	surface water	3.54e-06	2.76e-02	0	-6.63e-05	2.75e-02	0.13%
Metals, remaining unspeciated	surface water	6.74e-04	9.75e-03	0	-3.42e-05	1.04e-02	0.05%
COD	treatment	0	8.33e-03	0	0	8.33e-03	0.04%
Oil & grease	surface water	0	7.46e-03	0	0	7.46e-03	0.04%
Nitrogen	surface water	4.46e-05	7.18e-03	0	0	7.23e-03	0.03%
Calcium (+2)	surface water	4.96e-03	0	0	0	4.96e-03	0.02%
Carbonate ion	surface water	4.83e-03	0	0	0	4.83e-03	0.02%
Phenol	surface water	6.25e-05	3.63e-03	0	-9.41e-06	3.68e-03	0.02%
Fluoride	surface water	1.89e-05	3.45e-03	0	0	3.47e-03	0.02%
Salts (unspecified)	surface water	1.71e-03	1.62e-03	0	-4.21e-06	3.33e-03	0.02%
Suspended solids	treatment	0	1.29e-03	1.78e-03	1.78e-07	3.07e-03	0.01%
Fluorides (F-)	surface water	9.63e-05	2.97e-03	0	-7.72e-06	3.06e-03	0.01%

CRT Hazardous Waste Outputs

The total mass of hazardous waste generated throughout the life-cycle of the CRT (Figure 2-20) is mostly from the amount of the monitor that is assumed to be placed in a hazardous waste landfill (Table 2-31). This 7.2 kg is based on the proportion of monitors assumed to be hazardous waste as determined in Section 2.5 (EOL) and is approximately 87% of the hazardous waste generated in the EOL stage. Compared to the total mass of hazardous wastes produced throughout the CRT life-cycle, the EOL stage contributes about 88%. The disposition of the waste will be used to determine how impacts are calculated in Chapter 3. Figure 2-20 shows what portion of hazardous wastes are reported as being landfilled, recycled/reused, or treated. The amount of hazardous waste from the upstream and manufacturing stages are negligible, by comparison. Table 2-31 and Table J-6 in Appendix J list the hazardous wastes and where each hazardous waste is disposed.

Table 2-31. Top 99.9% of CRT hazardous waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of total
EOL CRT monitor, landfilled	landfill	0	0	0	7.20E+00	7.20E+00	76.1%
Hazardous waste	landfill	3.85E-04	6.15E-01	0	-1.50E-03	6.14E-01	6.49%
CRT glass, cullet	R/R	0	0	0	4.84E-01	4.84E-01	5.12%
CRT glass, funnel	R/R	0	0	0	2.29E-01	2.29E-01	2.42%
Transformer	R/R	0	0	0	2.28E-01	2.28E-01	2.41%
PWB-waste cupric etchant	R/R	0	2.25E-01	0	0	2.25E-01	2.38%
Printed wiring board (PWB)	R/R	0	0	0	1.46E-01	1.46E-01	1.54%
General hazardous waste	treatment	0	1.24E-01	0	0	1.24E-01	1.31%
PWB-solder dross	R/R	0	6.70E-02	0	0	6.70E-02	0.71%
General hazardous waste	landfill	4.85E-02	0	0	-9.61E-05	4.84E-02	0.51%
PWB-decontaminating debris	treatment	0	1.55E-02	0	0	1.55E-02	0.16%
PWB-route dust	R/R	0	1.20E-02	0	0	1.20E-02	0.13%
PWB-lead contaminated waste oil	treatment	0	1.16E-02	0	0	1.16E-02	0.12%
Chrome liquid waste (D007 waste)	R/R	0	9.80E-03	0	0	9.80E-03	0.10%
Cinders from CRT glass mfg (70% PbO)	landfill	0	8.26E-03	0	0	8.26E-03	0.09%
Unspecified sludge	R/R	0	5.56E-03	0	0	5.56E-03	0.06%
Unspecified sludge	landfill	0	5.22E-03	0	0	5.22E-03	0.06%
CRT glass funnel EP dust (Pb) (D008 waste)	R/R	0	5.01E-03	0	0	5.01E-03	0.05%
Waste acid (mostly 3% HCl solution)	R/R	0	3.93E-03	0	0	3.93E-03	0.04%
Frit	landfill	0	2.99E-03	0	0	2.99E-03	0.03%
Slag and ash	landfill	0	2.47E-03	0	0	2.47E-03	0.03%
Broken CRT glass	landfill	0	1.88E-03	0	0	1.88E-03	0.02%
Hydrofluoric acid	landfill	0	1.78E-03	0	0	1.78E-03	0.02%

R/R: recycling/reuse.
See Appendix J for complete inventory table.

CRT Solid Waste Outputs

Figure 2-21 shows that both the manufacturing and use stages contribute significant amounts of solid waste by mass to the CRT life-cycle. The majority of the solid waste is landfilled. In terms of mass, the greatest contributor to the solid waste outputs for the CRT life-cycle is coal waste that is a result of generating electricity (Table 2-32). Therefore, coal waste is predominately in the use stage, which uses the most electricity, but also in the manufacturing stage, and to a much lesser degree in the EOL stage. Note that the electricity generation processes that support the secondary data used were derived from a different source (i.e., *Ecobilan*) and do not include coal waste as an output; however, the equally large amount of solid waste generated from those processes is listed as "slag and ash" in the upstream and manufacturing inventories. Overall, the top 80% of solid waste generated in the CRT life-cycle is from coal waste, slag and ash, dust/sludge, and fly/bottom ash. Note that different inventories used in this project have varying nomenclature and some of these solid wastes may indeed overlap. Note also that the mass of a CRT monitor that is assumed to be landfilled at the EOL (3.9 kg/functional unit) is only approximately 2% of the total mass of solid waste in the CRT life-cycle. See Appendix J, Table J-7 for the complete CRT solid waste inventory.

Table 2-32. Top 99% of CRT solid waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of total
Coal waste	landfill	0	1.46E+00	5.09E+01	5.09E-03	5.23E+01	30.37%
Slag and ash	landfill	9.65E-02	6.66E+01	0	-1.49E+01	5.18E+01	30.06%
Dust/sludge	landfill	0	5.64E-01	1.97E+01	1.97E-03	2.02E+01	11.75%
Fly/bottom ash	landfill	0	3.65E-01	1.27E+01	1.27E-03	1.31E+01	7.59%
Unspecified solid waste	landfill	4.94E+00	0	0	-7.86E-01	4.15E+00	2.41%
EOL CRT Monitor, landfilled	landfill	0	0	0	3.91E+00	3.91E+00	2.27%
Unspecified solid waste	treatment	0	3.66E+00	0	0	3.66E+00	2.12%
Unspecified solid waste	recycle/reuse	3.07E+00	4.33E-01	0	0	3.50E+00	2.03%
Unspecified waste	landfill	0	3.38E+00	0	-1.49E-02	3.36E+00	1.95%
EOL CRT Monitor, incinerated	treatment	0	0	0	3.31E+00	3.31E+00	1.92%
Iron scrap	recycle/reuse	3.43E-01	0	0	2.50E+00	2.85E+00	1.65%
EOL CRT Monitor, recycled	recycle/reuse	0	0	0	2.42E+00	2.42E+00	1.40%
Broken CRT glass	recycle/reuse	0	1.08E+00	0	0	1.08E+00	0.62%
Mixed industrial (waste)	landfill	4.87E-02	1.00E+00	0	-5.12E-04	1.05E+00	0.61%
Slag and ash	recycle/reuse	0	6.85E-01	0	-3.01E-03	6.82E-01	0.40%
EOL CRT Monitor, remanufactured	recycle/reuse	0	0	0	6.60E-01	6.60E-01	0.38%
Mining waste	landfill	4.48E-01	0	0	-1.90E-06	4.48E-01	0.26%
Mineral waste	landfill	4.42E-01	2.61E-03	0	-6.76E-06	4.44E-01	0.26%
Carbon Steel Scrap	recycle/reuse	0	0	0	4.10E-01	4.10E-01	0.24%
flame retardant high-impact polystyrene (HIPS)	recycle/reuse	0	0	0	4.03E-01	4.03E-01	0.23%
Waste water treatment (WWT) sludge	recycle/reuse	0	3.72E-01	0	0	3.72E-01	0.22%
Ferric chloride	recycle/reuse	0	3.69E-01	0	0	3.69E-01	0.21%
CRT glass, faceplate	recycle/reuse	0	0	0	3.54E-01	3.54E-01	0.21%

CRT Radioactive Waste Outputs

Radioactive waste outputs in the CRT inventory are found only in the electricity generation and cold-rolled steel production process. Therefore, radioactive wastes will be found wherever electricity is used in a process in the CRT life-cycle. Only very small amounts (approximately 0.003 kg/functional unit) of radioactive waste are generated over the entire life-cycle of the CRT (Figure 2-22 and Table 2-33). As expected, the majority of this is linked to the use stage, where most electricity is used in the CRT life-cycle. Low-level radioactive waste (79%) and depleted uranium (20%) are most of the waste, with very small amounts of highly radioactive waste and some unspecified radioactive waste in the inventory. The inventory of radioactive waste outputs is small, and therefore, Table 2-33 lists all material outputs associated with radioactive waste, in descending order of quantity. Table J-8 in Appendix J lists these in alphabetical order.

Table 2-33. CRT radioactive waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of total
Low-level radioactive waste	landfill	4.11E-04	1.38E-04	1.76E-03	1.76E-07	2.31E-03	79.5%
Uranium, depleted	landfill	0	4.15E-05	5.27E-04	5.27E-08	5.69E-04	19.6%
Radioactive waste (unspecified)	landfill	1.88E-05	0	0	0	1.88E-05	0.6%
Highly radioactive waste (Class C)	landfill	8.65E-06	0	0	0	8.65E-06	0.3%
Total radioactive wastes		4.39E-04	1.80E-04	2.28E-03	2.29E-07	2.90E-03	100.0%

CRT Radioactivity Outputs

Radioactivity is also inventoried in this project as isotopes that are released to the environment. Radioactivity is measured in Bequerels and may be released to air, water, or land. The quantity of radioactivity for each life-cycle stage and different dispositions is presented in Figure 2-23. Table 2-34 shows the top 99.9% of the radioactivity outputs.

Table 2-34. Top 99.9% of CRT radioactivity outputs (Bq/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of total
Molybdenum-99 (isotope)	treatment	0	3.72e+06	4.73e+07	4.73e+03	5.10e+07	56.75%
Plutonium-241 (isotope)	landfill	3.74e+07	0	0	0	3.74e+07	41.67%
Xenon-133 (isotope)	air	2.43e+03	6.28e+03	3.12e+05	3.12e+01	3.21e+05	0.36%
Tritium-3 (isotope)	treatment	0	2.20e+04	2.80e+05	2.80e+01	3.02e+05	0.34%
Plutonium-240 (isotope)	landfill	1.62e+05	0	0	0	1.62e+05	0.18%
Cesium-135 (isotope)	landfill	1.46e+05	0	0	0	1.46e+05	0.16%
Radon-222 (isotope)	air	1.37e+05	0	0	0	1.37e+05	0.15%
Plutonium-239 (isotope)	landfill	1.14e+05	0	0	0	1.14e+05	0.13%
Xenon-133 (isotope)	treatment	0	3.48e+03	4.43e+04	4.43e+00	4.78e+04	0.05%
Tritium-3 (isotope)	air	3.47e+02	2.95e+03	3.74e+04	3.75e+00	4.07e+04	0.05%
Xenon-133M (isotope)	air	0	1.99e+04	2.07e+04	2.07e+00	4.06e+04	0.05%
Krypton-85 (isotope)	air	1.73e+02	2.08e+03	2.65e+04	2.65e+00	2.87e+04	0.03%

See Appendix J for complete inventory table.

Radioactivity outputs are related to the generation of electricity and therefore the greatest quantity of radioactivity is from the use stage, as expected. Table J-9 in Appendix J lists the complete inventory.

CRT Manufacturing Stage

The inventory tables that show the specific materials (i.e., those in Appendix J and Tables 2-26 through 2-34) are the sums of the materials from one or more processes within a life-cycle stage. To burrow down deeper into the data, the manufacturing stage inventory data are broken down by process or group of processes. Groups of processes were combined when fewer than three companies provided data for a process or when confidentiality agreements precluded presenting individual process data. The manufacturing process groups are presented in Table

2-35. Also for confidentiality purposes, upstream and EOL data (derived from *Ecobilan's* data) were not broken down by process. Burrowing further into the contributing processes or process groups is necessary for future manufacturing improvement assessments. Burrowing further into process-specific data at the use stage is not necessary because electricity generation is the only process in the use stage.

Table 2-35. CRT process groups

Process group	Process(es) included
Monitor assembly	monitor assembly
Tube	CRT (tube) manufacturing
Glass/frit	CRT glass manufacturing, frit manufacturing
PWB	PWB manufacturing
Japanese grid	electricity generation - Japanese electric grid
U.S. grid	electricity generation - U.S. electric grid
Fuels	production of fuel oils #2, #4 and #6, LPG, and natural gas

Tables 2-36 through 2-44 list the specific inventories for each process group in the manufacturing stage for each input and output type. Figures 2-24 through 2-34 graph the total inventories for each process group for each input and output type. It should be noted that the input/output type that had the greatest contribution in the manufacturing stage compared to other stages was fuel inputs, which also translated into total energy inputs being greatest in the manufacturing stage. Nonetheless, for purposes of showing more detail in the manufacturing stage and allowing for improvement assessments for manufacturers, the individual material contributions for each manufacturing process group are presented below.

Of the total 421 kg of primary materials per functional unit in the manufacturing stage, fuels production contributes the greatest (374 kg/functional unit), followed by monitor assembly (20.1 kg/functional unit), and then tube manufacturing (11.9 kg/functional unit) (Figure 2-24). The specific material contributions are presented in Table 2-36. Only small amounts of ancillary materials are used in the CRT life cycle and the manufacturing stage only contributed a small percentage of the overall ancillary materials in the life-cycle. However, within the manufacturing life-cycle stage, fuels production and PWB manufacturing had the greatest amount of ancillary materials (1.16 kg/functional unit each) (Figure 2-25).

Table 2-36. CRT manufacturing stage primary material inputs

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
Monitor assembly			
ABS resin	4.24e-01	2.11%	
Aluminum (elemental)	3.60e-01	1.79%	
Audio cable assembly	9.45e-02	0.47%	
Cables/wires	6.12e-02	0.31%	
Cables/wires	3.33e-01	1.66%	
Cathode ray tube (CRT)	1.07e+01	53.30%	
Connector	5.67e-02	0.28%	
CRT magnet assembly	7.56e-02	0.38%	
CRT shield assembly - ASTM A366/CC#2	2.42e-01	1.21%	
Deflection Yoke assembly	1.51e-01	0.75%	
Demagnetic coil - PU coated paper	1.26e-01	0.63%	
Ferrite	1.70e-01	0.85%	
Phosphate ester	8.31e-03	0.04%	
Polycarbonate resin	9.23e-01	4.60%	
Polystyrene (PS, high impact)	1.51e-01	0.75%	
Power cord assembly	1.13e-01	0.57%	
PPE	7.35e-01	3.66%	
Printed wiring board (PWB)	8.47e-01	4.22%	
Solder, unspecified	2.67e-02	0.13%	
Steel	3.45e+00	17.21%	
Styrene-butadiene copolymers	8.27e-01	4.13%	
Tricresyl phosphate	2.30e-02	0.11%	
Triphenyl phosphate	5.29e-02	0.26%	
Video cable assembly	1.13e-01	0.57%	
Total	**2.01e+01**	100.00%	**4.76%**
Tube			
Amyl acetate (mixed isomers)	1.20e-03	0.01%	
Aquadag	2.06e-02	0.17%	
Blue Phosphor (ZnS)	3.84e-03	0.03%	
Blue Phosphor (ZnS.Ag.Al)	1.67e-03	0.01%	
CRT glass, unspecified	9.76e+00	81.70%	
Electron gun	1.01e-01	0.84%	
Frit	6.67e-02	0.56%	
Green Phosphor (ZnS)	3.34e-03	0.03%	
Green Phosphor (ZnS.Cu.Al)	1.34e-03	0.01%	
Nickel Alloy (invar)	2.72e-01	2.28%	
Red Phosphor (Y2O2S)	4.65e-03	0.04%	
Red Phosphor (Y2O2S.Eu)	1.33e-03	0.01%	
Steel	1.71e+00	14.30%	
Total	**1.19e+01**	100.00%	**2.84%**

Table 2-36. CRT manufacturing stage primary material inputs

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
Glass/frit			
Barium Carbonate	2.97e-01	4.52%	
Glass, unspecified	4.91e-02	0.75%	
Lead	4.47e-01	6.82%	
Potassium Carbonate	3.78e-01	5.76%	
Recycled CRT Glass	2.06e+00	31.37%	
Sand	2.40e+00	36.57%	
Sodium Carbonate	4.88e-01	7.43%	
Strontium Carbonate	3.31e-01	5.05%	
Zircon Sand	5.43e-02	0.83%	
Borax	8.00e-03	0.12%	
Lead	4.67e-02	0.71%	
Silica	5.33e-03	0.08%	
Total	**6.56e+00**	100.00%	**1.56%**
PWB			
PWB-laminate	8.47e-01	94.35%	
Solder (63% tin; 37% lead)	5.08e-02	5.66%	
Total	**8.98e-01**	100.00%	**0.21%**
Japanese grid			
Coal, average (in ground)	2.28e+00	47.41%	
Natural gas	1.25e+00	25.89%	
Petroleum (in ground)	1.29e+00	26.69%	
Uranium, yellowcake	3.04e-04	0.01%	
Total	**4.82e+00**	100.00%	**1.14%**
U.S. grid			
Coal, average (in ground)	2.86e+00	90.97%	
Natural gas	2.23e-01	7.10%	
Petroleum (in ground)	6.07e-02	1.93%	
Uranium, yellowcake	7.74e-05	<0.01%	
Total	**3.15e+00**	100.01%	**0.75%**
Fuels			
Petroleum (in ground)	3.70e+02	99.12%	
Natural gas (in ground)	3.27e+00	0.88%	
Total	**3.74e+02**	100.00%	**88.74%**
Grand Total	**4.21e+02**		**100.00%**

Table 2-37. CRT manufacturing stage ancillary material inputs

Material	**Quantity (kg/ (functional unit)**	**% of process group total**	**% of grand total**
Process group			
Monitor assembly			
2,2,4-trimethylpentane	1.50e-04	0.72%	
Cyclohexane	1.88e-04	0.90%	
Fluorocarbon resin	3.75e-05	0.18%	
Isopropyl alcohol	1.94e-02	93.40%	
Surfactant, unspecified	1.42e-04	0.68%	
Synthetic resin, unspecified	8.53e-04	4.10%	
Total	**2.08e-02**	**4.79%**	**0.59%**
Tube			
Acetone	3.17e-04	0.04%	
Acrylic Polymer, unspecified	9.13e-03	1.02%	
Alkali cleaning agent	7.72e-02	8.61%	
Alkali soda (to neutralize acid waste water)	5.45e-02	6.08%	
Ammonia	1.19e-04	0.01%	
Ammonium bifluoride	2.04e-03	0.23%	
Ammonium Dichromate	3.50e-05	<0.01%	
Ammonium fluoride	8.91e-04	0.10%	
Ammonium hydroxide	1.41e-03	0.16%	
Ammonium Oxalate	8.92e-05	0.01%	
Ammonium Oxalate Monohydrate	3.16e-04	0.04%	
Boric acid	4.73e-03	0.53%	
Calcium Chloride	1.27e-01	14.18%	
Calcium hydroxide	9.54e-02	10.64%	
Chlorine	4.03e-02	4.50%	
Chromium (VI)	7.63e-05	0.01%	
Dimethyl Formamide	4.36e-05	<0.01%	
Ferric chloride	1.37e-01	15.32%	
HV Carbon (paste)	1.14e-05	<0.01%	
Hydrochloric acid	4.39e-02	4.89%	
Hydrofluoric acid	7.39e-03	0.82%	
Hydrogen peroxide	5.34e-02	5.96%	
Isopentylacetate	1.74e-03	0.19%	
Muratic Acid (drum)	1.87e-03	0.21%	
Nitric acid	8.17e-03	0.91%	
Nitrogen	4.57e-02	5.10%	
Oxalic acid	5.35e-05	0.01%	
Oxygen (Liquid)	7.57e-03	0.84%	
Periodic Acid	2.26e-04	0.03%	
Polyvinyl alcohol	8.11e-03	0.90%	
Polyvinyl Pyrrolidone (PVP)	2.41e-02	2.69%	
Sodium Dichromate	1.05e-04	0.01%	
Sodium Dichromate Dihydrate (VI)	3.10e-05	<0.01%	

Table 2-37. CRT manufacturing stage ancillary material inputs

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
Sodium hydroxide	3.52e-03	0.39%	
Sodium Hypochlorite	9.25e-05	0.01%	
Sodium Metabisulfite	4.67e-03	0.52%	
Sodium Persulfate	3.54e-04	0.04%	
Sulfuric acid	5.58e-02	6.23%	
Sulfuric acid, aluminum salt	6.75e-02	7.53%	
Toluene	4.80e-03	0.54%	
unspecified CRT process material	5.77e-03	0.64%	
Xylene (mixed isomers)	4.80e-04	0.05%	
Total	**8.97e-01**	**100.00%**	**25.36%**
Glass/frit			
Aluminum Oxide	3.37e-02	17.30%	
Cerium Oxide	3.28e-03	1.68%	
Chromium Oxide	5.62e-05	0.03%	
Hydrofluoric acid	7.91e-02	40.61%	
Pumice	7.86e-02	40.37%	
Total	**1.95e-01**	**100.00%**	**5.51%**
PWB			
Ammonium chloride	7.76e-02	6.68%	
Ammonium hydroxide	7.76e-02	6.68%	
Formaldehyde	6.60e-03	0.57%	
Glycol ethers	2.35e-02	2.03%	
Hydrochloric acid	1.92e-01	16.51%	
Hydrogen peroxide	3.10e-02	2.67%	
Nitric acid	1.36e-01	11.70%	
Polyethylene glycol	5.04e-02	4.34%	
Potassium hydroxide	4.27e-02	3.68%	
Potassium permanganate	1.16e-03	0.10%	
Potassium peroxymonosulfate	7.06e-02	6.08%	
PWB-solder mask solids	4.37e-02	3.76%	
Sodium Carbonate	3.22e-02	2.77%	
Sodium hydroxide	1.94e-01	16.71%	
Sulfuric acid	1.83e-01	15.72%	
Total	**1.16e+00**	**100.00%**	**32.84%**
Japanese grid			
Lime	1.35e-02	30.57%	
Limestone	3.06e-02	69.43%	
Total	**4.41e-02**	100.00%	**1.25%**
U.S. grid			
Lime	1.69e-02	30.52%	
Limestone	3.85e-02	69.48%	

Table 2-37. CRT manufacturing stage ancillary material inputs

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
Total	**5.53e-02**	100.00%	**1.57%**
Fuels			
Bauxite (Al2O3, ore)	4.47e-02	3.85%	
Limestone (CaCO3, in ground)	1.08e+00	92.71%	
Sand (in ground)	2.74e-02	2.36%	
Sodium chloride (NaCl, in ground or in sea)	1.26e-02	1.08%	
Total	**1.16e+00**	100.00%	**32.89%**
Grand Total	**3.54e+00**		**100.00%**

Table 2-38. CRT manufacturing stage utility inputs

Material	Quantity	% of process group total	% of grand total
Process group			
Fuels (kg/functional unit):			
Monitor assembly			
Fuel oil #4	**??**		**ERR**
Tube			
Fuel oil #6	3.68e+00	75.86%	
LNG	3.35e-01	6.91%	
Natural gas	8.37e-01	17.23%	
Total	**4.86e+00**	100.00%	**1.14%**
Glass/frit			
Fuel oil #2	1.16e+00	0.33%	
Liquified petroleum gas (LPG)	3.51e+02	99.33%	
Natural gas	1.21e+00	0.34%	
Total	**3.53e+02**	100.00%	**82.72%**
PWB			
Natural gas	**??**		**ERR**
Fuels			
Coal, average (in ground)	1.36e+01	19.71%	
Natural gas (in ground)	4.56e+01	66.20%	
Petroleum (in ground)	9.71e+00	14.08%	
Uranium (U, ore)	2.29e-04	<0.01%	
Total	**6.89e+01**	100.01%	**16.14%**
Grand Total	**4.27e+02**		**100.00%**
Electricity (MJ/functional unit):			
Monitor assembly	1.33e+01		10.27%
Tube	3.19e+01		24.68%
Glass/frit	7.40e+01		57.27%
PWB	1.00e+01		7.77%
Total	**1.29e+02**		**100.00%**
Water (kg or L/functional unit):			
Monitor assembly	3.51e+01		0.31%
Tube	8.11e+02		7.09%
Glass/frit	0		0.00%
PWB	4.22e+01		0.37%
Japanese grid	4.43e+01		0.39%
U.S. grid	1.82e+01		0.16%
Fuels	1.05e+04		91.69%
Total	**1.14e+04**		**100.00%**
Total energy (fuels and electricity, MJ/functional unit):			
Monitor assembly	1.90e+01		0.10%
Tube	2.37e+02		1.29%

Table 2-38. CRT manufacturing stage utility inputs

Material	**Quantity**	**% of process group total**	**% of grand total**
Process group			
Glass/frit	1.52e+04		83.23%
PWB	2.74e+01		0.15%
Fuels	2.79e+03		15.22%
Total	**1.83e+04**		**100.00%**

Table 2-39. CRT manufacturing stage air emissions

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
Tube			
Carbon monoxide	1.70E-02	50.61%	
Dimethyl Formamide	3.49E-05	0.10%	
Nitrogen oxides	2.17E-03	6.48%	
Nonmethane hydrocarbons, remaining unspeciated	1.59E-04	0.47%	
Sulfur oxides	9.96E-03	29.73%	
Toluene	3.84E-03	11.46%	
Xylene (mixed isomers)	3.84E-04	1.15%	
Total	**3.35E-02**	100.00%	**0.02%**
Glass/frit			
Barium	9.33E-10	<0.01%	
Carbon dioxide	2.85E+00	98.45%	
Carbon monoxide	1.64E-04	0.01%	
Chromium	1.39E-07	<0.01%	
Cobalt	1.43E-10	<0.01%	
Copper	6.33E-10	<0.01%	
Fluorides (F-)	2.93E-05	<0.01%	
Lead	3.22E-07	<0.01%	
Manganese	4.67E-10	<0.01%	
Nickel	5.33E-10	<0.01%	
Nitrogen oxides	4.47E-02	1.54%	
PM	1.10E-04	<0.01%	
Sulfur oxides	5.08E-05	<0.01%	
Zinc (elemental)	4.67E-09	<0.01%	
Total	**2.90E+00**	1.57%	**1.59%**
PWB			
Formaldehyde	**3.88E-05**		**0.00%**
Japanese grid			
1,1,1-Trichloroethane	6.46E-08	<0.01%	
1,2-Dichloroethane	4.57E-08	<0.01%	
2,3,7,8-TCDD	1.68E-14	<0.01%	
2,3,7,8-TCDF	5.84E-14	<0.01%	
2,4-Dinitrotoluene	3.19E-10	<0.01%	
2-Chloroacetophenone	8.00E-09	<0.01%	
2-Methylnaphthalene	2.38E-10	<0.01%	
5-Methyl chrysene	2.51E-11	<0.01%	
Acenaphthene	4.32E-09	<0.01%	
Acenaphthylene	3.29E-10	<0.01%	
Acetaldehyde	6.52E-07	<0.01%	
Acetophenone	1.71E-08	<0.01%	
Acrolein	3.31E-07	<0.01%	
Anthracene	4.55E-10	<0.01%	

Table 2-39. CRT manufacturing stage air emissions

Material	**Quantity (kg/ (functional unit)**	**% of process group total**	**% of grand total**
Process group			
Antimony	9.50E-07	<0.01%	
Arsenic	7.01E-07	<0.01%	
Barium	5.18E-07	<0.01%	
Benzene	1.52E-06	<0.01%	
Benzo[a]anthracene	8.00E-10	<0.01%	
Benzo[a]pyrene	4.35E-11	<0.01%	
Benzo[b,j,k]fluoranthene	3.89E-10	<0.01%	
Benzo[g,h,i]perylene	4.30E-10	<0.01%	
Benzyl chloride	8.00E-07	<0.01%	
Beryllium	3.23E-08	<0.01%	
Biphenyl	1.94E-09	<0.01%	
Bromoform	4.46E-08	<0.01%	
Bromomethane	1.83E-07	<0.01%	
Cadmium	1.41E-07	<0.01%	
Carbon dioxide	1.54E+01	99.14%	
Carbon disulfide	1.49E-07	<0.01%	
Carbon monoxide	2.80E-03	0.02%	
Chloride ions	6.14E-05	<0.01%	
Chlorobenzene	2.51E-08	<0.01%	
Chloroform	6.74E-08	<0.01%	
Chromium (III)	5.52E-07	<0.01%	
Chromium (VI)	1.34E-07	<0.01%	
Chrysene	5.35E-10	<0.01%	
Cobalt	1.18E-06	<0.01%	
Copper	3.18E-07	<0.01%	
Cumene hydroperoxide	6.06E-09	<0.01%	
Cyanide (-1)	2.86E-06	<0.01%	
Di(2-ethylhexyl)phthalate	8.34E-08	<0.01%	
Dibenzo[a,h]anthracene	2.96E-10	<0.01%	
Dichloromethane	3.31E-07	<0.01%	
Dimethyl sulfate	5.49E-08	<0.01%	
Dioxins, remaining unspeciated	7.46E-13	<0.01%	
Ethyl Chloride	4.80E-08	<0.01%	
Ethylbenzene	1.19E-07	<0.01%	
Ethylene dibromide	1.37E-09	<0.01%	
Fluoranthene	1.75E-09	<0.01%	
Fluorene	1.83E-09	<0.01%	
Fluorides (F-)	6.60E-06	<0.01%	
Formaldehyde	1.02E-05	<0.01%	
Furans, remaining unspeciated	1.19E-12	<0.01%	

Table 2-39. CRT manufacturing stage air emissions

Material	**Quantity (kg/ (functional unit)**	**% of process group total**	**% of grand total**
Process group			
Hexane	7.66E-08	<0.01%	
Hydrochloric acid	1.37E-03	<0.01%	
Hydrofluoric acid	1.71E-04	<0.01%	
Indeno(1,2,3-cd)pyrene	4.48E-10	<0.01%	
Isophorone	6.63E-07	<0.01%	
Lead (Pb, ore)	4.41E-07	<0.01%	
Magnesium	1.26E-05	<0.01%	
Manganese (Mn, ore)	1.09E-06	<0.01%	
Mercury	1.18E-07	<0.01%	
Methane	8.13E-05	<0.01%	
Methyl chloride	6.06E-07	<0.01%	
Methyl ethyl ketone	4.46E-07	<0.01%	
Methyl hydrazine	1.94E-07	<0.01%	
Methyl methacrylate	2.29E-08	<0.01%	
Methyl tert-butyl ether	3.99E-08	<0.01%	
Molybdenum	1.55E-07	<0.01%	
Naphthalene	2.21E-07	<0.01%	
Nickel	1.47E-05	<0.01%	
Nitrogen oxides	4.07E-02	0.26%	
Nitrous oxide	1.12E-04	<0.01%	
o-xylene	1.93E-08	<0.01%	
Phenanthrene	5.21E-09	<0.01%	
Phenol	1.83E-08	<0.01%	
PM-10	2.00E-03	0.01%	
Propionaldehyde	4.34E-07	<0.01%	
Pyrene	1.26E-09	<0.01%	
Selenium	1.61E-06	<0.01%	
Styrene	2.86E-08	<0.01%	
Sulfur dioxide	8.62E-02	0.56%	
Tetrachloroethylene	4.92E-08	<0.01%	
TOCs, remaining unspeciated	1.97E-04	<0.01%	
Toluene	1.43E-06	<0.01%	
Vanadium	5.71E-06	<0.01%	
Vinyl acetate	8.67E-09	<0.01%	
Xylene (mixed isomers)	4.23E-08	<0.01%	
Zinc (elemental)	5.15E-06	<0.01%	
Total	**1.55E+01**	100.00%	**8.50%**
U.S. grid			
1,1,1-Trichloroethane	3.06E-08	<0.01%	
1,2-Dichloroethane	5.73E-08	<0.01%	
2,3,7,8-TCDD	2.05E-14	<0.01%	

Table 2-39. CRT manufacturing stage air emissions

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
2,3,7,8-TCDF	7.30E-14	<0.01%	
2,4-Dinitrotoluene	4.01E-10	<0.01%	
2-Chloroacetophenone	1.00E-08	<0.01%	
2-Methylnaphthalene	4.26E-11	<0.01%	
5-Methyl chrysene	3.15E-11	<0.01%	
Acenaphthene	9.06E-10	<0.01%	
Acenaphthylene	3.60E-10	<0.01%	
Acetaldehyde	8.16E-07	<0.01%	
Acetophenone	2.15E-08	<0.01%	
Acrolein	4.15E-07	<0.01%	
Anthracene	3.11E-10	<0.01%	
Antimony	6.96E-08	<0.01%	
Arsenic	5.99E-07	<0.01%	
Barium	3.28E-08	<0.01%	
Benzene	1.86E-06	<0.01%	
Benzo[a]anthracene	1.48E-10	<0.01%	
Benzo[a]pyrene	5.44E-11	<0.01%	
Benzo[b,j,k]fluoranthene	1.70E-10	<0.01%	
Benzo[g,h,i]perylene	5.75E-11	<0.01%	
Benzyl chloride	1.00E-06	<0.01%	
Beryllium	3.05E-08	<0.01%	
Biphenyl	2.43E-09	<0.01%	
Bromoform	5.58E-08	<0.01%	
Bromomethane	2.29E-07	<0.01%	
Cadmium	7.69E-08	<0.01%	
Carbon dioxide	7.10E+00	98.98%	
Carbon disulfide	1.86E-07	<0.01%	
Carbon monoxide	1.29E-03	0.02%	
Chloride ions	2.90E-06	<0.01%	
Chlorobenzene	3.15E-08	<0.01%	
Chloroform	8.45E-08	<0.01%	
Chromium (III)	3.88E-07	<0.01%	
Chromium (VI)	1.15E-07	<0.01%	
Chrysene	1.63E-10	<0.01%	
Cobalt	1.94E-07	<0.01%	
Copper	1.59E-08	<0.01%	
Cumene	7.59E-09	<0.01%	
Cyanide (-1)	3.58E-06	<0.01%	
Di(2-ethylhexyl)phthalate	1.04E-07	<0.01%	
Dibenzo[a,h]anthracene	1.40E-11	<0.01%	
Dichloromethane	4.15E-07	<0.01%	

Table 2-39. CRT manufacturing stage air emissions

Material	**Quantity (kg/ (functional unit)**	**% of process group total**	**% of grand total**
Process group			
Dimethyl sulfate	6.87E-08	<0.01%	
Dioxins, remaining unspeciated	9.33E-13	<0.01%	
Ethyl Chloride	6.01E-08	<0.01%	
Ethylbenzene	1.35E-07	<0.01%	
Ethylene dibromide	1.72E-09	<0.01%	
Fluoranthene	1.07E-09	<0.01%	
Fluorene	1.34E-09	<0.01%	
Fluoride	3.12E-07	<0.01%	
Formaldehyde	1.35E-06	<0.01%	
Furans, remaining unspeciated	1.49E-12	<0.01%	
Hexane	9.59E-08	<0.01%	
Hydrochloric acid	1.72E-03	0.02%	
Hydrofluoric acid	2.15E-04	<0.01%	
Indeno(1,2,3-cd)pyrene	1.05E-10	<0.01%	
Isophorone	8.30E-07	<0.01%	
Lead	2.04E-07	<0.01%	
Magnesium	1.57E-05	<0.01%	
Manganese	7.28E-07	<0.01%	
Mercury	1.20E-07	<0.01%	
Methane	1.03E-02	0.14%	
Methyl chloride	7.59E-07	<0.01%	
Methyl ethyl ketone	5.58E-07	<0.01%	
Methyl hydrazine	2.43E-07	<0.01%	
Methyl methacrylate	2.86E-08	<0.01%	
Methyl tert-butyl ether	5.01E-08	<0.01%	
Molybdenum	9.32E-09	<0.01%	
Naphthalene	2.92E-08	<0.01%	
Nickel	1.09E-06	<0.01%	
Nitrogen oxides	1.88E-02	0.26%	
Nitrous oxide	5.42E-05	<0.01%	
o-xylene	9.11E-10	<0.01%	
Phenanthrene	4.00E-09	<0.01%	
Phenol	2.29E-08	<0.01%	
Phosphorus (yellow or white)	7.91E-08	<0.01%	
PM-10	9.22E-04	0.01%	
Propionaldehyde	5.44E-07	<0.01%	
Pyrene	5.32E-10	<0.01%	
Selenium	1.87E-06	<0.01%	
Styrene	3.58E-08	<0.01%	
Sulfur dioxide	3.98E-02	0.56%	
Tetrachloroethylene	6.16E-08	<0.01%	

Table 2-39. CRT manufacturing stage air emissions

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
TOCs, remaining unspeciated	9.19E-05	<0.01%	
Toluene	4.06E-07	<0.01%	
Vanadium	2.81E-07	<0.01%	
Vinyl acetate	1.09E-08	<0.01%	
Xylene (mixed isomers)	5.30E-08	<0.01%	
Zinc (elemental)	2.43E-07	<0.01%	
Total	**7.17E+00**	100.00%	**3.93%**
Fuels			
1,1,1-Trichloroethane	1.36E-07	<0.01%	
1,2-Dichloroethane	2.71E-07	<0.01%	
1,4-Dichlorobenzene	3.06E-07	<0.01%	
2,4-Dinitrotoluene	1.90E-09	<0.01%	
2-Chloroacetophenone	4.75E-08	<0.01%	
2-Methylnaphthalene	6.11E-09	<0.01%	
3-Methylcholanthrene	4.59E-10	<0.01%	
5-Methyl chrysene	1.49E-10	<0.01%	
Acenaphthene	5.31E-09	<0.01%	
Acenaphthylene	2.17E-09	<0.01%	
Acetaldehyde	3.86E-06	<0.01%	
Acetophenone	1.02E-07	<0.01%	
Acrolein	1.97E-06	<0.01%	
Aldehydes	1.52E-03	<0.01%	
Aluminum (elemental)	1.98E-05	<0.01%	
Ammonia	2.35E-03	<0.01%	
Anthracene	2.12E-09	<0.01%	
Antimony	6.36E-07	<0.01%	
Aromatic hydrocarbons	5.29E-08	<0.01%	
Arsenic	1.41E-05	<0.01%	
Barium	3.33E-07	<0.01%	
Benzene	1.57E-02	0.01%	
Benzo[a]anthracene	1.27E-09	<0.01%	
Benzo[a]pyrene	6.94E-10	<0.01%	
Benzo[b,j,k]fluoranthene	7.46E-10	<0.01%	
Benzo[b]fluoranthene	5.07E-10	<0.01%	
Benzo[g,h,i]perylene	5.63E-10	<0.01%	
Benzo[k]fluoranthene	5.07E-10	<0.01%	
Benzyl chloride	4.75E-06	<0.01%	
Beryllium	1.42E-06	<0.01%	
Biphenyl	1.15E-08	<0.01%	
Bromoform	2.64E-07	<0.01%	
Bromomethane	1.08E-06	<0.01%	

Table 2-39. CRT manufacturing stage air emissions

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
Butane	5.35E-04	<0.01%	
Cadmium	8.20E-07	<0.01%	
Calcium	1.72E-05	<0.01%	
Carbon dioxide	1.54E+02	97.92%	
Carbon disulfide	8.81E-07	<0.01%	
Carbon monoxide	4.36E-01	0.28%	
Chloride ions	3.39E-05	<0.01%	
Chlorine	5.84E-09	<0.01%	
Chlorobenzene	1.49E-07	<0.01%	
Chloroform	4.00E-07	<0.01%	
Chromium (III)	2.13E-05	<0.01%	
Chromium (VI)	2.13E-05	<0.01%	
Chrysene	1.22E-09	<0.01%	
Cobalt	2.54E-06	<0.01%	
Copper	1.57E-06	<0.01%	
Cumene	3.59E-08	<0.01%	
Cyanide (-1)	1.69E-05	<0.01%	
Di(2-ethylhexyl)phthalate	4.95E-07	<0.01%	
Dibenzo[a,h]anthracene	3.61E-10	<0.01%	
Dichloromethane	1.97E-06	<0.01%	
Dimethyl sulfate	3.25E-07	<0.01%	
Dimethylbenzanthracene	3.82E-09	<0.01%	
Dioxins, remaining unspeciated	1.10E-10	<0.01%	
Ethane	7.90E-04	<0.01%	
Ethyl Chloride	2.85E-07	<0.01%	
Ethylbenzene	6.44E-07	<0.01%	
Ethylene dibromide	8.14E-09	<0.01%	
Fluoranthene	5.74E-09	<0.01%	
Fluorene	7.03E-09	<0.01%	
Fluorides (F-)	3.84E-06	<0.01%	
Formaldehyde	1.19E-03	<0.01%	
Furans, remaining unspeciated	5.11E-10	<0.01%	
Halogenated hydrocarbons (unspecified)	2.94E-13	<0.01%	
HALON-1301	5.11E-10	<0.01%	
Hexane	4.59E-04	<0.01%	
Hydrocarbons, remaining unspeciated	1.58E-01	0.10%	
Hydrochloric acid	8.14E-03	<0.01%	
Hydrofluoric acid	1.02E-03	<0.01%	
Hydrogen sulfide	3.11E-03	<0.01%	
Indeno(1,2,3-cd)pyrene	9.43E-10	<0.01%	
Iron	3.83E-05	<0.01%	

Table 2-39. CRT manufacturing stage air emissions

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
Isophorone	3.93E-06	<0.01%	
Lead	1.25E-05	<0.01%	
Magnesium	7.46E-05	<0.01%	
Manganese	2.26E-05	<0.01%	
Mercury	8.81E-07	<0.01%	
Metals, remaining unspeciated	3.16E-07	<0.01%	
Methane	8.98E-01	0.57%	
Methyl chloride	3.59E-06	<0.01%	
Methyl ethyl ketone	2.64E-06	<0.01%	
Methyl hydrazine	1.15E-06	<0.01%	
Methyl methacrylate	1.36E-07	<0.01%	
Methyl tert-butyl ether	2.37E-07	<0.01%	
Molybdenum	1.97E-06	<0.01%	
Naphthalene	3.54E-07	<0.01%	
Nickel	1.24E-04	<0.01%	
Nitrogen oxides	5.88E-01	0.37%	
Nitrous oxide	1.64E-02	0.01%	
Nonmethane hydrocarbons, remaining unspeciated	1.10E-01	0.07%	
n-Propane	1.69E-06	<0.01%	
Other organics	7.83E-02	0.05%	
o-xylene	1.11E-06	<0.01%	
Pentane	6.62E-04	<0.01%	
Phenanthrene	2.30E-08	<0.01%	
Phenol	1.08E-07	<0.01%	
Phosphorus (yellow or white)	1.25E-05	<0.01%	
PM	1.31E-01	0.08%	
PM-10	2.28E-04	<0.01%	
Polycyclic aromatic hydrocarbons	5.87E-11	<0.01%	
Propionaldehyde	2.58E-06	<0.01%	
Pyrene	3.65E-09	<0.01%	
Selenium	9.47E-06	<0.01%	
Silicon	1.72E-05	<0.01%	
Sodium	1.02E-04	<0.01%	
Styrene	1.69E-07	<0.01%	
Sulfur oxides	8.10E-01	0.52%	
Tetrachloroethylene	2.92E-07	<0.01%	
Toluene	3.81E-06	<0.01%	
Vanadium	2.68E-04	<0.01%	

Table 2-39. CRT manufacturing stage air emissions

Material	Quantity (kg/ (functional unit)	% of process group total	% of grand total
Process group			
Vinyl acetate	5.15E-08	<0.01%	
Zinc (elemental)	1.02E-05	<0.01%	
Total	**1.57E+02**	100.00%	**85.96%**
Grand Total	**1.83E+02**		**100.00%**

Table 2-40. CRT manufacturing stage water outputs (wastewaters and pollutants)

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process group				
WASTEWATER STREAMS				
Tube				
Wastewater stream	treatment	5.26e+01	9.87%	
Wastewater stream	surface water	4.81e+02	90.13%	
Total		**5.33e+02**	100.00%	**35.42%**
Glass/frit				
Wastewater stream	surface water	**3.62e+01**		**2.40%**
PWB				
Wastewater stream	treatment	**4.22e+01**		**2.80%**
Fuels				
Wastewater stream	surface water	**8.94e+02**		**59.38%**
Grand Total		**1.51e+03**		**100.00%**
WASTEWATER POLLUTANTS				
Tube				
BOD	surface water	6.39e-03	5.34%	
Chromium ore	surface water	1.02e-05	<0.01%	
Chromium ore	treatment	1.03e-06	<0.01%	
COD	surface water	7.22e-03	6.04%	
COD	treatment	8.33e-03	6.97%	
Copper	surface water	1.80e-06	<0.01%	
Cyanide (-1)	surface water	6.06e-07	<0.01%	
Dissolved solids	treatment	8.01e-02	67.03%	
Fluoride	surface water	3.45e-03	2.89%	
Fluoride	treatment	3.51e-04	0.29%	
Iron	surface water	1.65e-04	0.14%	
Lead	surface water	3.01e-06	<0.01%	
Lead	treatment	1.03e-06	<0.01%	
Manganese	surface water	3.60e-06	<0.01%	
Molybdenum	surface water	1.20e-07	<0.01%	
Nickel	surface water	7.93e-05	0.07%	
Nitrogen	surface water	7.18e-03	6.01%	
Oil & grease	surface water	2.41e-04	0.20%	
Phosphate as P2O5	surface water	1.21e-06	<0.01%	
Phosphorus (yellow or white)	surface water	5.05e-05	0.04%	
Suspended solids	surface water	4.63e-03	3.87%	
Suspended solids	treatment	1.28e-03	1.07%	
Zinc (elemental)	surface water	1.39e-05	0.01%	
Zinc (elemental)	treatment	1.03e-06	<0.01%	
Total		**1.20e-01**	100.00%	**2.51%**
Glass/frit				
BOD	surface water	8.20e-06	<0.01%	

Table 2-40. CRT manufacturing stage water outputs (wastewaters and pollutants)

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process group				
Chloride ions	surface water	1.01e+00	21.73%	
Chromium	surface water	8.20e-08	<0.01%	
COD	surface water	8.20e-06	<0.01%	
Dissolved solids	surface water	3.62e+00	77.84%	
Fluorides (F-)	surface water	2.93e-03	0.06%	
Iron	surface water	2.77e-03	0.06%	
Lead	surface water	4.34e-05	<0.01%	
Nickel	surface water	8.20e-08	<0.01%	
Nitrates/nitrites	surface water	3.95e-06	<0.01%	
Oil & grease	surface water	7.22e-03	0.16%	
Suspended solids	surface water	7.23e-03	0.16%	
Total		**4.65e+00**	100.00%	**97.45%**
PWB				
Copper (+1 & +2)	treatment	9.71e-05	85.71%	
Lead cmpds	treatment	1.62e-05	14.29%	
Total		**1.13e-04**	100.00%	**0.00%**
Japanese grid				
Sulfate ion (-4)	surface water	8.72e-04	97.46%	
Suspended solids	surface water	2.27e-05	2.54%	
Total		**8.94e-04**	100.00%	**0.02%**
U.S. grid				
Sulfate ion (-4)	treatment	1.09e-03	97.46%	
Suspended solids	treatment	2.84e-05	2.54%	
Total		**1.12e-03**	100.00%	**0.02%**
Fuels				
Acids (H+)	surface water	2.50e-09	<0.01%	
Adsorbable organic halides	surface water	2.27e-15	<0.01%	
Aluminum (+3)	surface water	8.62e-10	<0.01%	
Ammonia ions	surface water	1.01e-07	0.10%	
Aromatic hydrocarbons	surface water	5.33e-13	<0.01%	
Barium cmpds	surface water	1.71e-12	<0.01%	
BOD	surface water	1.21e-06	1.22%	
Cadmium cmpds	surface water	1.78e-15	<0.01%	
Chloride ions	surface water	3.56e-05	36.07%	
Chromium (III)	surface water	3.31e-10	<0.01%	
Chromium (VI)	surface water	3.31e-10	<0.01%	
COD	surface water	9.80e-06	9.92%	
Copper (+1 & +2)	surface water	3.55e-14	<0.01%	
Cyanide (-1)	surface water	2.49e-15	<0.01%	
Dissolved organics	surface water	6.62e-09	<0.01%	
Dissolved solids	surface water	2.21e-07	0.22%	
Fluorides (F-)	surface water	1.80e-08	0.02%	

Table 2-40. CRT manufacturing stage water outputs (wastewaters and pollutants)

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process group				
Halogenated matter (organic)	surface water	7.11e-16	<0.01%	
Hydrocarbons, remaining unspeciated	surface water	2.61e-09	<0.01%	
Iron (+2 & +3)	surface water	3.79e-11	<0.01%	
Lead cmpds	surface water	7.11e-15	<0.01%	
Mercury compounds	surface water	8.17e-18	<0.01%	
Metals, remaining unspeciated	surface water	6.27e-08	0.06%	
Nickel cmpds	surface water	3.55e-15	<0.01%	
Nitrate	surface water	4.53e-09	<0.01%	
Other nitrogen	surface water	9.59e-14	<0.01%	
Phenol	surface water	2.21e-08	0.02%	
Phosphates	surface water	2.02e-11	<0.01%	
Polycyclic aromatic hydrocarbons	surface water	8.53e-15	<0.01%	
Salts (unspecified)	surface water	9.83e-09	<0.01%	
Sodium (+1)	surface water	4.59e-05	46.44%	
Sulfate ion (-4)	surface water	4.26e-09	<0.01%	
Sulfide	surface water	1.38e-09	<0.01%	
Suspended solids	surface water	5.19e-06	5.26%	
TOCs	surface water	5.33e-12	<0.01%	
Toluene	surface water	7.82e-14	<0.01%	
Waste oil	surface water	6.26e-07	0.63%	
Zinc (+2)	surface water	1.58e-10	<0.01%	
Total		**9.88e-05**	100.00%	**0.00%**
Grand Total		**4.77e+00**		**100.00%**

Table 2-41. CRT manufacturing stage hazardous waste outputs (kg/functional unit)

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process group				
Tube				
Frit	landfill	2.99e-03	15.58%	
Lead sulfate cake	landfill	2.67e-05	0.14%	
Silica coat waste	treatment	2.86e-04	1.49%	
Slag and ash	landfill	2.47e-03	12.90%	
Slurry scrap (chromium-based)	landfill	8.62e-04	4.50%	
Spent solvent, unspecified	treatment	2.75e-04	1.43%	
Unspecified sludge	landfill	5.22e-03	27.26%	
Unspecified sludge	recycling/reuse	5.56e-03	29.03%	
Waste oxygenated solvents	treatment	9.48e-05	0.49%	
Waste water treatment (WWT) filters	landfill	3.40e-04	1.78%	
Total		**1.81e-02**	100.00%	**1.61%**
Glass/frit				
Barium debris (D008 waste)	landfill	2.14e-04	0.59%	
Broken CRT glass	landfill	1.88e-03	5.17%	
Chrome debris (D007 waste)	treatment	1.47e-04	0.41%	
Chrome liquid waste (D007 waste)	recycling/reuse	9.80e-03	26.95%	
cinders from CRT glass mfg (70% PbO)	landfill	8.26e-03	22.71%	
CRT glass faceplate EP dust (Pb) (D008 waste)	landfill	1.03e-03	2.83%	
CRT glass funnel EP dust (Pb) (D008 waste)	recycling/reuse	5.01e-03	13.78%	
Hazardous sludge (Pb) (D008)	landfill	1.52e-03	4.17%	
Hydrofluoric acid	landfill	1.78e-03	4.89%	
Lead contaminated grit (D008 waste)	landfill	3.46e-05	0.10%	
Lead debris (D008 waste)	landfill	2.14e-04	0.59%	
sludge from CRT glass mfg (1% PbO)	landfill	8.77e-04	2.41%	
Waste acid (mostly 3% HCl solution)	recycling/reuse	3.93e-03	10.81%	
Waste Batch (Ba, Pb) (D008 waste)	landfill	1.41e-03	3.89%	
Waste finishing sludge (Pb) (D008 waste)	landfill	2.56e-04	0.70%	
Total		**3.64e-02**	100.00%	**3.23%**
PWB				
General Hazardous Waste	treatment	1.24e-01	27.26%	
PWB-Decontaminating debris	treatment	1.55e-02	3.41%	
PWB-Lead contaminated waste oil	treatment	1.16e-02	2.56%	
PWB-Route dust	recycling/reuse	1.20e-02	2.64%	
PWB-Solder dross	recycling/reuse	6.70e-02	14.72%	
PWB-Waste cupric etchant	recycling/reuse	2.25e-01	49.42%	
Total		**4.55e-01**	100.00%	**40.49%**
Fuels				
Hazardous waste	landfill	**6.15e-01**		**54.67%**

Table 2-41. CRT manufacturing stage hazardous waste outputs (kg/functional unit)

Material	Disposition	Quantity (kg/ functional unit)	% of process group total	% of grand total
Process group				
Grand Total		**1.12e+00**		**100.00%**

Table 2-42. CRT manufacturing stage solid waste outputs (kg/functional unit)

Material	Disposition	Quantity(kg/ functional unit)	% of process group total	% of grand total
Process group				
Monitor Assembly				
Broken CRT glass	recycling/reuse	3.82e-01	75.07%	
Cables/wires	recycling/reuse	8.86e-03	1.74%	
Printed wiring board (PWB)	recycling/reuse	3.70e-02	7.28%	
Waste plastics from CRT monitor	recycling/reuse	8.09e-02	15.91%	
Total		**5.09e-01**	100.00%	**0.63%**
Tube				
Broken CRT glass	recycling/reuse	6.94e-01	37.43%	
Ferric chloride	recycling/reuse	3.69e-01	19.93%	
Sludge (aquadag)	landfill	2.22e-03	0.12%	
Sludge (phosphor)	landfill	4.31e-03	0.23%	
Spent solvents (toluene,xylene,dimethyl formamide,isopropyl alcohol)	recycling/reuse	4.17e-02	2.25%	
Unspecified sludge	recycling/reuse	1.26e-01	6.78%	
Waste alkali (cleaning caustic and alkali soda effluent)	recycling/reuse	2.12e-02	1.15%	
Waste metals, unspecified	recycling/reuse	8.79e-02	4.74%	
Waste oil	recycling/reuse	1.43e-03	0.08%	
Waste oil	treatment	2.55e-03	0.14%	
Waste Plastic (packing material)	treatment	3.01e-02	1.63%	
Waste Plastic (styrene foam)	recycling/reuse	3.77e-03	0.20%	
Waste water treatment (WWT) sludge	landfill	8.43e-02	4.55%	
Waste water treatment (WWT) sludge	recycling/reuse	3.72e-01	20.06%	
Wastepaper	recycling/reuse	8.34e-03	0.45%	
Wood, average	landfill	4.94e-03	0.27%	
Total		**1.85e+00**	100.00%	**2.28%**
Glass/frit				
abrasive sludge	recycling/reuse	4.21e-02	11.34%	
acid absorbent	landfill	8.13e-05	0.02%	
blasting media	landfill	3.66e-04	0.10%	
Cobalt nitrate	treatment	6.10e-05	0.02%	
CRT glass, faceplate	landfill	2.43e-02	6.54%	
Diesel fuel	treatment	4.07e-05	0.01%	
Dust	treatment	3.43e-03	0.92%	
Nickel nitrate	treatment	6.10e-05	0.02%	
Oily rags & filter media	landfill	3.25e-04	0.09%	
Oily rags & filter media	recycling/reuse	4.07e-05	0.01%	
parts cleaner solvent	recycling/reuse	8.13e-05	0.02%	
Plating process sludge	landfill	3.28e-04	0.09%	
Potassium Carbonate	landfill	3.30e-03	0.89%	
sludge (calcium fluoride, CaF2)	recycling/reuse	1.75e-02	4.72%	

Table 2-42. CRT manufacturing stage solid waste outputs (kg/functional unit)

Material	Disposition	Quantity(kg/ functional unit)	% of process group total	% of grand total
Process group				
Sodium Carbonate	landfill	3.29e-03	0.89%	
Unspecified sludge	landfill	7.69e-03	2.07%	
Waste alkali, unspecified	treatment	4.21e-05	0.01%	
Waste oil	treatment	6.54e-03	1.76%	
Waste refractory	landfill	2.44e-03	0.66%	
Waste water treatment (WWT) sludge	landfill	2.59e-01	69.68%	
PM	landfill	5.33e-04	0.14%	
Total		**3.72e-01**	100.00%	**0.46%**
PWB				
PWB-Drill dust	landfill	1.49e-02	0.36%	
Unspecified solid waste	recycling/reuse	4.33e-01	10.53%	
Unspecified solid waste	treatment	3.66e+00	89.11%	
Total		**4.11e+00**	100.00%	**5.06%**
Japanese grid				
Coal waste	landfill	6.48e-01	61.12%	
Dust/sludge	landfill	2.50e-01	23.59%	
Fly/bottom ash	landfill	1.62e-01	15.28%	
Total		**1.06e+00**	100.00%	**1.31%**
U.S. grid				
Coal waste	landfill	8.12e-01	61.10%	
Dust/sludge	landfill	3.14e-01	23.63%	
Fly/bottom ash	landfill	2.03e-01	15.27%	
Total		**1.33e+00**	100.00%	**1.64%**
Fuels				
Aluminum scrap	recycling/reuse	1.82e-04	<0.01%	
Aluminum scrap, Wabash 319	recycling/reuse	5.08e-07	<0.01%	
Bauxite residues	landfill	1.21e-02	0.02%	
FGD sludge	landfill	2.14e-01	0.30%	
Mineral waste	landfill	2.61e-03	<0.01%	
Mixed industrial (waste)	landfill	1.00e+00	1.39%	
Non toxic chemical waste (unspecified)	landfill	6.11e-04	<0.01%	
Slag and ash	landfill	6.66e+01	92.62%	
Slag and ash	recycling/reuse	6.85e-01	0.95%	
Unspecified solid waste (incinerated)	treatment	1.33e-02	0.02%	
Unspecified waste	landfill	3.38e+00	4.70%	
Total		**7.19e+01**	100.04%	**88.62%**
Grand Total		**8.12e+01**		**100.00%**

Table 2-43. CRT manufacturing stage radioactive waste outputs

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process group				
Japanese grid				
Low-level radioactive waste	landfill	1.10e-04	76.93%	
Uranium, depleted	landfill	3.31e-05	23.07%	
Total		**1.43e-04**	100.00%	**79.72%**
U.S. grid				
Low-level radioactive waste	landfill	2.80e-05	76.93%	
Uranium, depleted	landfill	8.41e-06	23.07%	
Total		**3.65e-05**	100.00%	**20.28%**
Grand Total		**1.80e-04**		**100.00%**

Table 2-44. CRT manufacturing stage radioactivity outputs

Material	**Disposition**	**Quantity (Bq/ functional unit)**	**% of process group total**	**% of grand total**
Process group				
Japanese grid				
Antimony-124 (isotope)	treatment	4.95e-01	<0.01%	
Antimony-125 (isotope)	treatment	1.97e+00	<0.01%	
Argon-41 (isotope)	air	1.00e+03	0.03%	
Barium-140 (isotope)	treatment	3.67e-02	<0.01%	
Bromine-89 (isotope)	air	1.16e-04	<0.01%	
Bromine-90 (isotope)	air	4.72e-05	<0.01%	
Cesium-134 (isotope)	air	3.18e-03	<0.01%	
Cesium-134 (isotope)	treatment	1.32e+00	<0.01%	
Cesium-137 (isotope)	air	2.40e-02	<0.01%	
Cesium-137 (isotope)	treatment	1.99e+00	<0.01%	
Chromium-51 (isotope)	air	6.29e-02	<0.01%	
Chromium-51 (isotope)	treatment	2.39e+00	<0.01%	
Cobalt-57 (isotope)	air	1.69e-04	<0.01%	
Cobalt-57 (isotope)	treatment	5.78e-02	<0.01%	
Cobalt-58 (isotope)	air	2.16e-03	<0.01%	
Cobalt-58 (isotope)	treatment	2.35e+01	<0.01%	
Cobalt-60 (isotope)	air	1.62e-02	<0.01%	
Cobalt-80 (isotope)	treatment	6.17e+00	<0.01%	
Iodine-131 (isotope)	air	7.58e-02	<0.01%	
Iodine-131 (isotope)	treatment	1.10e+00	<0.01%	
Iodine-132 (isotope)	air	1.54e-02	<0.01%	
Iodine-132 (isotope)	treatment	4.17e-01	<0.01%	
Iodine-133 (isotope)	air	7.03e+01	<0.01%	
Iodine-133 (isotope)	treatment	4.72e-01	<0.01%	
Iodine-134 (isotope)	air	7.98e-02	<0.01%	
Iodine-135 (isotope)	air	4.01e-03	<0.01%	
Iodine-135 (isotope)	treatment	3.38e-01	<0.01%	
Iron-55 (isotope)	treatment	5.62e+00	<0.01%	
Iron-59 (isotope)	treatment	2.88e-01	<0.01%	
Krypton-85 (isotope)	air	1.66e+03	0.06%	
Krypton-85M (isotope)	air	8.06e+01	<0.01%	
Krypton-85M (isotope)	treatment	1.49e+00	<0.01%	
Krypton-87 (isotope)	air	3.00e+01	<0.01%	
Krypton-88 (isotope)	air	1.41e+02	<0.01%	
Lanthanum-140 (isotope)	treatment	3.93e-02	<0.01%	
Manganese-54 (isotope)	air	8.92e-04	<0.01%	
Manganese-54 (isotope)	treatment	1.57e+00	<0.01%	
Molybdenum-99 (isotope)	treatment	2.97e+06	98.42%	
Niobium-95 (isotope)	air	3.54e-05	<0.01%	
Niobium-95 (isotope)	treatment	4.05e-01	<0.01%	
Rubidium-88 (isotope)	air	3.29e-01	<0.01%	

Table 2-44. CRT manufacturing stage radioactivity outputs

Material	**Disposition**	**Quantity (Bq/ functional unit)**	**% of process group total**	**% of grand total**
Process group				
Ruthenium-103 (isotope)	treatment	4.95e-02	<0.01%	
Silver-110M (isotope)	air	1.06e-06	<0.01%	
Silver-110M (isotope)	treatment	5.78e-01	<0.01%	
Sodium-24 (isotope)	treatment	8.80e-02	<0.01%	
Strontium-89 (isotope)	treatment	9.51e-02	<0.01%	
Strontium-90 (isotope)	treatment	2.24e-02	<0.01%	
Strontium-95 (isotope)	treatment	2.46e-01	<0.01%	
Sulfur-136 (isotope)	treatment	5.30e-02	<0.01%	
Technetium-99M (isotope)	air	4.75e-06	<0.01%	
Technetium-99M (isotope)	treatment	3.45e-02	<0.01%	
Tin-113 (isotope)	treatment	5.46e-02	<0.01%	
Tritium-3 (isotope)	air	2.35e+03	0.08%	
Tritium-3 (isotope)	treatment	1.76e+04	0.58%	
Xenon-131M (isotope)	air	1.36e+02	<0.01%	
Xenon-131M (isotope)	treatment	1.81e+01	<0.01%	
Xenon-133 (isotope)	air	1.30e+03	0.04%	
Xenon-133 (isotope)	treatment	2.78e+03	0.09%	
Xenon-133M (isotope)	air	1.96e+04	0.65%	
Xenon-133M (isotope)	treatment	2.28e+01	<0.01%	
Xenon-135 (isotope)	air	7.39e+02	0.02%	
Xenon-135 (isotope)	treatment	2.07e+01	<0.01%	
Xenon-135M (isotope)	air	1.41e+01	<0.01%	
Xenon-138 (isotope)	air	4.68e+01	<0.01%	
Zinc-85 (isotope)	treatment	2.65e-02	<0.01%	
Zirconium-95 (isotope)	air	9.16e-05	<0.01%	
Total		**3.01e+06**	100.00%	**79.70%**
U.S. grid				
Antimony-124 (isotope)	treatment	1.26e-01	<0.01%	
Antimony-125 (isotope)	treatment	5.02e-01	<0.01%	
Argon-41 (isotope)	air	2.55e+02	0.03%	
Barium-140 (isotope)	treatment	9.33e-03	<0.01%	
Bromine-89 (isotope)	air	2.95e-05	<0.01%	
Bromine-90 (isotope)	air	1.20e-05	<0.01%	
Cesium-134 (isotope)	air	8.09e-04	<0.01%	
Cesium-134 (isotope)	treatment	3.37e-01	<0.01%	
Cesium-136 (isotope)	treatment	1.44e-02	<0.01%	
Cesium-137 (isotope)	air	6.11e-03	<0.01%	
Cesium-137 (isotope)	treatment	5.06e-01	<0.01%	
Chromium-51 (isotope)	air	1.60e-02	<0.01%	
Chromium-51 (isotope)	treatment	6.07e-01	<0.01%	
Cobalt-57 (isotope)	air	4.30e-05	<0.01%	
Cobalt-57 (isotope)	treatment	1.47e-02	<0.01%	

Table 2-44. CRT manufacturing stage radioactivity outputs

Material	**Disposition**	**Quantity (Bq/ functional unit)**	**% of process group total**	**% of grand total**
Process group				
Cobalt-58 (isotope)	air	5.49e+01	<0.01%	
Cobalt-58 (isotope)	treatment	5.98e+00	<0.01%	
Cobalt-60 (isotope)	air	4.13e-03	<0.01%	
Cobalt-80 (isotope)	treatment	1.57e+00	<0.01%	
Iodine-131 (isotope)	air	1.93e-02	<0.01%	
Iodine-131 (isotope)	treatment	2.80e-01	<0.01%	
Iodine-132 (isotope)	air	3.92e-03	<0.01%	
Iodine-132 (isotope)	treatment	1.06e-01	<0.01%	
Iodine-133 (isotope)	air	1.79e+01	<0.01%	
Iodine-133 (isotope)	treatment	1.20e-01	<0.01%	
Iodine-134 (isotope)	air	2.03e-02	<0.01%	
Iodine-135 (isotope)	air	1.02e-03	<0.01%	
Iodine-135 (isotope)	treatment	8.60e-02	<0.01%	
Iron-55 (isotope)	treatment	1.43e+00	<0.01%	
Iron-59 (isotope)	treatment	7.34e-02	<0.01%	
Krypton-85 (isotope)	air	4.23e+02	0.06%	
Krypton-85M (isotope)	air	2.05e+01	<0.01%	
Krypton-85M (isotope)	treatment	3.78e-01	<0.01%	
Krypton-87 (isotope)	air	7.62e+00	<0.01%	
Krypton-88 (isotope)	air	3.58e+01	<0.01%	
Lanthanum-140 (isotope)	treatment	9.99e-03	<0.01%	
Manganese-54 (isotope)	air	2.27e-04	<0.01%	
Manganese-54 (isotope)	treatment	4.00e-01	<0.01%	
Molybdenum-99 (isotope)	treatment	7.55e+05	98.41%	
Niobium-95 (isotope)	air	9.01e-06	<0.01%	
Niobium-95 (isotope)	treatment	1.03e-01	<0.01%	
Rubidium-88 (isotope)	air	8.37e-02	<0.01%	
Ruthenium-103 (isotope)	treatment	1.26e-02	<0.01%	
Silver-110M (isotope)	air	2.69e-07	<0.01%	
Silver-110M (isotope)	treatment	1.47e-01	<0.01%	
Sodium-24 (isotope)	treatment	2.24e-02	<0.01%	
Strontium-89 (isotope)	treatment	2.42e-02	<0.01%	
Strontium-90 (isotope)	treatment	5.69e-03	<0.01%	
Strontium-95 (isotope)	treatment	6.27e-02	<0.01%	
Sulfur-136 (isotope)	treatment	1.35e-02	<0.01%	
Technetium-99M (isotope)	air	1.21e-06	<0.01%	
Technetium-99M (isotope)	treatment	8.77e-03	<0.01%	
Tin-113 (isotope)	treatment	1.39e-02	<0.01%	
Tritium-3 (isotope)	air	5.98e+02	0.08%	
Tritium-3 (isotope)	treatment	4.47e+03	0.58%	
Xenon-131M (isotope)	air	3.45e+01	<0.01%	
Xenon-131M (isotope)	treatment	4.60e+00	<0.01%	

Table 2-44. CRT manufacturing stage radioactivity outputs

Material	Disposition	Quantity (Bq/ functional unit)	% of process group total	% of grand total
Process group				
Xenon-133 (isotope)	air	4.98e+03	0.65%	
Xenon-133 (isotope)	treatment	7.07e+02	0.09%	
Xenon-133M (isotope)	air	3.31e+02	0.04%	
Xenon-133M (isotope)	treatment	5.79e+00	<0.01%	
Xenon-135 (isotope)	treatment	5.27e+00	<0.01%	
Xenon-135M (isotope)	air	3.59e+00	<0.01%	
Xenon-138 (isotope)	air	1.19e+01	<0.01%	
Zinc-85 (isotope)	treatment	6.75e-03	<0.01%	
Zirconium-95 (isotope)	air	2.33e-05	<0.01%	
Total		**7.67e+05**	100.00%	**20.27%**
Fuels				
Radioactive substance (unspecified)	air	9.19e+02	99.08%	
Radioactive substance (unspecified)	surface water	8.52e+00	0.92%	
Total		**9.27e+02**	100.00%	**0.02%**
Grand Total		**3.78e+06**		**100.00%**

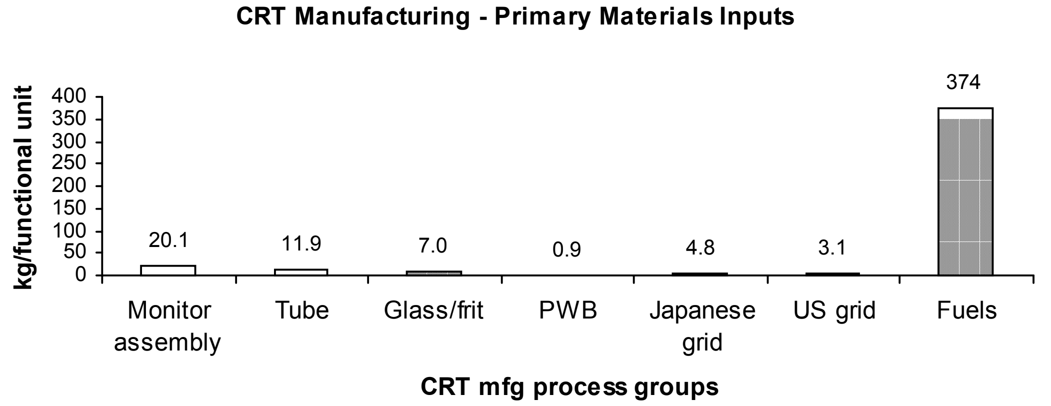

Figure 2-24. CRT manufacturing primary inputs

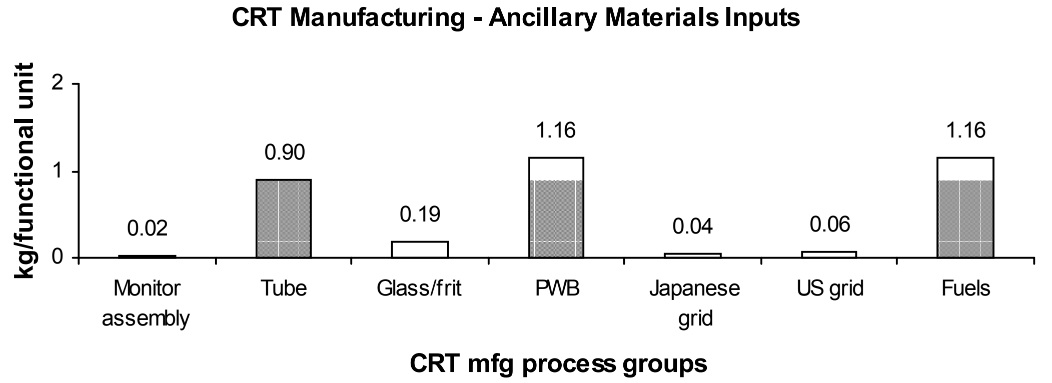

Figure 2-25. CRT manufacturing ancillary inputs

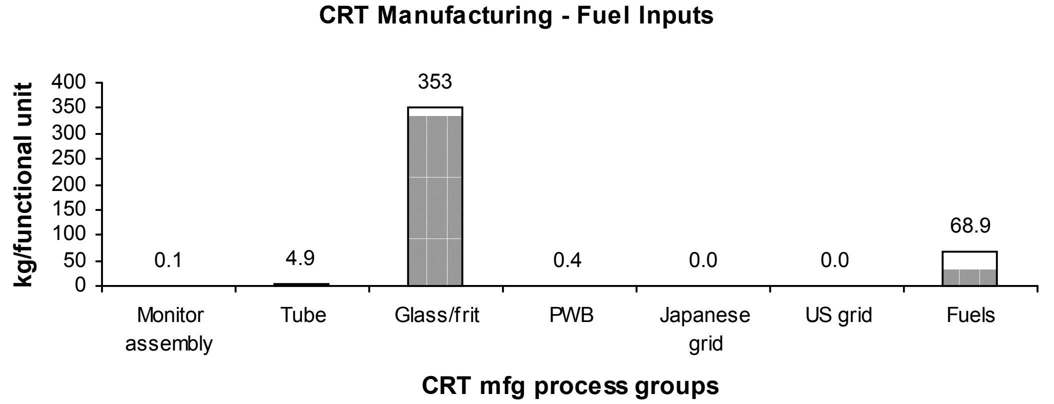

Figure 2-26. CRT manufacturing fuel inputs

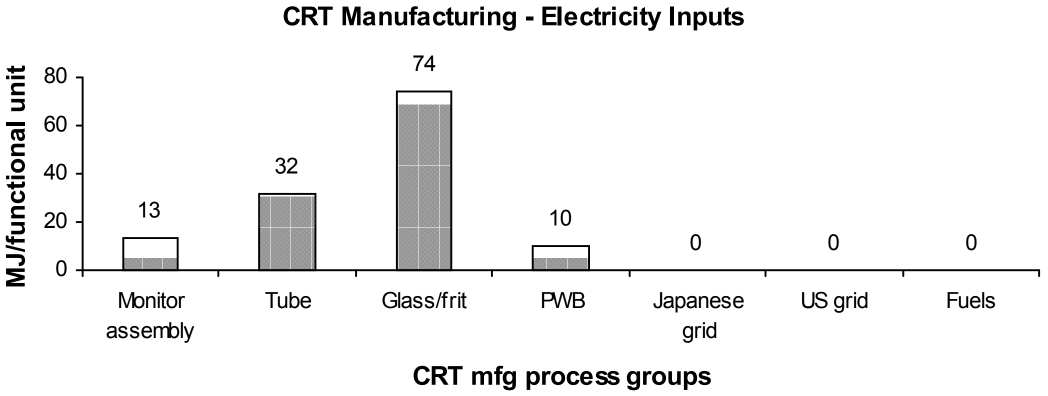

Figure 2-27. CRT manufacturing electricity inputs

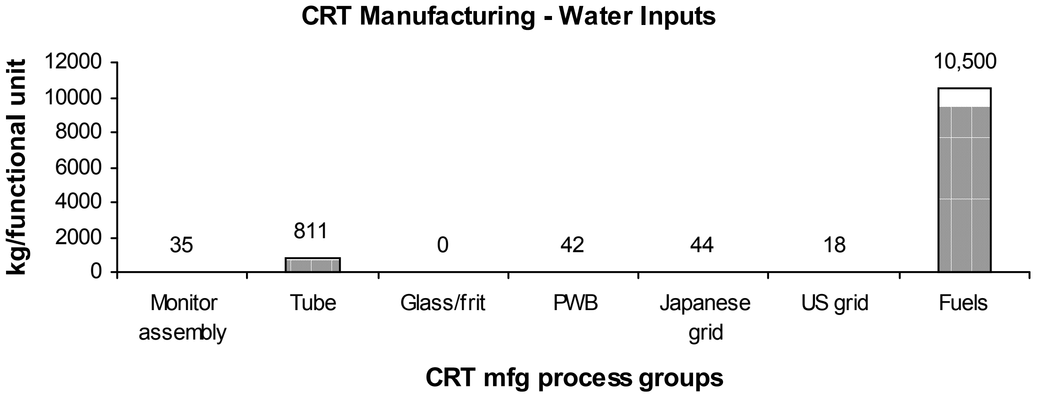

Figure 2-28. CRT manufacturing water inputs

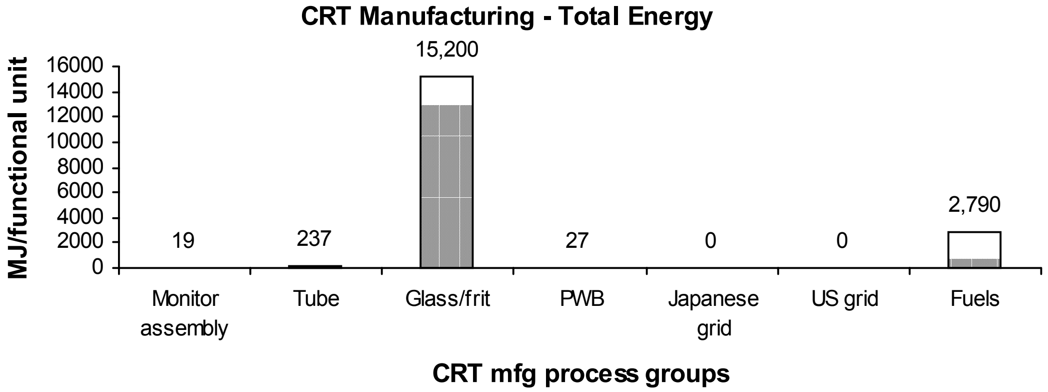

Figure 2-29. CRT manufacturing energy inputs

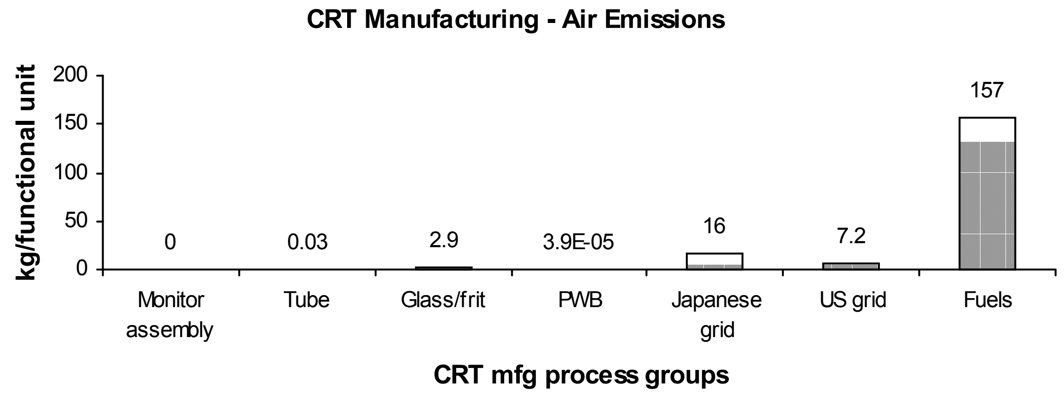

Figure 2-30. CRT manufacturing air emissions

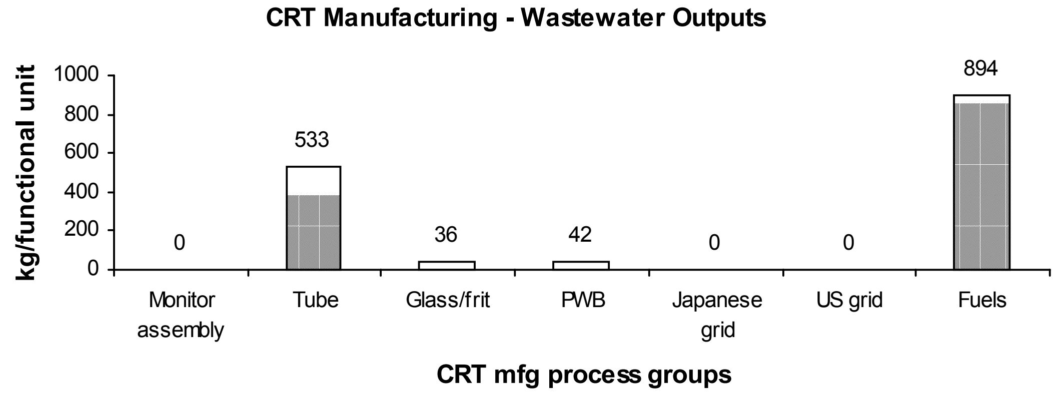

Figure 2-31. CRT manufacturing wastewater outputs

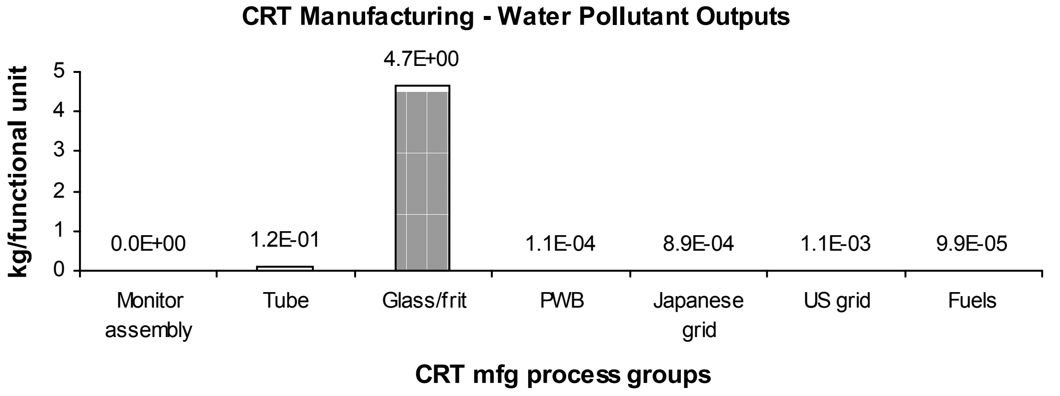

Figure 2-32. CRT manufacturing water pollutant outputs

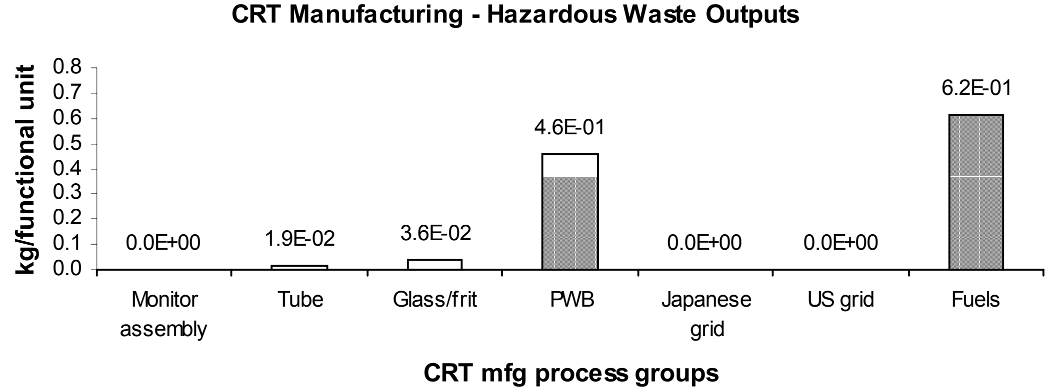

Figure 2-33. CRT manufacturing hazardous waste outputs

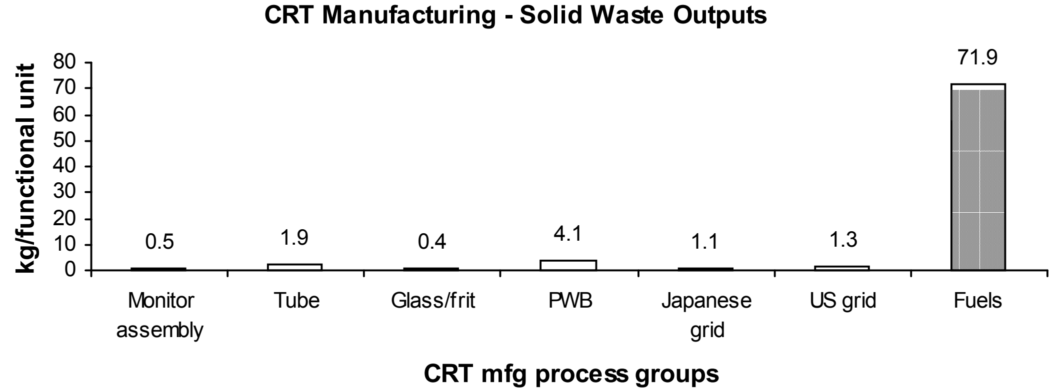

Figure 2-34. CRT manufacturing solid waste outputs

Among the utility inputs, both fuels and electricity were greatest in the glass/frit manufacturing processes (Figures 2-26 and 2-27). The fuels, especially, are dominated by the glass/frit process group, representing 83% of the mass of all the fuels in the manufacturing life-cycle stage. It is LPG in this inventory that clearly dominates the fuel inputs at about 351 kg/functional unit (99% of the glass/frit fuel inputs) (Table 2-38). Water inputs are greatest in the fuel production processes, contributing 1,050 kg (or liter)/functional unit (Figure 2-28). Total energy use from manufacturing is shown in Figure 2-29. The glass/frit manufacturing process group contributes the greatest to the total energy impacts in the manufacturing stage. A sensitivity analysis will be conducted on the glass data and more details are provided in Section 2.7.3.

For outputs from the manufacturing stage, the mass of air emissions are dominated by fuel production (Figure 2-30). Individual material (pollutant) contributions for each process group are presented in Table 2-39. Wastewater outputs (i.e., the volume or mass of wastewater released) are also greatest from the fuel production processes (Figure 2-31; Table 2-40);

however, the mass of chemical pollutants in the wastewater is greatest from the glass/frit manufacturing process group (4.65 kg/functional unit) out of the total manufacturing stage mass of pollutants, which is 4.77 kg/functional unit (Figure 2-32; Table 2-40).

Hazardous wastes from the CRT manufacturing stage were a small portion of the overall hazardous wastes generated by mass. Nonetheless, for purposes of future manufacturing stage improvement assessments, Table 2-41 presents the individual material contributions for each manufacturing process group; and Figure 2-33 shows that fuels production contributes the most (0.62 kg/functional unit) hazardous waste to the manufacturing stage. Manufacturing solid wastes are not as small a portion of the total mass of solid wastes throughout the CRT life-cycle (42%) as hazardous wastes are, as was depicted in Figure 2-21. Fuels production is the greatest contributor to manufacturing-generated solid wastes (71.9 kg/functional unit), followed by PWB manufacturing (4.1 kg/functional unit) (Figure 2-34 and Table 2-43).

Radioactive waste and radioactivity are directly related to the electricity generation process and therefore, only the Japanese and U.S. electric grid processes generate these outputs (some small radioactivity outputs are generated by fuels production processes) in the manufacturing stage. (These outputs also occur in upstream processes that have an electric grid included in the inventory.) Tables 2-44 and 2-45 show that more radioactive wastes and radioactivity are from the Japanese grid. This is a result of more manuf acturing processes as modeled in this project being in Japan.

2.7.1.2 LCD inventory results

The LCD inventory is presented similar to the CRT inventory above. The total LCD inventory presented in Table 2-24 and Figures 2-5, 2-6, and 2-7 shows the inventory from all life-cycle stages combined. The totals by life-cycle stage are presented in Table 2-45, Figure 2-35, Figure 2-36, and Figure 2-37.

Table 2-45. LCD inventory by life-cycle stage

Inventory type	Upstream	Mfg	Use	EOL	Total	Units*
Inputs						
Primary materials	2.35e+02	4.92e+01	8.01e+01	-2.19e+00	3.62e+02	kg
Ancillary materials	1.06e+00	2.04e+02	1.29e+00	2.11e+00	2.08e+02	kg
Water	2.63e+02	2.15e+03	4.25e+02	-1.80e+01	2.82e+03	kg
Fuels	??	??	??	??	0.00e+00	kg (or L)
Electricity	3.46e+01	3.16e+02	8.53e+02	1.62e-01	1.20e+03	MJ
Total energy	6.33e+02	1.44e+03	8.53e+02	-8.44e+01	2.84e+03	MJ
Outputs						
Air pollutants	1.12e+02	6.48e+01	1.68e+02	1.30e+00	3.46e+02	kg
Wastewater	8.57e+00	3.12e+03	0	-2.41e+00	3.13e+03	kg
Water pollutants	4.60e-01	1.23e+00	2.62e-02	-4.09e-02	1.68e+00	kg (or L)
Hazardous waste	6.72e-03	4.64e+00	0	1.64e+00	6.29e+00	kg
Solid waste	1.31e+01	1.26e+01	3.11e+01	-4.42e+00	5.23e+01	kg
Radioactive waste	2.21e+01	3.14e+03	3.11e+01	-5.23e+00	3.19e+03	kg
Radioactivity	1.20e+07	1.02e+07	1.79e+07	3.40e+03	4.01e+07	Bq

*Per functional unit (i.e., one LCD monitor over its effective life)

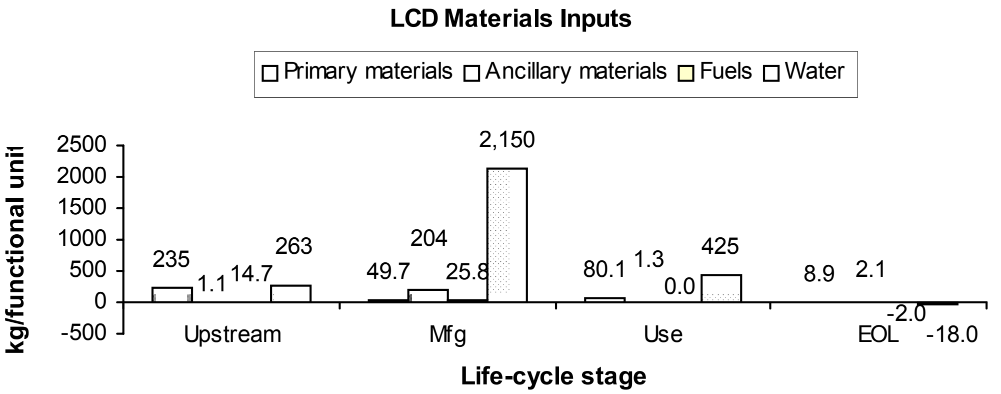

Figure 2-35. LCD mass-based material inputs by life-cycle stage

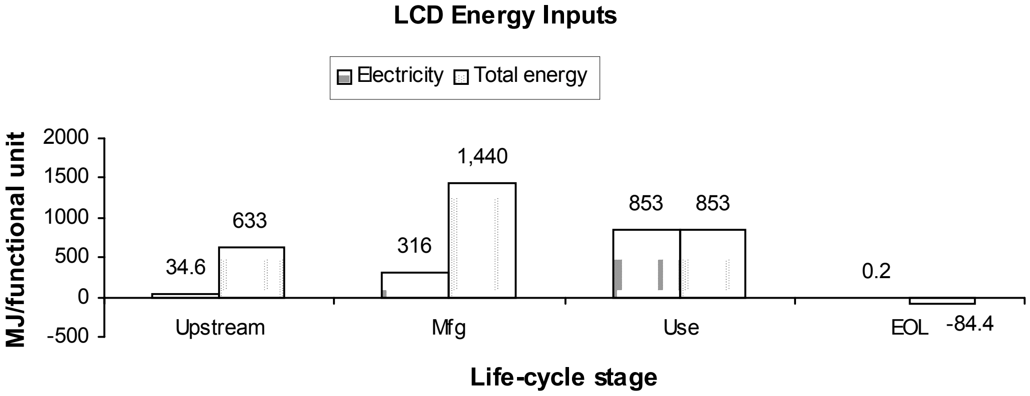

Figure 2-36. LCD energy-based inputs by life-cycle stage

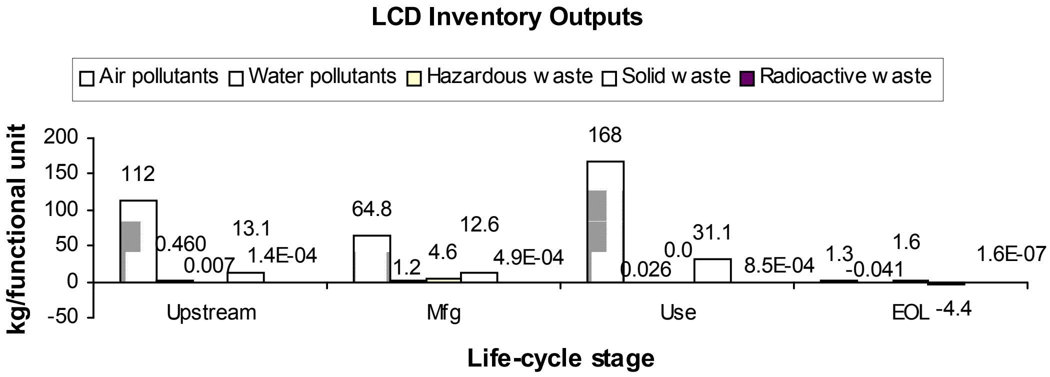

Figure 2-37. LCD mass-based material outputs by life-cycle stage

Considering inputs, Figure 2-35 shows that of the inputs measured in mass, the water inputs constitute the majority of the inputs by mass for the entire life cycle, and most of the water inputs are in the manufacturing life-cycle stage. Details on each inventory type are provided below. When considering which life-cycle stage contributes most to an inventory category, the manufacturing stage has the largest inventory by mass for ancillary materials, fuels, and water inputs. Primary material inputs are dominated by the upstream stages while electricity inputs are dominated by the use stage. The total energy is dominated by the manufacturing life-cycle stage (Figure 2-36). Note that LPG production from glass manufacturing does not dominate much of the LCD inventory as it did for the CRT because of the smaller amount of glass used in the LCD compared to the CRT.

Of the outputs measured in mass (air emissions, wastewater, water pollutants and hazardous, solid, and radioactive waste), wastewater constitutes the greatest output (Table 2-46); however, wastewater alone is not used to calculate impacts. Instead, water pollutants are used to calculate impacts and therefore listed separately in the inventory. Of the remaining outputs measured in mass (i.e., air emissions, water pollutants and hazardous, solid and radioactive waste), which are shown in Figure 2-37, air emissions are the greatest contributor to the outputs. Note again, as mentioned for the CRT, that radioactivity is measured in Bequerels (Bq) and cannot be compared on the same scale.

Considering each output type and their contributions by life-cycle stage, the mass of water pollutants is greatest in the manufacturing life-cycle stage, due to the fuel production processes that support fuel consumption in the manufacturing processes being included in the manufacturing life-cycle stage. Wastewater and hazardous waste outputs are greatest in the manufacturing stage; air emissions, solid waste, radioactive waste, and radioactivity have the greatest contribution from the use stage. As with the CRT, all the output totals represented in Table 2-45 include outputs to all dispositions.

The tables and figures discussed above show the total inventories for particular input or output types by life-cycle stage. Tables in Appendix J list each material that contributes to those totals. Figures 2-38 through 2-50 show the total contribution by life-cycle stage, based on the entire input/output type-specific tables in Appendix J. Summary tables for the LCD (Tables 2-46 through 2-54), developed from the Tables in Appendix J, show the top contributing inventory items to each input or output type. Note that Table 2-48 includes input/output types that are classified together as utilities: water, fuel, electricity and total energy.

LCD Primary Inputs

Figure 2-38 shows that most LCD primary materials by mass are from the upstream life-cycle stages. The top 99.9% of the materials contributing to the total LCD primary input inventory are shown in Table 2-46. The largest material contributors are natural gas, coal and petroleum (a combined 89% of all the primary LCD inputs), which are used to generate electricity consumed throughout the life-cycle of the monitor. Most of the electricity consumed in the LCD life-cycle is in the manufacturing and use stages, as was seen in Figure 2-36. However, most of the natural gas primary material reported in the materials processing stage (229 kg/functional unit) is not used to generate electricity, but is an ancillary material in the LCD monitor/module manufacturing process. More detail on the processes that contribute greatest within the manufacturing stage will be presented after brief discussions of the life-cycle stage breakdowns for each inventory type. For the complete list of primary materials in the LCD inventory, the total mass, and the mass contribution of each life-cycle stage, see Appendix J, Table J-10.

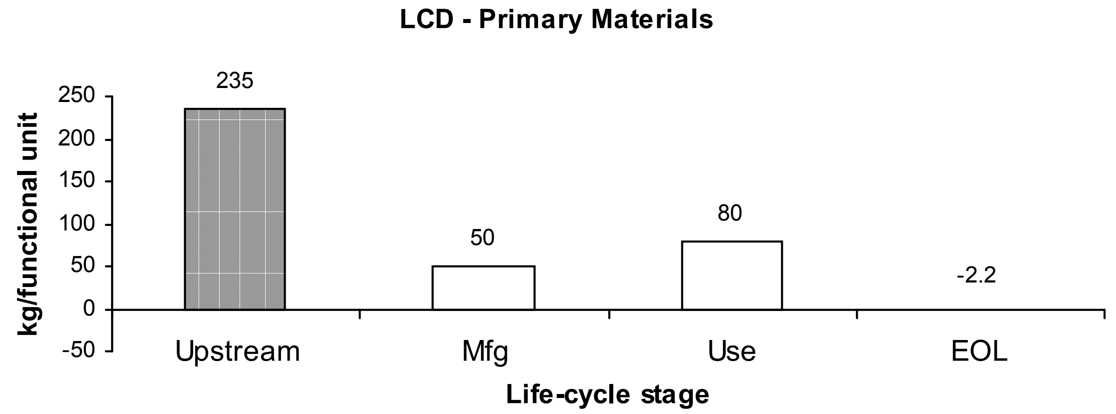

Figure 2-38. LCD primary material inputs by life-cycle stage

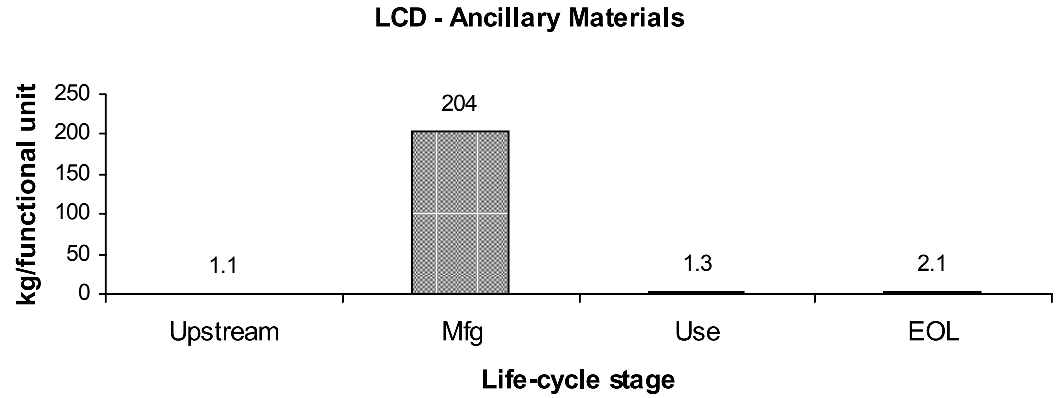

Figure 2-39. LCD ancillary material inputs by life-cycle stage

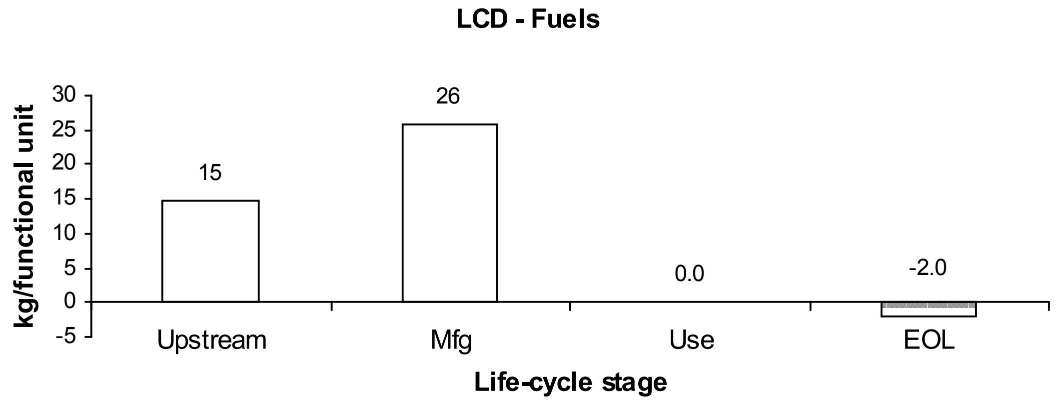

Figure 2-40. LCD fuel inputs by life-cycle stage

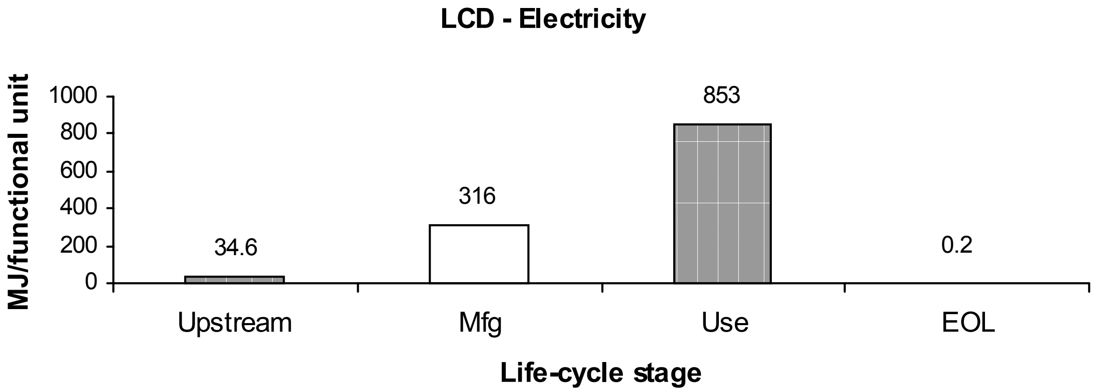

Figure 2-41. LCD electricity inputs by life-cycle stage

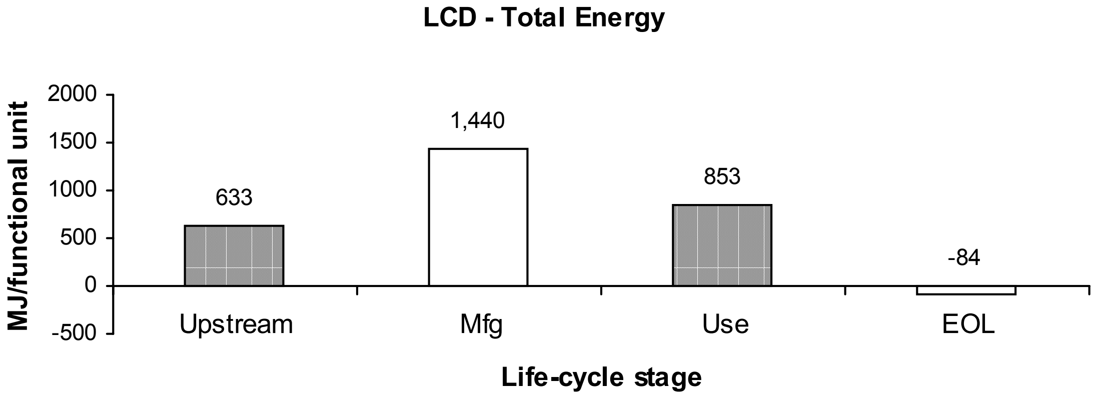

Figure 2-42. LCD energy inputs by life-cycle stage

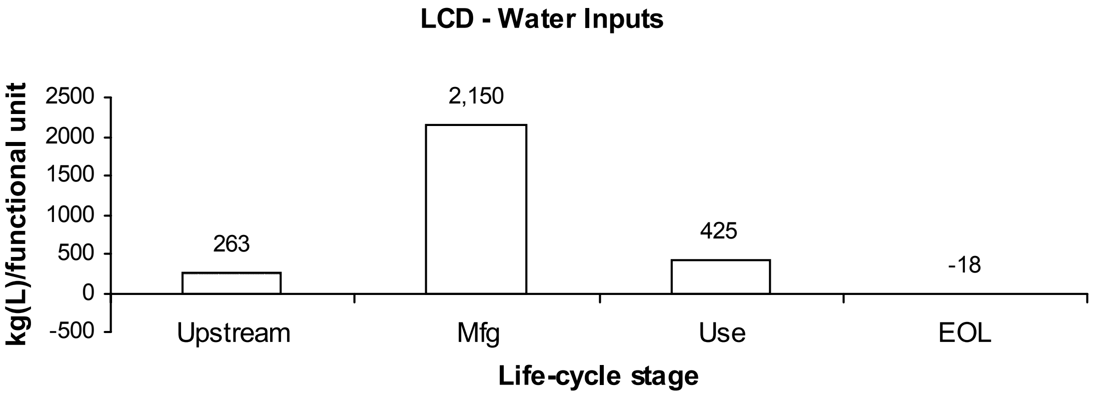

Figure 2-43. LCD water inputs by life-cycle stage

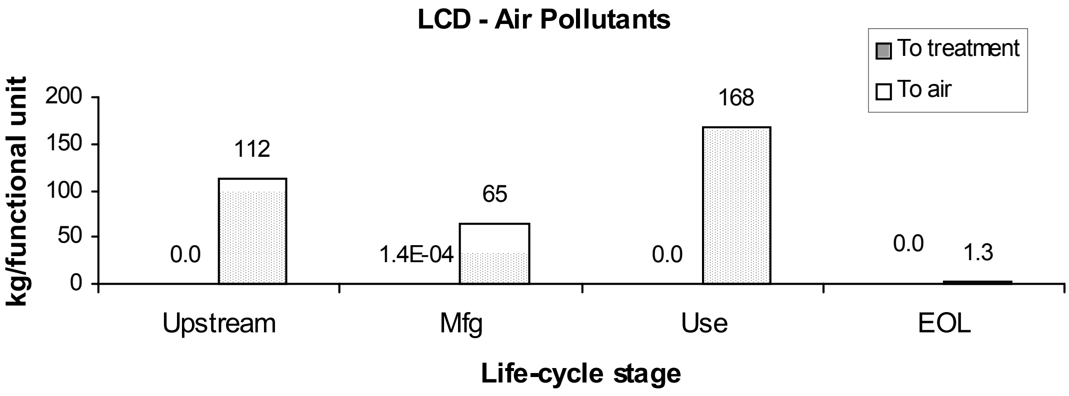

Figure 2-44. LCD air outputs by life-cycle stage

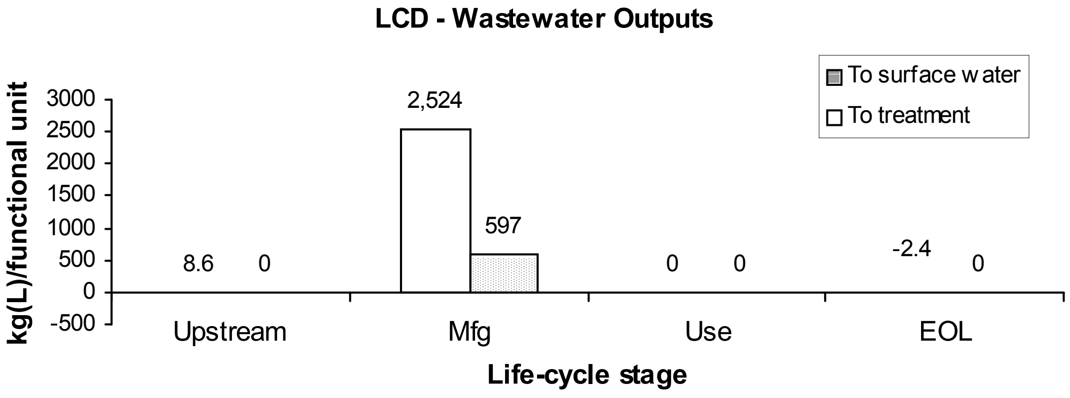

Figure 2-45. LCD wastewater outputs by life-cycle stage

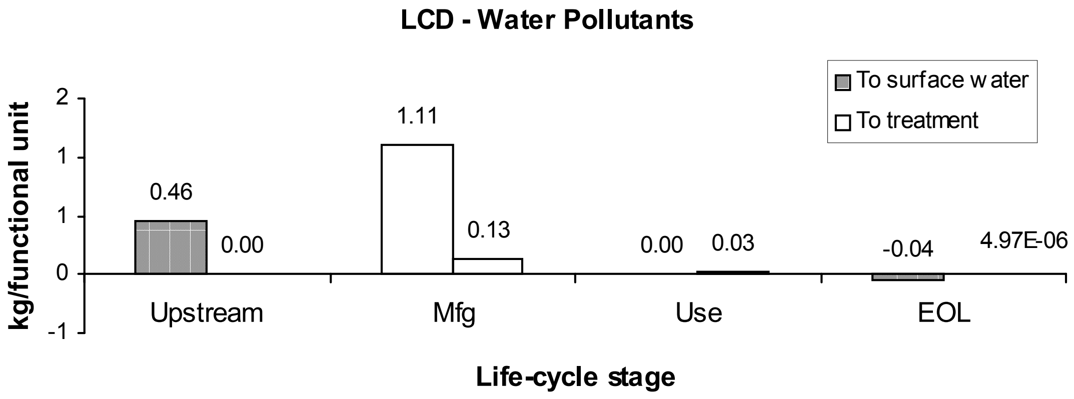

Figure 2-46. LCD water pollutant outputs by life-cycle stage

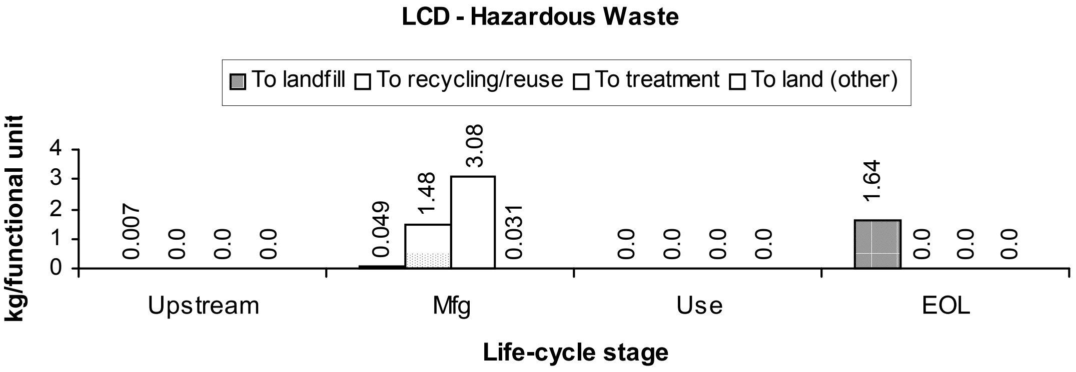

Figure 2-47. LCD hazardous waste outputs by life-cycle stage

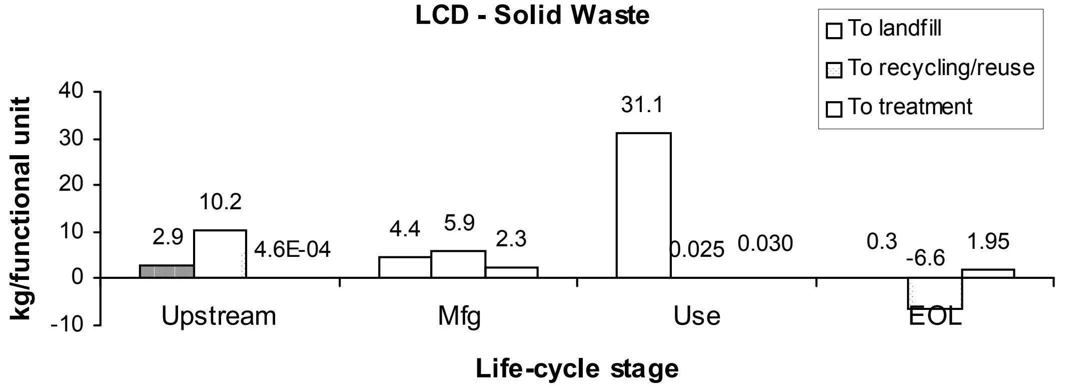

Figure 2-48. LCD solid waste outputs by life-cycle stage

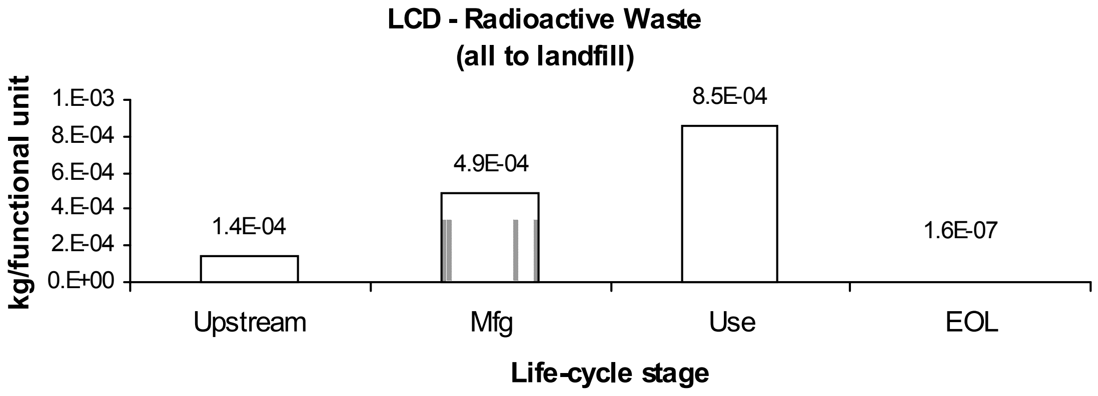

Figure 2-49. LCD radioactive waste outputs by life-cycle stage

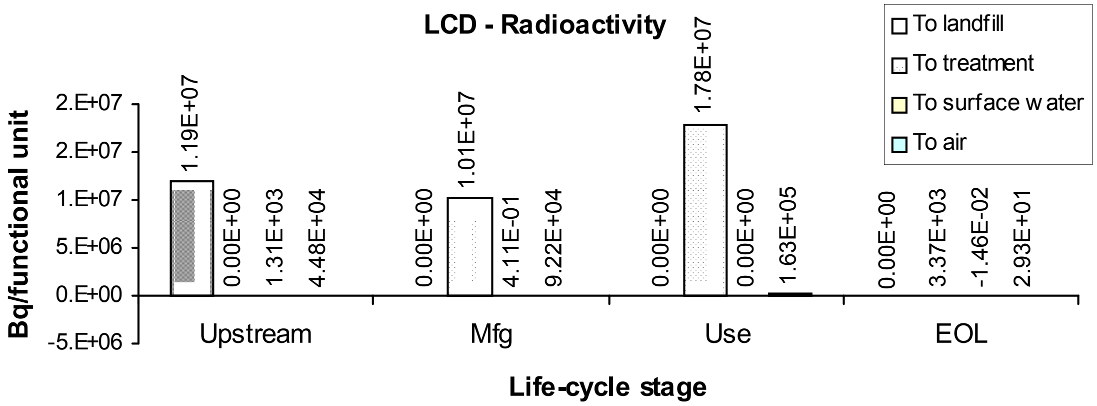

Figure 2-50. LCD radioactivity outputs by life-cycle stage

Table 2-46. Top 99.9% of LCD primary material inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% of total
Natural gas (in ground)	2.29E+02	5.16E+00	0	-1.08E+00	2.33E+02	64.25%
Coal, average (in ground)	1.72E+00	8.03E+00	6.69E+01	1.27E-02	7.67E+01	21.15%
Petroleum (in ground)	7.09E-01	2.23E+01	1.42E+00	-1.00E+00	2.34E+01	6.45%
Natural gas	0	4.22E+00	5.22E+00	-5.75E-02	9.39E+00	2.59%
Assembled LCD monitor	0	0	6.50E+00	0	6.50E+00	1.79%
Iron (Fe, ore)	3.26E+00	0	0	0	3.26E+00	0.90%
Steel	0	2.53E+00	0	0	2.53E+00	0.70%
Assembled 15" LCD backlight unit	0	1.48E+00	0	0	1.48E+00	0.41%
LCD module	0	1.18E+00	0	0	1.18E+00	0.33%
Polycarbonate resin	0	5.16E-01	0	0	5.16E-01	0.14%
Bauxite (Al2O3, ore)	0	5.09E-01	0	0	5.09E-01	0.14%
Iron scrap	4.63E-01	0	0	0	4.63E-01	0.13%
LCD glass	0	4.52E-01	0	0	4.52E-01	0.12%
Poly(methyl methacrylate)	0	3.83E-01	0	0	3.83E-01	0.11%
15" LCD light guide	0	3.74E-01	0	0	3.74E-01	0.10%
PWB-laminate	0	3.74E-01	0	0	3.74E-01	0.10%
Printed wiring board (PWB)	0	3.74E-01	0	0	3.74E-01	0.10%
Styrene-butadiene copolymers	0	3.62E-01	0	0	3.62E-01	0.10%
PPE	0	3.00E-01	0	0	3.00E-01	0.08%
Cables/wires	0	2.34E-01	0	0	2.34E-01	0.06%
LCD front glass (with color filters)	0	1.78E-01	0	0	1.78E-01	0.05%
Aluminum (elemental)	0	1.34E-01	0	0	1.34E-01	0.04%
Sand	0	1.11E-01	0	0	1.11E-01	0.03%
Recycled LCD glass	0	9.54E-02	0	0	9.54E-02	0.03%

LCD Ancillary Inputs

As presented in Figure 2-39, the greatest mass of ancillary LCD inputs is in the manufacturing life-cycle stage at approximately 204 kg/functional unit. Table 2-47 shows that liquified natural gas (LNG) contributes about 93% to this total. It is in the LCD module/monitor manufacturing process where this large amount of LNG was reported as an ancillary material (to be discussed below). Note that this is separate from LNG reported as a fuel, and LNG as an ancillary material is not used to calculate energy impacts in the LCIA. Following LNG is nitrogen at about 3% and clay at less than 1% of the total ancillary materials by mass. Excluding LNG from the inventory, nitrogen constitutes about 50% and clay 14% of the total ancillary materials in the LCD life-cycle. The contributions from the manufacturing stage will be discussed in further detail below. See Table J-11 in Appendix J for the complete list of ancillary materials in the LCD inventory.

Table 2-47. Top 99% of LCD ancillary material inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% of total
LNG	0	1.94e+02	0	0	1.94e+02	93.19%
Nitrogen	0	6.02e+00	0	0	6.02e+00	2.89%
Clay (in ground)	1.30e-03	0	0	1.69e+00	1.69e+00	0.81%
Limestone	0	1.08e-01	8.99e-01	1.71e-04	1.01e+00	0.48%
Sand (in ground)	9.55e-03	1.32e-03	0	5.60e-01	5.71e-01	0.27%
Sodium hydroxide	0	4.45e-01	0	0	4.45e-01	0.21%
Hydrogen	0	4.44e-01	0	0	4.44e-01	0.21%
Lime	0	4.74e-02	3.95e-01	7.49e-05	4.42e-01	0.21%
Sodium chloride (NaCl, in ground or sea)	4.37e-01	6.08e-04	0	1.08e-05	4.38e-01	0.21%
Limestone (CaCO3, in ground)	5.07e-01	5.49e-02	0	-1.55e-01	4.06e-01	0.20%
Isopropyl alcohol	0	3.49e-01	0	0	3.49e-01	0.17%
Sulfuric acid	0	3.25e-01	0	0	3.25e-01	0.16%

LCD Utility Inputs

Utility inputs in the LCD life-cycle are presented in Table 2-48 and include fuel (kg/functional unit), electricity (MJ/functional unit), water inputs (kg or L/functional unit), and total energy (MJ/functional unit; a combination of fuel and electricity inputs). Table 2-48 and Figure 2-40 show that most fuels (26 kg/functional unit) are used in the manufacturing stage. This represents 67% of the total fuels. LPG (16.8 kg/functional unit) dominates the total fuel inputs at 44% of all the fuels in the LCD life-cycle. More detail as to the breakdown by process within the manufacturing stage will be presented below after each input/output type is discussed.

Electricity inputs are dominated by the use stage (853 MJ/functional unit), followed by the manufacturing stage (316 MJ/functional unit) (see Figure 2-41). When fuel energy and electrical energy are combined into a total energy input value, the overall energy from manufacturing exceeds that from the use stage (1,440 MJ/functional unit versus 853 MJ/functional unit). This is also depicted in Figure 2-42.

The other utility considered in Table 2-48 is water (Figure 2-43). Approximately 76% (2,150 L/functional unit) of the water inputs in the LCD life-cycle are from the manufacturing processes. The life-cycle stage contributing the next most to water inputs is the use stage at 15% (425 L/functional unit). The upstream contributes about 9% (263 L/functional unit). Table J-12 in Appendix J provides the complete list of inventory items for the LCD.

Table 2-48. LCD utility inputs

Material	Upstream	Mfg	Use	EOL	Total	% of total
Fuels (kg/functional unit):						
LPG	0	1.68E+01	0	1.38E-03	1.68E+01	43.63%
Natural gas (in ground)	1.03E+01	2.41E+00	0	-1.38E-01	1.26E+01	32.66%
LNG	0	3.22E+00	0	0	3.22E+00	8.34%
Coal, average (in ground)	2.49E+00	6.86E-01	0	-7.66e-03	3.17E+00	8.21%
Petroleum (in ground)	1.52E+00	4.84E-01	0	-3.81e-02	1.96e+00	5.08%
Kerosene	0	4.65E-01	0	0	4.65e-01	1.21%
Coal, lignite (in ground)	4.10E-01	0	0	0	4.10e-01	1.06%
Natural gas	0	1.16E+00	0	-8.61E-01	3.01e-01	0.78%
Steam	0	1.45E-01	0	0	1.45e-01	0.37%
Fuel oil #6	0	1.25E-01	0	0	1.25e-01	0.33%
Fuel oil #2	0	5.42E-02	0	0	5.42e-02	0.14%
Uranium (U, ore)	7.86E-05	1.15E-05	0	0	9.01e-05	<0.01%
Fuel oil #4	0	2.11E-01	0	-9.09e-01	-6.99e-01	-1.81%
Total fuels	1.47E+01	2.58e+01	0	-1.95E+00	3.86e+01	100.00%
Electricity (MJ/functional unit):						
Electricity	3.46e+01	3.16e+02	8.53e+02	1.62e-01	1.20e+03	
Water (kg or L/functional unit):						
Water	2.63E+02	2.15E+03	4.25E+02	-1.80E+01	2.82e+03	
Total energy (fuels and electricity, MJ/functional unit):						
Energy	6.33E+02	1.44E+03	8.53E+02	-8.44E+01	2.84E+03	

LCD Air Outputs

Air emissions from the LCD life-cycle are greatest (by mass) in the use stage as seen in Figure 2-44. This indicates that most air emissions by mass are from the generation of electricity used by consumers of the monitors. Forty-nine percent of the total life-cycle air emissions by mass (or about 168 kg/functional unit) are from the use stage. Carbon dioxide (CO_2) emissions from the use stage alone constitute about 166 kg/functional unit, or almost 48% of all air emissions by mass in the life-cycle and nearly 99% of the use stage air emissions. The remaining air emissions that contribute to the top 99.99% of air emissions are presented in Table 2-49 and the complete list of air emissions are presented alphabetically in Table J-13 in Appendix J. The appendix also provides life-cycle stage subtotals. The next largest air emissions, by life-cycle stage, are emitted during the upstream stages, which contribute about 32% to the total life-cycle air emissions. All the air emissions in the inventory except for ethylacetate and methyl ethyl ketone from the manufacturing stage (a combined 1.36×10^{-4} kg/functional unit) were reported as being emitted directly to the air (see Appendix J, Table J-13). Only those materials directly released to the air are used to calculate impacts. This will be discussed further in Chapter 3.

Table 2-49. Top 99.99% of LCD air emissions (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of total
Carbon dioxide	Air	1.07e+02	6.22e+01	1.66e+02	1.39e+00	3.36e+02	97.18%
Methane	Air	3.54e+00	1.22e-01	2.41e-01	-2.82e-02	3.87e+00	1.12%
Nitrogen oxides	Air	6.56e-01	7.62e-01	4.39e-01	-1.36e-02	1.84e+00	0.53%
Sulfur dioxide	Air	4.63e-02	2.95e-01	9.30e-01	2.96e-04	1.27e+00	0.37%
Tetramethyl ammonium	Air	0	6.43e-01	0	0	6.43e-01	0.19%
Other organics	Air	4.45e-01	1.35e-02	0	-2.41e-03	4.56e-01	0.13%
Carbon monoxide	Air	3.74e-01	3.85e-02	3.02e-02	-3.45e-03	4.39e-01	0.13%
Nitrogen fluoride	Air	0	2.45e-01	0	0	2.45e-01	0.07%
Nonmethane hydrocarbons	Air	2.07e-01	8.87e-03	0	-1.26e-03	2.15e-01	0.06%
Hydrochloric acid	Air	1.50e-03	6.58e-02	4.02e-02	-6.88e-04	1.07e-01	0.03%
Benzene	Air	8.85e-02	2.70e-03	4.36e-05	-4.82e-04	9.07e-02	0.03%
PM	Air	9.16e-02	6.99e-03	0	-1.24e-02	8.62e-02	0.02%
Ammonia	Air	1.12e-02	6.26e-02	0	-6.95e-05	7.37e-02	0.02%
Phosphine	Air	0	6.26e-02	0	0	6.26e-02	0.02%
Hydrofluoric acid	Air	2.27e-04	5.27e-02	5.02e-03	-1.47e-04	5.78e-02	0.02%
Sulfur oxides	Air	2.57e-02	4.07e-02	0	-1.93e-02	4.71e-02	0.01%
Unspecified LCD process	Air	0	4.49e-02	0	0	4.49e-02	0.01%
Cr-etchant, unspecified	Air	0	4.12e-02	0	0	4.12e-02	0.01%
Nitrogen dioxide	Air	3.08e-02	0	0	4.46e-04	3.12e-02	<0.01%
PM-10	Air	3.45e-07	6.85e-03	2.16e-02	3.43e-06	2.84e-02	<0.01%
Isopropyl alcohol	Air	0	1.78e-02	0	0	1.78e-02	<0.01%
Hydrocarbons, remaining	Air	9.30e-03	7.75e-03	0	-6.51e-04	1.64e-02	<0.01%
Al-etchant, unspecified	Air	0	1.37e-02	0	0	1.37e-02	<0.01%

LCD Water Outputs

The volume (or mass) of wastewater released throughout the LCD life-cycle is approximately 3,128 L (kg) per functional unit. Approximately 19% of that is sent to treatment as opposed to direct discharge to surface water (81%; Figure 2-45). The mass of chemical pollutants within the wastewater streams were calculated separately from the total wastewater volume. The total mass of water pollutants released, presented by life-cycle stage are shown in Figure 2-46. Of the small amount of water pollutants released, the manufacturing life-cycle stage contributes the greatest with approximately 1.23 kg per functional unit. This is about 73% of all the water pollutants for the entire life-cycle. The upstream stages have the second greatest mass of water pollutants at nearly 0.46 kg/functional unit (27%). The use and EOL stages are small contributors, with the EOL being negative due to recovery processes within the EOL stage. To see the top 99% contributors to the water pollutant quantities, Table 2-50 reveals that chloride and sodium ions contribute nearly 61% to all the water pollutants in the life-cycle, mostly from the manufacturing and upstream stages. For the complete inventory, listing water pollutants alphabetically and by life-cycle stage, see Appendix J, Table J-14. Further details on the manufacturing stage will be provided later.

Table 2-50. Top 99% of LCD water pollutant outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of total
Chloride ions	surface water	2.33e-01	3.12e-01	0	-1.58e-02	5.29e-01	31.53%
Sodium (+1)	surface water	1.73e-01	3.41e-01	0	-2.03e-02	4.94e-01	29.42%
Dissolved solids	surface water	3.21e-03	1.75e-01	0	-5.69e-05	1.78e-01	10.63%
COD	surface water	7.67e-03	8.20e-02	0	-2.69e-03	8.70e-02	5.18%
Nitrogen	surface water	1.44e-05	7.98e-02	0	0	7.98e-02	4.76%
Suspended solids	surface water	4.98e-03	5.80e-02	0	-1.44e-03	6.15e-02	3.66%
BOD	treatment	0	5.74e-02	0	0	5.74e-02	3.42%
COD	treatment	0	3.90e-02	0	0	3.90e-02	2.33%
BOD	surface water	7.72e-04	2.79e-02	0	-3.18e-04	2.83e-02	1.69%
Sulfate ion (-4)	surface water	2.40e-02	2.94e-03	0	-1.20e-06	2.69e-02	1.60%
Sulfate ion (-4)	treatment	0	1.32e-04	2.55e-02	4.84e-06	2.57e-02	1.53%
Fluorides (F-)	surface water	5.14e-05	1.29e-02	0	-5.01e-06	1.30e-02	0.77%
Nitrogen	treatment	0	1.26e-02	0	0	1.26e-02	0.75%
Phosphorus (yellow or white)	treatment	0	6.91e-03	0	0	6.91e-03	0.41%
Waste oil	surface water	1.75e-03	4.87e-03	0	-2.06e-04	6.41e-03	0.38%
Suspended solids	treatment	0	5.60e-03	6.65e-04	1.26e-07	6.26e-03	0.37%
Phosphorus (yellow or white)	surface water	1.92e-06	4.33e-03	0	0	4.33e-03	0.26%
Colon bacillus (bacteria in large intestine)	surface water	0	3.89e-03	0	0	3.89e-03	0.23%
Oil & grease	treatment	0	3.61e-03	0	0	3.61e-03	0.21%

LCD Hazardous Waste Outputs

The total mass of hazardous waste generated throughout the life-cycle of the LCD is about 6.29 kg/functional unit. Figure 2-47 shows that this is mostly from the manufacturing stage, which contributes 4.64 kg/functional unit, or almost 74%. The EOL stage hazardous waste outputs equal 1.64 kg/functional unit, or 26%. The disposition of the waste will be used to determine how impacts are calculated in Chapter 3. Only hazardous wastes sent to landfills are directly calculated as impacts, which will be presented and discussed in Chapter 3. Figure 2-47 shows what portion of hazardous wastes are landfilled, recycled/reused, treated or otherwise land-applied. Nearly all of the hazardous waste in the manufacturing stage (~99%) is recycled/reused or treated. Less than 1% of the hazardous waste from the manufacturing stage is landfilled. Nearly all the hazardous waste from the EOL stage is landfilled. Table 2-51 shows the top contributors to the LCD life-cycle. Note that multiple entries of a material are due to different dispositions for that material. See Table J-15 in Appendix J for the complete alphabetical inventory of hazardous waste outputs. Additional detail on the manufacturing stage are presented below.

Table 2-51. Top 99% of LCD hazardous waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of total
Isopropyl alcohol	treatment	0	1.91E+00	0	0	1.91E+00	30.41%
EOL LCD Monitor, landfilled	landfill	0	0	0	1.64E+00	1.64E+00	26.13%
Waste acid (mainly HF)	recycling/reuse	0	5.69E-01	0	0	5.69E-01	9.04%
Thinner, unspecified	treatment	0	5.40E-01	0	0	5.40E-01	8.57%
Remover, unspecified	treatment	0	3.03E-01	0	0	3.03E-01	4.81%
Sodium sulfate	recycling/reuse	0	2.44E-01	0	0	2.44E-01	3.89%
Isopropyl alcohol	recycling/reuse	0	1.69E-01	0	0	1.69E-01	2.69%
Tetramethyl ammonium hydroxide	recycling/reuse	0	1.42E-01	0	0	1.42E-01	2.26%
Waste acid (mainly HF)	treatment	0	1.36E-01	0	0	1.36E-01	2.15%
PWB-Waste cupric etchant	recycling/reuse	0	9.93E-02	0	0	9.93E-02	1.58%
Remover, unspecified	recycling/reuse	0	8.84E-02	0	0	8.84E-02	1.40%
Hazardous waste, unspecified	treatment	0	6.16E-02	0	0	6.16E-02	0.98%
Rinse, unspecified	recycling/reuse	0	4.67E-02	0	0	4.67E-02	0.74%
Spent solvent (non-halogenated)	treatment	0	4.66E-02	0	0	4.66E-02	0.74%
Hazardous waste, unspecified	landfill	6.72E-03	2.97E-02	0	-1.05E-03	3.54E-02	0.56%
Waste acids, unspecified	recycling/reuse	0	3.24E-02	0	0	3.24E-02	0.52%
Unspecified sludge	land (other than landfill)	0	3.09E-02	0	0	3.09E-02	0.49%
PWB-Solder dross	recycling/reuse	0	2.96E-02	0	0	2.96E-02	0.47%
Acetone	treatment	0	2.77E-02	0	0	2.77E-02	0.44%
Waste solvent (photoresist)	treatment	0	2.17E-02	0	0	2.17E-02	0.35%
Waste solvent (photoresist)	recycling/reuse	0	2.05E-02	0	0	2.05E-02	0.33%
Spent solvent (with halogenated materials)	treatment	0	1.55E-02	0	0	1.55E-02	0.25%
Phosphoric acid	landfill	0	1.44E-02	0	0	1.44E-02	0.23%

LCD Solid Waste Outputs

Figure 2-48 shows that the use stage contributes the most amount (31 kg/functional unit) of solid waste by mass to the LCD life-cycle, and 100% of that waste is landfilled. The manufacturing stage contributes 12.6 kg/functional unit. In terms of mass, the greatest material contributors to the solid waste outputs for the LCD life-cycle are coal waste (~41%), followed by dust/sludge (16%). Most of this is from the generation of electricity in the use stage (Table 2-52). Note also that the mass of an LCD monitor that is assumed to be landfilled (0.89 kg/functional unit) is 1.7% of the total mass of solid waste in the LCD life-cycle. See Appendix J, Table J-16 for the complete LCD solid waste inventory. The manufacturing stage breakdown will be discussed at the end of this section.

Table 2-52. Top 99% of LCD solid waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of total
Coal waste	landfill	0	2.28E+00	1.90E+01	3.60E-03	2.13E+01	40.64%
Dust/sludge	landfill	0	8.80E-01	7.34E+00	1.39E-03	8.23E+00	15.72%
Fly/bottom ash	landfill	0	5.70E-01	4.75E+00	9.01E-04	5.32E+00	10.16%
Unspecified solid waste	landfill	2.40E+00	0	0	-5.10E-01	1.89E+00	3.62%
Slag and ash	recycle/reuse	8.02E+00	3.40E+00	0	-9.67E+00	1.75E+00	3.35%
Unspecified solid waste	recycle/reuse	1.50E+00	2.11E-01	0	0	1.71E+00	3.27%
Unspecified solid waste	treatment	0	1.63E+00	0	0	1.63E+00	3.11%
Iron scrap	recycle/reuse	1.67E-01	0	0	1.10E+00	1.27E+00	2.42%
EOL LCD Monitor, incinerated	treatment	0	0	0	9.75E-01	9.75E-01	1.86%
EOL LCD Monitor, recycled	recycle/reuse	0	0	0	9.75E-01	9.75E-01	1.86%
EOL LCD Monitor, remanufactured	recycle/reuse	0	0	0	9.75E-01	9.75E-01	1.86%
EOL LCD Monitor, landfilled	landfill	0	0	0	8.94E-01	8.94E-01	1.71%
Unspecified sludge	recycle/reuse	0	8.46E-01	0	0	8.46E-01	1.62%
Waste LCD glass	recycle/reuse	0	7.20E-01	0	0	7.20E-01	1.38%
Unspecified waste	recycle/reuse	4.05E-01	1.72E-01	0	-9.83E-03	5.67E-01	1.08%
CARBON STEEL SCRAP	recycle/reuse	0	0	0	4.58E-01	4.58E-01	0.88%
Waste plastic from LCD modules	treatment	0	4.03E-01	0	0	4.03E-01	0.77%
Polycarbonate	recycle/reuse	0	0	0	3.90E-01	3.90E-01	0.75%
Waste alkali, unspecified	recycle/reuse	0	3.23E-01	0	0	3.23E-01	0.62%
Waste acid (containing F and detergents)	landfill	0	2.70E-01	0	0	2.70E-01	0.52%
Waste LCD glass	landfill	0	2.63E-01	0	0	2.63E-01	0.50%
Mineral waste	landfill	2.20E-01	1.26E-04	0	-4.46E-06	2.21E-01	0.42%
Mining waste	landfill	1.41E-01	0	0	-1.23E-06	1.41E-01	0.27%
Slag and ash	landfill	8.19E-02	3.49E-02	0	-1.99E-03	1.15E-01	0.22%
Waste acids, unspecified	treatment	0	1.05E-01	0	0	1.05E-01	0.20%
Mixed industrial (waste)	landfill	4.34E-02	4.83E-02	0	-1.35E-03	9.04E-02	0.17%
Waste alkali (color filter developer, unspecified)	recycle/reuse	0	8.91E-02	0	0	8.91E-02	0.17%

LCD Radioactive Waste Outputs

Radioactive waste outputs in the LCD inventory are limited to the electricity generation and steel production processes, with steel production processes accounting for only about 9% of the total. Therefore, radioactive wastes will be found wherever electricity is used in a process in the LCD life-cycle. Only very small amounts (approximately 0.0015 kg/functional unit) of radioactive waste are generated over the entire life-cycle of the LCD (Figure 2-49 and Table 2-53). As expected, the majority of this is linked to the use stage, where most electricity is used in the LCD life-cycle, followed by the manufacturing stage. Low-level radioactive waste (78%) and depleted uranium (21%) are most of the waste, with negligible amounts of highly radioactive waste and unspecified radioactive waste. The inventory of radioactive waste outputs is small, and therefore, Table 2-53 lists all material outputs associated with radioactive waste, in descending order of quantity. Table J-17 in Appendix J lists these in alphabetical order.

Table 2-53. LCD radioactive waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of total
Low-level radioactive waste	landfill	1.28E-04	3.74E-04	6.56E-04	1.24E-07	1.16E-03	78.49%
Uranium, depleted	landfill	0	1.12E-04	1.97E-04	3.73E-08	3.09E-04	20.93%
Radioactive waste (unspecified)	landfill	5.77E-06	0	0	0	5.77E-06	0.39%
Highly radioactive waste (Class C)	landfill	2.72E-06	0	0	0	2.72E-06	0.18%
Total radioactive wastes		1.37E-04	4.87E-04	8.52E-04	1.62E-07	1.48E-03	100.00%

LCD Radioactivity Outputs

Radioactivity is also inventoried in this project as isotopes that are released to the environment. Radioactivity is measured in Bequerels and may be released to air, water, or land, or may also be treated. The quantity of radioactivity for each life-cycle stage and different dispositions are presented in Figure 2-50. Table 2-54 shows the top contributors to the total radioactivity outputs. Radioactivity outputs are associated with the generation of electricity and, therefore, the greatest quantity of radioactivity is from the use stage. Appendix J, Table J-18 lists the complete inventory.

Table 2-54. Top 99.9% of LCD radioactivity outputs (Bq/functional unit)

Material	Disposition	Upstream	Mfg.	Use	EOL	Total	% of total
Molybdenum-99 (isotope)	treatment	0	1.01e+07	1.76e+07	3.35e+03	2.77e+07	69.09%
Plutonium-241 (isotope)	landfill	1.18e+07	0	0	0	1.18e+07	29.33%
Tritium-3 (isotope)	treatment	0	5.96e+04	1.04e+05	1.98e+01	1.64e+05	0.41%
Xenon-133 (isotope)	air	7.63e+02	4.98e+03	1.16e+05	2.21e+01	1.22e+05	0.30%
Xenon-133M (isotope)	air	0	6.59e+04	7.73e+03	1.47e+00	7.36e+04	0.18%
Plutonium-240 (isotope)	landfill	5.08e+04	0	0	0	5.08e+04	0.13%
Cesium-135 (isotope)	landfill	4.59e+04	0	0	0	4.59e+04	0.11%
Radon-222 (isotope)	air	4.30e+04	0	0	0	4.30e+04	0.11%
Plutonium-239 (isotope)	landfill	3.57e+04	0	0	0	3.57e+04	0.09%
Xenon-133 (isotope)	treatment	0	9.43e+03	1.65e+04	3.13e+00	2.60e+04	0.06%
Tritium-3 (isotope)	air	1.09e+02	7.98e+03	1.40e+04	2.65e+00	2.21e+04	0.05%
Krypton-85 (isotope)	air	5.45e+01	5.64e+03	9.88e+03	1.88e+00	1.56e+04	0.04%

LCD Manufacturing Stage

The inventory tables that show the specific materials in each inventory (i.e., those in Appendix J and Tables 2-46 through 2-54) are the sums of the materials from one or more processes within a life-cycle stage. To burrow down deeper into the data, the manufacturing stage inventory data are broken down by process or group of processes. Similar to the CRT analysis, groups of processes were combined where fewer than three companies provided data for a process or where confidentiality agreements precluded presenting individual process data (Table 2-55). Burrowing further into the contributing processes or process groups is necessary for future manufacturing improvement assessments.

Table 2-55. LCD process groups

Process group	Process(es) included
Monitor/module	panel/module manufacturing, monitor assembly
Panel components	polarizer manufacturing, patterning color filters on glass, liquid crystal manufacturing
LCD glass	LCD glass manufacturing
Backlight	backlight unit assembly, backlight light guide, cold cathode fluorescent lamp manufacturing
PWB	PWB manufacturing
Japanese grid	electricity generation - Japanese electric grid
U.S. grid	electricity generation - U.S. electric grid
Fuels	production of fuel oils #2, #4 and #6, LPG, and natural gas

Tables 2-56 through 2-64 list the specific inventories for each process group in the manufacturing stage for each input and output type. Figures 2-51 through 2-61 graph the total inventories for each process group for each input and output type. As revealed in Table 2-45, ancillary material inputs, fuels, water and total energy inputs all were greatest in the manufacturing stage. Similarly, wastewater, water pollutant and hazardous waste outputs were also greatest in the manufacturing stage. Similar to the discussion for CRTs, the manufacturing stage inventories by process group, for all input and output types, are presented here to reveal more specifics about the inventory and to allow manufacturers to conduct improvement assessments.

Table 2-56. LCD manufacturing stage primary material inputs

Material	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Module/Monitor			
1,4-butanolide	4.06e-04	0.01%	
1-methyl-2-pyrrolidinone	4.06e-04	0.04%	
2-(2-butoxyethoxy)-ethanol acetate	8.08e-06	<0.01%	
AlNd	2.97e-05	<0.01%	
Aluminum (elemental)	1.01e-01	1.34%	
Assembled 15" LCD backlight unit	1.48e+00	19.67%	
Cables/wires	2.30e-01	3.07%	
Glycol ethers	4.06e-04	0.01%	
Indium tin oxide	5.26e-04	0.01%	
LCD front glass (with color filters)	1.78e-01	2.38%	
LCD glass	2.16e-01	2.88%	
LCD material (confidential)	3.11e-04	<0.01%	
LCD module	1.18e+00	15.78%	
LCD spacers, unspecified	1.69e-05	<0.01%	
Liquid crystals, for 15" LCD	1.24e-03	0.02%	
Mild fiber	7.34e-07	<0.01%	
Molybdenum	1.78e-04	<0.01%	
MoW	9.09e-04	0.01%	
Polarizer	4.07e-02	0.54%	
Polycarbonate resin	4.01e-01	5.35%	
Polyimide alignment layer, unspecified	4.86e-04	0.01%	
PPE	3.00e-01	4.00%	
Printed wiring board (PWB)	3.74e-01	4.98%	
Solder (60% tin, 40% lead)	3.81e-02	0.51%	
Steel	2.50e+00	33.38%	
Styrene-butadiene copolymers	3.62e-01	4.82%	
Titanium	1.33e-04	<0.01%	
Triallyl isocyanurate	1.54e-05	<0.01%	
Triphenyl phosphate	9.25e-02	1.23%	
Unspecified LCD material	1.19e-04	<0.01%	
Total	**7.50e+00**	100.00%	**15.26%**
Panel Components			
3,4,5-trifluorobromobenzene	2.64e-04	0.08%	
3,4-difluorobromobenzene	3.65e-04	0.04%	
4-4(-propylcyclohexyl)cyclohexanone	2.18e-04	0.07%	
4-bromophenol	3.27e-04	0.10%	
4-ethylphenol	7.00e-05	0.02%	
4-pentylphenol	3.42e-04	0.11%	
4-propionylphenol	1.94e-04	0.06%	
LCD glass	2.36e-01	74.75%	
Pigment color resist, unspecified	3.72e-02	11.80%	

Table 2-56. LCD manufacturing stage primary material inputs

Material	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Polyester adhesive	6.25e-04	0.20%	
Polyethylene terephthalate	3.14e-02	9.96%	
Polyvinyl alcohol	8.61e-03	2.73%	
Total	**3.16e-01**	100.00%	**0.64%**
Glass mfg			
Barium Carbonate	1.37e-02	4.90%	
Glass, unspecified	2.28e-03	0.23%	
Potassium Carbonate	1.75e-02	6.24%	
Recycled LCD glass	9.54e-02	34.00%	
Sand	1.11e-01	39.64%	
Sodium Carbonate	2.26e-02	8.05%	
Strontium Carbonate	1.53e-02	5.47%	
Zircon Sand	2.51e-03	0.90%	
Total	**2.81e-01**	99.42%	**0.57%**
Backlight			
15" LCD light guide	3.74e-01	37.18%	
Aluminum (elemental)	3.35e-02	3.35%	
Argon	3.53e-05	<0.01%	
Backlight lamp (CCFL)	1.94e-03	0.19%	
Cables/wires	3.43e-03	0.34%	
Glass, unspecified	4.14e-02	4.11%	
Mercury	3.99e-06	<0.01%	
Metals, remaining unspeciated	6.81e-04	0.07%	
Neon	6.31e-05	0.01%	
Poly(methyl methacrylate)	3.83e-01	38.12%	
Polycarbonate resin	1.14e-01	11.38%	
Polyethylene terephthalate	2.74e-02	2.72%	
Rubber, unspecified	6.01e-04	0.06%	
Steel	2.52e-02	2.50%	
Total	**1.01e+00**	100.04%	**2.04%**
PWB			
PWB-laminate	3.74e-01	94.35%	
Solder (63% tin; 37% lead)	2.24e-02	5.66%	
Total	**3.96e-01**	100.00%	**0.81%**
Japanese Grid			
Coal, average (in ground)	7.69e+00	47.41%	
Natural gas	4.20e+00	25.89%	
Petroleum (in ground)	4.33e+00	26.69%	
Uranium, yellowcake	1.02e-03	0.01%	
Total	**1.62e+01**	100.00%	**32.96%**
U.S. Grid			
Coal, average (in ground)	3.47e-01	90.97%	

Table 2-56. LCD manufacturing stage primary material inputs

Material	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Natural gas	2.71e-02	7.10%	
Petroleum (in ground)	7.36e-03	1.93%	
Uranium, yellowcake	9.39e-06	<0.01%	
Total	**3.82e-01**	100.01%	**0.78%**
Fuel Production			
Natural gas (in ground)	5.16e+00	22.33%	
Petroleum (in ground)	1.79e+01	77.67%	
Total	**2.31e+01**	100.00%	**46.94%**
Grand Total	**4.92e+01**		**100.00%**

Table 2-57. LCD manufacturing stage ancillary material inputs

Material	**Quantity(kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Module/Monitor			
1,4-butanolide	4.04e-05	6.91%	
1-Methoxy-2-propanol	1.10e-02	100.00%	
2-(2-butoxyethoxy)-ethanol	3.04e-02	0.02%	
2,2,4-trimethylpentane	1.52e-05	<0.01%	
2-ethoxyl ethylacetate	1.78e-03	<0.01%	
Acetic acid	6.40e-03	<0.01%	
Acetone	1.03e-02	0.01%	
Al-etchant, unspecified	5.88e-03	<0.01%	
Aluminum sulfate	1.05e-01	0.05%	
Ammonia	1.55e-02	0.01%	
Ammonium bifluoride	2.36e-03	<0.01%	
Ammonium fluoride	1.14e-02	0.01%	
Ammonium hydroxide	5.15e-06	<0.01%	
Argon	7.87e-03	<0.01%	
Calcium hydroxide	1.39e-01	0.07%	
Carbon dioxide	3.74e-05	<0.01%	
Chlorine	1.55e-02	0.01%	
Cleaner, unspecified	1.47e-04	<0.01%	
Cresol-formaldehyde resin	8.29e-04	<0.01%	
Cr-etchant, unspecified	1.77e-02	0.01%	
Cyclohexane	2.03e-05	<0.01%	
Dimethylsulfoxide	6.63e-02	0.03%	
Ethanol	1.35e-02	0.01%	
Ethanol amine	7.85e-02	0.04%	
Ferric chloride	8.92e-03	<0.01%	
Fluorocarbon resin	3.38e-06	<0.01%	
Flux, unspecified	7.35e-05	<0.01%	
Glycol ethers	2.12e-02	0.01%	
Helium	6.18e-04	<0.01%	
Hexamethyldisilizane	2.58e-04	<0.01%	
Hydrochloric acid	4.31e-02	0.02%	
Hydrofluoric acid	4.21e-02	0.02%	
Hydrogen	4.44e-01	0.22%	
Hydrogen peroxide	1.47e-04	<0.01%	
Isopropyl alcohol	3.49e-01	0.17%	
ITO etchant, unspecified	2.94e-03	<0.01%	
Krypton	2.58e-05	<0.01%	
LNG	1.94e+02	95.80%	
Methyl ethyl ketone	7.35e-06	<0.01%	
Monosilane	1.12e-03	<0.01%	
N-Butylacetate	3.83e-02	0.02%	

Table 2-57. LCD manufacturing stage ancillary material inputs

Material	Quantity(kg/ functional unit)	% of process group total	% of grand total
Process Group			
Nitric acid	1.24e-02	0.01%	
Nitrogen	5.90e+00	2.91%	
Nitrogen fluoride	1.08e-01	0.05%	
Nitrous oxide	1.36e-03	<0.01%	
Oxygen	7.75e-03	<0.01%	
Perfluoromethane	1.29e-03	<0.01%	
Phosphine	2.69e-02	0.01%	
Phosphoric acid	3.95e-02	0.02%	
Photoresist, unspecified	1.38e-02	0.01%	
Polyaluminum chloride	6.40e-03	<0.01%	
Polyethylene mono(nonylphenyl) ether glycol	3.40e-04	<0.01%	
Polyimide, unspecified	2.94e-05	<0.01%	
Propylene glycol	4.46e-03	<0.01%	
Propylene glycol monomethyl ether acetate	1.56e-02	0.01%	
Rinse, unspecified	5.27e-02	0.03%	
Sodium dihydrogen phosphate dihydrate	4.06e-06	<0.01%	
Sodium hydroxide	3.59e-01	0.18%	
Solder, unspecified	7.35e-05	<0.01%	
Sulfur hexafluoride	1.62e-02	0.01%	
Sulfuric acid	2.29e-01	0.11%	
Surfactant, unspecified	1.09e-04	<0.01%	
Synthetic resin, unspecified	6.57e-04	<0.01%	
Tetramethyl ammonium hydroxide	1.29e-01	0.06%	
Unspecified LCD process material	2.58e-02	0.01%	
Water	6.88e-02	0.03%	
Xylene (mixed isomers)	1.57e-03	<0.01%	
Total	**2.03e+02**	**206.91%**	**99.48%**
Panel Components			
Acetone	1.03e-02	3.19%	
Borax	9.13e-05	0.01%	
Carbon dioxide	4.82e-03	1.50%	
Cyclohexane	3.89e-03	1.21%	
Developing solution, unspecified	4.00e-02	12.45%	
Diluent, unspecified	8.27e-03	2.57%	
Ethanol	1.17e-02	3.65%	
Ethylacetate	9.68e-04	0.30%	
Exfoliation liquid, unspecified	1.43e-02	4.44%	
HCFC-225ca	1.37e-04	0.04%	
HCFC-225cb	1.37e-04	0.04%	
Heptane	1.03e-02	3.19%	
Hydrochloric acid	1.74e-03	0.54%	
Hydrogen	3.14e-06	<0.01%	

Table 2-57. LCD manufacturing stage ancillary material inputs

Material	**Quantity(kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Methyl ethyl ketone	4.84e-04	0.15%	
Nitric acid second cerium ammonium	1.13e-02	3.51%	
Nitrogen	1.17e-01	36.27%	
Orthoboric acid	7.30e-04	0.23%	
Perchloric acid	3.82e-03	1.19%	
Photoresist, unspecified	2.94e-03	0.91%	
Polyethylene terephthalate	3.20e-02	9.93%	
Sulfuric acid	1.58e-02	4.91%	
Tetrahydrofuran	3.82e-03	1.19%	
Toluene	2.75e-02	8.56%	
Total	**3.22e-01**	99.99%	**0.16%**
LCD Glass			
Aluminum Oxide	1.56e-03	17.30%	
Cerium Oxide	1.52e-04	1.68%	
Chromium Oxide	2.60e-06	0.03%	
Hydrofluoric acid	3.66e-03	40.61%	
Pumice	3.64e-03	40.37%	
Total	**9.02e-03**	100.00%	**0.00%**
Backlight			
Diethyl ether	9.28e-05	14.78%	
Ethanol	4.63e-05	7.36%	
Process material for backlight assembly	7.03e-05	11.19%	
Unspecified ancillary material	4.19e-04	66.67%	
Total	**6.28e-04**	100.00%	**0.00%**
PWB			
Ammonium chloride	3.42e-02	6.68%	
Ammonium hydroxide	3.42e-02	3.42%	
Formaldehyde	2.91e-03	0.57%	
Glycol ethers	1.04e-02	2.03%	
Hydrochloric acid	8.46e-02	16.51%	
Hydrogen peroxide	1.37e-02	2.67%	
Nitric acid	5.99e-02	11.70%	
Polyethylene glycol	2.23e-02	4.34%	
Potassium hydroxide	1.88e-02	3.68%	
Potassium permanganate	5.14e-04	0.10%	
Potassium peroxymonosulfate	3.12e-02	6.08%	
PWB-solder mask solids	1.93e-02	3.76%	
Sodium Carbonate	1.42e-02	2.77%	
Sodium hydroxide	8.56e-02	16.71%	
Sulfuric acid	8.05e-02	15.72%	
Total	**5.12e-01**	96.74%	**0.25%**
Japanese Grid			

Table 2-57. LCD manufacturing stage ancillary material inputs

Material	**Quantity(kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Lime	4.53e-02	30.57%	
Limestone	1.03e-01	69.43%	
Total	**1.48e-01**	100.00%	**0.07%**
U.S. Grid			
Lime	2.05e-03	30.52%	
Limestone	4.66e-03	69.48%	
Total	**6.71e-03**	100.00%	**0.00%**
Fuel Production			
Bauxite (Al2O3, ore)	2.16e-03	3.66%	
Limestone (CaCO3, in ground)	5.49e-02	93.07%	
Sand (in ground)	1.32e-03	2.24%	
Sodium chloride (NaCl, in ground or in sea)	6.08e-04	1.03%	
Total	**5.90e-02**	100.00%	**0.03%**
Grand Total	**2.04e+02**		**100.00%**

Table 2-58. LCD manufacturing stage utility inputs

Material	**Quantity**	**% of process group total**	**% of grand total**
Process group			
Fuels (kg/functional unit):			
Monitor/Module			
Fuel oil #4	2.11e-01	4.09%	
Kerosene	2.98e-01	5.77%	
LNG	3.22e+00	62.40%	
Liquified petroleum gas (LPG)	5.83e-01	11.30%	
Natural gas	8.48e-01	16.44%	
Total	**5.16e+00**	95.91%	**20.13%**
Panel Components			
Kerosene	1.68e-01	31.97%	
Natural gas	1.18e-07	<0.01%	
Steam (100 psig)	1.45e-01	27.56%	
Fuel oil #2	4.07e-04	0.08%	
Fuel oil #6	1.25e-01	23.91%	
Natural gas	8.64e-02	16.47%	
Total	**5.25e-01**	68.03%	**2.05%**
LCD glass			
Fuel oil #2	5.38e-02	0.33%	
Liquified petroleum gas (LPG)	1.62e+01	99.33%	
Natural gas	5.63e-02	0.34%	
Total	**1.64e+01**	100.00%	**63.87%**
Backlight			
LNG	4.17e-06	50.00%	
Natural gas	4.17e-06	50.00%	
Total	**8.33e-06**	200.00%	**0.00%**
PWB			
Natural gas	**??**		**ERR**
Fuels			
Coal, average (in ground)	6.86e-01	19.19%	
Natural gas (in ground)	2.41e+00	67.27%	
Petroleum (in ground)	4.84e-01	13.54%	
Uranium (U, ore)	1.15e-05	<0.01%	
Total	**3.58e+00**	100.00%	**13.96%**
Grand Total	**2.56e+01**		**100.00%**
Electricity (MJ/functional unit):			
Monitor/Module	2.59e+02		**81.80%**
Panel Components	4.64e+01		**14.70%**
LCD glass	2.20e+00		**0.70%**
Backlight	4.46e+00		**1.41%**
PWB	4.43e+00		**1.40%**
Total	**3.16e+02**		**100.00%**

Table 2-58. LCD manufacturing stage utility inputs

Material	**Quantity**	**% of process group total**	**% of grand total**
Process group			
Water (kg or L/functional unit):			
Monitor/Module	1.08e+03		**49.96%**
Panel Components	2.08e+02		**9.66%**
LCD glass	1.62e+00		**0.08%**
Backlight	1.92e+02		**8.91%**
PWB	1.86e+01		**0.86%**
Japanese electric grid	1.49e+02		**6.91%**
U.S. electric grid	2.20e+00		**0.10%**
Fuels	5.07e+02		**23.53%**
Total	**2.15e+03**		**100.00%**
Total energy (fuels and electricity, MJ/functional unit):			
Monitor/Module	5.08e+02		**35.36%**
Panel Components	6.29e+01		**4.38%**
LCD glass	7.05e+02		**49.03%**
Backlight	4.46e+00		**0.31%**
PWB	1.21e+01		**0.84%**
Fuels	1.45e+02		**10.09%**
Total	**1.44e+03**		**100.00%**

Table 2-59. LCD manufacturing stage air outputs

Material	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Module/Monitor			
Acetic acid	1.36e-03	0.07%	
Acetone	1.86e-04	0.02%	
Al-etchant, unspecified	1.37e-02	0.75%	
Ammonia	6.23e-02	3.41%	
Argon	5.80e-03	0.32%	
Carbon dioxide	2.16e-03	0.12%	
Cr-etchant, unspecified	4.12e-02	2.25%	
Cyclohexane	4.85e-05	<0.01%	
Diethylene glycol	9.69e-05	0.01%	
Hexamethyldisilizane	1.37e-06	<0.01%	
Hydrochloric acid	6.06e-02	3.31%	
Hydrofluoric acid	5.21e-02	2.85%	
Hydrogen	1.33e-04	0.01%	
Isopropyl alcohol	1.78e-02	0.97%	
ITO etchant, unspecified	6.86e-03	0.38%	
Monosilane	1.54e-03	0.08%	
N-bromoacetamide	9.18e-03	0.50%	
Nitric acid	2.69e-04	0.01%	
Nitrogen fluoride	2.45e-01	13.43%	
Nitrogen oxides	5.48e-01	30.00%	
Phosphine	6.26e-02	3.43%	
Phosphoric acid	4.85e-05	<0.01%	
PM	1.10e-05	<0.01%	
Polyimide, unspecified	1.40e-04	0.01%	
Sulfur hexafluoride	7.30e-03	0.40%	
Sulfur oxides	1.12e-03	0.06%	
Tetramethyl ammonium hydroxide	6.43e-01	35.16%	
Unspecified LCD process material	4.49e-02	2.46%	
Total	**1.83e+00**	100.00%	**2.82%**
Panel Components			
Carbon dioxide	4.82e-03	81.79%	
Ethylacetate	2.44e-06	<0.01%	
HCFC-225ca	1.40e-04	2.37%	
HCFC-225cb	1.40e-04	2.37%	
Heptane	7.77e-05	1.32%	
Hydrochloric acid	7.32e-06	0.12%	
Methyl ethyl ketone	1.35e-04	2.29%	
Nitrogen oxides	4.11e-04	6.98%	
Nonmethane hydrocarbons, remaining unspeciated	7.77e-05	1.32%	
PM	2.74e-05	0.47%	
Toluene	5.44e-05	0.92%	

Table 2-59. LCD manufacturing stage air outputs

Material	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Total	**5.89e-03**	100.00%	**0.01%**
LCD Glass			
Carbon dioxide	1.30e-01	98.45%	
Carbon monoxide	2.07e-07	<0.01%	
Chromium	6.40e-09	<0.01%	
Nitrogen oxides	2.04e-03	1.55%	
PM	5.06e-06	<0.01%	
Sulfur oxides	2.36e-06	<0.01%	
Total	**1.32e-01**	100.03%	**0.20%**
Backlight			
Diethyl ether	9.26e-05	0.31%	
Ethanol	4.63e-05	0.16%	
Nitrogen oxides	2.95e-02	99.29%	
Process material for backlight assembly	7.03e-05	0.24%	
Total	**2.97e-02**	100.00%	**0.05%**
PWB			
Formaldehyde	**1.71e-05**		**0.00%**
Japanese Grid			
1,1,1-Trichloroethane	2.17e-07	<0.01%	
1,2-Dichloroethane	1.54e-07	<0.01%	
2,3,7,8-TCDD	5.65e-14	<0.01%	
2,3,7,8-TCDF	1.96e-13	<0.01%	
2,4-Dinitrotoluene	1.07e-09	<0.01%	
2-Chloroacetophenone	2.69e-08	<0.01%	
2-Methylnaphthalene	8.00e-10	<0.01%	
5-Methyl chrysene	8.46e-11	<0.01%	
Acenaphthene	1.45e-08	<0.01%	
Acenaphthylene	1.11e-09	<0.01%	
Acetaldehyde	2.19e-06	<0.01%	
Acetophenone	5.77e-08	<0.01%	
Acrolein	1.11e-06	<0.01%	
Anthracene	1.53e-09	<0.01%	
Antimony	3.20e-06	<0.01%	
Arsenic	2.36e-06	<0.01%	
Barium	1.74e-06	<0.01%	
Benzene	5.13e-06	<0.01%	
Benzo[a]anthracene	2.69e-09	<0.01%	
Benzo[a]pyrene	1.46e-10	<0.01%	
Benzo[b,j,k]fluoranthene	1.31e-09	<0.01%	
Benzo[g,h,i]perylene	1.45e-09	<0.01%	
Benzyl chloride	2.69e-06	<0.01%	
Beryllium	1.09e-07	<0.01%	

Table 2-59. LCD manufacturing stage air outputs

Material	Quantity (kg/ functional unit)	% of process group total	% of grand total
Process Group			
Biphenyl	6.53e-09	<0.01%	
Bromoform	1.50e-07	<0.01%	
Bromomethane	6.15e-07	<0.01%	
Cadmium	4.74e-07	<0.01%	
Carbon dioxide	5.18e+01	99.14%	
Carbon disulfide	5.00e-07	<0.01%	
Carbon monoxide	9.43e-03	0.02%	
Chloride ions	2.07e-04	<0.01%	
Chlorobenzene	8.46e-08	<0.01%	
Chloroform	2.27e-07	<0.01%	
Chromium (III)	1.86e-06	<0.01%	
Chromium (VI)	4.51e-07	<0.01%	
Chrysene	1.80e-09	<0.01%	
Cobalt	3.98e-06	<0.01%	
Copper	1.07e-06	<0.01%	
Cumene hydroperoxide	2.04e-08	<0.01%	
Cyanide (-1)	9.61e-06	<0.01%	
Di(2-ethylhexyl)phthalate	2.81e-07	<0.01%	
Dibenzo[a,h]anthracene	9.95e-10	<0.01%	
Dichloromethane	1.11e-06	<0.01%	
Dimethyl sulfate	1.85e-07	<0.01%	
Dioxins, remaining unspeciated	2.51e-12	<0.01%	
Ethyl Chloride	1.61e-07	<0.01%	
Ethylbenzene	3.99e-07	<0.01%	
Ethylene dibromide	4.61e-09	<0.01%	
Fluoranthene	5.88e-09	<0.01%	
Fluorene	6.15e-09	<0.01%	
Fluorides (F-)	2.22e-05	<0.01%	
Formaldehyde	3.43e-05	<0.01%	
Furans, remaining unspeciated	4.00e-12	<0.01%	
Hexane	2.58e-07	<0.01%	
Hydrochloric acid	4.61e-03	0.01%	
Hydrofluoric acid	5.77e-04	<0.01%	
Indeno(1,2,3-cd)pyrene	1.51e-09	<0.01%	
Isophorone	2.23e-06	<0.01%	
Lead (Pb, ore)	1.48e-06	<0.01%	
Magnesium	4.23e-05	<0.01%	
Manganese (Mn, ore)	3.67e-06	<0.01%	
Mercury	3.97e-07	<0.01%	
Methane	2.73e-04	<0.01%	
Methyl chloride	2.04e-06	<0.01%	

Table 2-59. LCD manufacturing stage air outputs

Material	Quantity (kg/ functional unit)	% of process group total	% of grand total
Process Group			
Methyl ethyl ketone	1.50e-06	<0.01%	
Methyl hydrazine	6.54e-07	<0.01%	
Methyl methacrylate	7.69e-08	<0.01%	
Methyl tert-butyl ether	1.34e-07	<0.01%	
Molybdenum	5.20e-07	<0.01%	
Naphthalene	7.44e-07	<0.01%	
Nickel	4.95e-05	<0.01%	
Nitrogen oxides	1.37e-01	0.26%	
Nitrous oxide	3.76e-04	<0.01%	
o-xylene	6.49e-08	<0.01%	
Phenanthrene	1.75e-08	<0.01%	
Phenol	6.15e-08	<0.01%	
PM-10	6.72e-03	0.01%	
Propionaldehyde	1.46e-06	<0.01%	
Pyrene	4.24e-09	<0.01%	
Selenium	5.40e-06	<0.01%	
Styrene	9.61e-08	<0.01%	
Sulfur dioxide	2.90e-01	0.56%	
Tetrachloroethylene	1.65e-07	<0.01%	
TOCs, remaining unspeciated	6.63e-04	<0.01%	
Toluene	4.81e-06	<0.01%	
Vanadium	1.92e-05	<0.01%	
Vinyl acetate	2.92e-08	<0.01%	
Xylene (mixed isomers)	1.42e-07	<0.01%	
Zinc (elemental)	1.73e-05	<0.01%	
Total	**5.22e+01**	100.84%	**80.58%**
U.S. Grid			
1,1,1-Trichloroethane	3.71e-09	<0.01%	
1,2-Dichloroethane	6.95e-09	<0.01%	
2,3,7,8-TCDD	2.48e-15	<0.01%	
2,3,7,8-TCDF	8.86e-15	<0.01%	
2,4-Dinitrotoluene	4.86e-11	<0.01%	
2-Chloroacetophenone	1.22e-09	<0.01%	
2-Methylnaphthalene	5.16e-12	<0.01%	
5-Methyl chrysene	3.82e-12	<0.01%	
Acenaphthene	1.10e-10	<0.01%	
Acenaphthylene	4.37e-11	<0.01%	
Acetaldehyde	9.90e-08	<0.01%	
Acetophenone	2.60e-09	<0.01%	

Table 2-59. LCD manufacturing stage air outputs

Material	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Acrolein	5.04e-08	<0.01%	
Anthracene	3.77e-11	<0.01%	
Antimony	8.45e-09	<0.01%	
Arsenic	7.26e-08	<0.01%	
Barium	3.98e-09	<0.01%	
Benzene	2.26e-07	<0.01%	
Benzo[a]anthracene	1.80e-11	<0.01%	
Benzo[a]pyrene	6.60e-12	<0.01%	
Benzo[b,j,k]fluoranthene	2.06e-11	<0.01%	
Benzo[g,h,i]perylene	6.98e-12	<0.01%	
Benzyl chloride	1.22e-07	<0.01%	
Beryllium	3.69e-09	<0.01%	
Biphenyl	2.95e-10	<0.01%	
Bromoform	6.77e-09	<0.01%	
Bromomethane	2.78e-08	<0.01%	
Cadmium	9.33e-09	<0.01%	
Carbon dioxide	8.61e-01	98.98%	
Carbon disulfide	2.26e-08	<0.01%	
Carbon monoxide	1.57e-04	0.02%	
Chloride ions	3.52e-07	<0.01%	
Chlorobenzene	3.82e-09	<0.01%	
Chloroform	1.02e-08	<0.01%	
Chromium (III)	4.71e-08	<0.01%	
Chromium (VI)	1.40e-08	<0.01%	
Chrysene	1.98e-11	<0.01%	
Cobalt	2.35e-08	<0.01%	
Copper	1.93e-09	<0.01%	
Cumene	9.20e-10	<0.01%	
Cyanide (-1)	4.34e-07	<0.01%	
Di(2-ethylhexyl)phthalate	1.27e-08	<0.01%	
Dibenzo[a,h]anthracene	1.69e-12	<0.01%	
Dichloromethane	5.04e-08	<0.01%	
Dimethyl sulfate	8.33e-09	<0.01%	
Dioxins, remaining unspeciated	1.13e-13	<0.01%	
Ethyl Chloride	7.29e-09	<0.01%	
Ethylbenzene	1.64e-08	<0.01%	
Ethylene dibromide	2.08e-10	<0.01%	
Fluoranthene	1.30e-10	<0.01%	
Fluorene	1.63e-10	<0.01%	

Table 2-59. LCD manufacturing stage air outputs

Material	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Fluoride	3.78e-08	<0.01%	
Formaldehyde	1.64e-07	<0.01%	
Furans, remaining unspeciated	1.80e-13	<0.01%	
Hexane	1.16e-08	<0.01%	
Hydrochloric acid	2.08e-04	0.02%	
Hydrofluoric acid	2.60e-05	<0.01%	
Indeno(1,2,3-cd)pyrene	1.28e-11	<0.01%	
Isophorone	1.01e-07	<0.01%	
Lead	2.47e-08	<0.01%	
Magnesium	1.91e-06	<0.01%	
Manganese	8.83e-08	<0.01%	
Mercury	1.45e-08	<0.01%	
Methane	1.25e-03	0.14%	
Methyl chloride	9.20e-08	<0.01%	
Methyl ethyl ketone	6.77e-08	<0.01%	
Methyl hydrazine	2.95e-08	<0.01%	
Methyl methacrylate	3.47e-09	<0.01%	
Methyl tert-butyl ether	6.08e-09	<0.01%	
Molybdenum	1.13e-09	<0.01%	
Naphthalene	3.54e-09	<0.01%	
Nickel	1.33e-07	<0.01%	
Nitrogen oxides	2.28e-03	0.26%	
Nitrous oxide	6.58e-06	<0.01%	
o-xylene	1.10e-10	<0.01%	
Phenanthrene	4.85e-10	<0.01%	
Phenol	2.78e-09	<0.01%	
Phosphorus (yellow or white)	9.59e-09	<0.01%	
PM-10	1.12e-04	0.01%	
Propionaldehyde	6.60e-08	<0.01%	
Pyrene	6.45e-11	<0.01%	
Selenium	2.26e-07	<0.01%	
Styrene	4.34e-09	<0.01%	
Sulfur dioxide	4.83e-03	0.56%	
Tetrachloroethylene	7.47e-09	<0.01%	
TOCs, remaining unspeciated	1.12e-05	<0.01%	
Toluene	4.92e-08	<0.01%	
Vanadium	3.41e-08	<0.01%	
Vinyl acetate	1.32e-09	<0.01%	
Xylene (mixed isomers)	6.42e-09	<0.01%	

Table 2-59. LCD manufacturing stage air outputs

Material	Quantity (kg/ functional unit)	% of process group total	% of grand total
Process Group			
Zinc (elemental)	2.95e-08	<0.01%	
Total	**8.70e-01**	100.83%	**1.34%**
Fuel Production			
1,1,1-Trichloroethane	6.91e-09	<0.01%	
1,2-Dichloroethane	1.38e-08	<0.01%	
1,4-Dichlorobenzene	1.89e-08	<0.01%	
2,4-Dinitrotoluene	9.68e-11	<0.01%	
2-Chloroacetophenone	2.42e-09	<0.01%	
3-Methylcholanthrene	2.84e-11	<0.01%	
5-Methyl chrysene	7.60e-12	<0.01%	
Acenaphthene	2.77e-10	<0.01%	
Acenaphthylene	1.16e-10	<0.01%	
Acetaldehyde	1.97e-07	<0.01%	
Acetophenone	5.18e-09	<0.01%	
Acrolein	1.00e-07	<0.01%	
Aldehydes	8.98e-05	<0.01%	
Aluminum (elemental)	9.59e-07	<0.01%	
Ammonia	3.53e-04	<0.01%	
Anthracene	1.15e-10	<0.01%	
Antimony	1.15e-10	<0.01%	
Aromatic hydrocarbons	2.55e-09	<0.01%	
Arsenic	7.13e-07	<0.01%	
Barium	1.77e-08	<0.01%	
Benzene	2.70e-03	0.03%	
Benzo[a]anthracene	6.97e-11	<0.01%	
Benzo[a]pyrene	3.84e-11	<0.01%	
Benzo[b,j,k]fluoranthene	3.80e-11	<0.01%	
Benzo[b]fluoranthene	3.09e-11	<0.01%	
Benzo[g,h,i]perylene	3.21e-11	<0.01%	
Benzo[k]fluoranthene	3.09e-11	<0.01%	
Benzyl chloride	2.42e-07	<0.01%	
Beryllium	7.31e-08	<0.01%	
Biphenyl	5.88e-10	<0.01%	
Bromoform	1.35e-08	<0.01%	
Bromomethane	5.53e-08	<0.01%	
Butane	3.31e-05	<0.01%	
Cadmium	4.18e-08	<0.01%	
Calcium	8.31e-07	<0.01%	
Carbon dioxide	9.44e+00	97.19%	

Table 2-59. LCD manufacturing stage air outputs

Material	Quantity (kg/ functional unit)	% of process group total	% of grand total
Process Group			
Carbon disulfide	4.49e-08	<0.01%	
Carbon monoxide	2.89e-02	0.30%	
Chloride ions	1.75e-06	<0.01%	
Chlorine	1.01e-09	<0.01%	
Chlorobenzene	7.60e-09	<0.01%	
Chloroform	2.04e-08	<0.01%	
Chromium (III)	1.05e-06	<0.01%	
Chromium (VI)	1.05e-06	<0.01%	
Chrysene	6.70e-11	<0.01%	
Cobalt	1.27e-07	<0.01%	
Copper	7.98e-08	<0.01%	
Cumene	1.83e-09	<0.01%	
Cyanide (-1)	8.64e-07	<0.01%	
Di(2-ethylhexyl)phthalate	2.52e-08	<0.01%	
Dibenzo[a,h]anthracene	2.18e-11	<0.01%	
Dichloromethane	1.00e-07	<0.01%	
Dimethyl sulfate	1.66e-08	<0.01%	
Dimethylbenzanthracene	2.36e-10	<0.01%	
Dioxins, remaining unspeciated	5.60e-12	<0.01%	
Ethane	4.88e-05	<0.01%	
Ethyl Chloride	1.45e-08	<0.01%	
Ethylbenzene	3.28e-08	<0.01%	
Ethylene dibromide	4.15e-10	<0.01%	
Fluoranthene	3.01e-10	<0.01%	
Fluorene	3.66e-10	<0.01%	
Fluorides (F-)	1.98e-07	<0.01%	
Formaldehyde	5.78e-05	<0.01%	
Furans, remaining unspeciated	2.60e-11	<0.01%	
Halogenated hydrocarbons (unspecified)	1.42e-14	<0.01%	
HALON-1301	2.47e-11	<0.01%	
Hexane	2.84e-05	<0.01%	
Hydrocarbons, remaining unspeciated	7.75e-03	0.08%	
Hydrochloric acid	4.15e-04	<0.01%	
Hydrofluoric acid	5.18e-05	<0.01%	
Hydrogen sulfide	1.51e-04	<0.01%	
Indeno(1,2,3-cd)pyrene	5.31e-11	<0.01%	
Iron	1.85e-06	<0.01%	
Isophorone	2.00e-07	<0.01%	
Lead	6.39e-07	<0.01%	

Table 2-59. LCD manufacturing stage air outputs

Material	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group			
Magnesium	3.80e-06	<0.01%	
Manganese	1.15e-06	<0.01%	
Mercury	4.55e-08	<0.01%	
Metals, remaining unspeciated	1.60e-08	<0.01%	
Methane	1.20e-01	1.24%	
Methyl chloride	1.83e-07	<0.01%	
Methyl ethyl ketone	1.35e-07	<0.01%	
Methyl hydrazine	5.88e-08	<0.01%	
Methyl methacrylate	6.91e-09	<0.01%	
Methyl tert-butyl ether	1.21e-08	<0.01%	
Molybdenum	9.92e-08	<0.01%	
Naphthalene	1.98e-08	<0.01%	
Nickel	6.06e-06	<0.01%	
Nitrogen oxides	4.27e-02	0.44%	
Nitrous oxide	8.13e-04	0.01%	
Nonmethane hydrocarbons, remaining unspeciated	8.79e-03	0.09%	
n-Propane	8.67e-08	<0.01%	
Other organics	1.35e-02	0.14%	
o-xylene	1.59e-07	<0.01%	
Pentane	4.10e-05	<0.01%	
Phenanthrene	1.22e-09	<0.01%	
Phenol	5.53e-09	<0.01%	
Phosphorus (yellow or white)	6.10e-07	<0.01%	
PM	6.95e-03	0.07%	
PM-10	1.11e-05	<0.01%	
Polycyclic aromatic hydrocarbons	2.84e-12	<0.01%	
Propionaldehyde	1.31e-07	<0.01%	
Pyrene	2.00e-10	<0.01%	
Selenium	4.81e-07	<0.01%	
Silicon	8.31e-07	<0.01%	
Sodium	4.92e-06	<0.01%	
Styrene	8.64e-09	<0.01%	
Sulfur oxides	3.96e-02	0.41%	
Tetrachloroethylene	1.49e-08	<0.01%	
Toluene	2.63e-07	<0.01%	
Vanadium	1.30e-05	<0.01%	
Vinyl acetate	2.63e-09	<0.01%	
Zinc (elemental)	6.04e-07	<0.01%	
Total	**9.72e+00**	101.01%	**15.00%**

Table 2-59. LCD manufacturing stage air outputs

Material	Quantity (kg/ functional unit)	% of process group total	% of grand total
Process Group			
Grand Total	6.48e+01		100.00%

Table 2-60. LCD manufacturing stage water outputs

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group				
WASTEWATER STREAMS				
Module/monitor	both	2.87e+03		**91.80%**
Panel components	both	3.53e-01		**0.01%**
LCD glass	surface water	1.67e+00		**0.05%**
Backlight	both	1.92e+02		**6.15%**
PWB	treatment	1.86e+01		**0.60%**
Fuels	surface water	4.33e+01		**1.39%**
Total		**3.12e+03**		**100.00%**
WATER POLLUTANTS				
Module/monitor				
1,1,1-Trichloroethane	surface water	2.29e-08	<0.01%	
Antimony	surface water	1.14e-07	<0.01%	
Arsenic	surface water	1.14e-07	<0.01%	
BOD	surface water	1.74e-02	6.69%	
BOD	treatment	5.05e-02	19.41%	
Boron	surface water	4.58e-06	<0.01%	
Cadmium	surface water	1.14e-07	<0.01%	
Chromium	surface water	8.84e-06	<0.01%	
Chromium (VI)	surface water	2.29e-07	<0.01%	
COD	surface water	2.68e-03	1.03%	
COD	treatment	3.90e-02	14.99%	
Colon bacillus (bacteria in large intestine)	surface water	3.89e-03	1.50%	
Copper	surface water	9.18e-07	<0.01%	
Cyanide (-1)	surface water	3.66e-06	<0.01%	
Cyanide (-1)	treatment	6.67e-07	<0.01%	
Dissolved solids	surface water	7.55e-03	2.90%	
Fluorides (F-)	surface water	1.28e-02	4.91%	
Fluorides (F-)	treatment	2.40e-04	0.09%	
Hexane	surface water	5.88e-04	0.23%	
Iron	surface water	2.63e-06	<0.01%	
Lead	surface water	6.17e-06	<0.01%	
Manganese	surface water	2.29e-07	<0.01%	
Mercury	surface water	9.69e-08	<0.01%	
Nickel	surface water	2.29e-07	<0.01%	
Nitrogen	surface water	7.93e-02	30.45%	
Nitrogen	treatment	1.16e-02	4.45%	
Oil & grease	surface water	2.02e-04	0.08%	
Oil & grease	treatment	3.53e-03	1.35%	
Organic phosphorus, unspecified	surface water	2.29e-07	<0.01%	
Phenol	surface water	2.29e-07	<0.01%	
Phosphorus (yellow or white)	surface water	4.31e-03	1.65%	
Phosphorus (yellow or white)	treatment	6.91e-03	2.65%	

Table 2-60. LCD manufacturing stage water outputs

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group				
Polychlorinated biphenyls	surface water	1.14e-08	<0.01%	
Suspended solids	surface water	1.55e-02	5.96%	
Suspended solids	treatment	4.26e-03	1.64%	
Tetrachloroethylene	surface water	2.29e-08	<0.01%	
Tin	surface water	4.58e-07	<0.01%	
Trichloroethylene	surface water	2.29e-08	<0.01%	
Zinc (elemental)	surface water	2.63e-06	<0.01%	
Total		**2.60e-01**	100.21%	**21.11%**
Panel components				
BOD	surface water	1.34e-03	15.44%	
BOD	treatment	3.89e-03	44.73%	
Borax	treatment	1.31e-06	0.02%	
COD	surface water	2.21e-03	25.45%	
Hydrochloric acid	treatment	3.29e-06	0.04%	
Nitrogen	surface water	5.71e-04	6.58%	
Orthoboric acid	treatment	1.31e-06	0.02%	
Phosphorus (yellow or white)	surface water	2.48e-05	0.29%	
Suspended solids	surface water	6.46e-04	7.43%	
Total		**8.69e-03**	100.00%	**0.70%**
LCD glass				
BOD	surface water	3.80e-07	<0.01%	
Chloride ions	surface water	4.68e-02	21.73%	
Chromium	surface water	3.80e-09	<0.01%	
COD	surface water	3.80e-07	<0.01%	
Dissolved solids	surface water	1.68e-01	77.84%	
Fluorides (F-)	surface water	1.36e-04	0.06%	
Iron	surface water	1.28e-04	0.06%	
Lead	surface water	2.01e-06	<0.01%	
Nickel	surface water	3.80e-09	<0.01%	
Nitrate	surface water	1.83e-07	<0.01%	
Oil & grease	surface water	3.34e-04	0.16%	
Suspended solids	surface water	3.35e-04	0.16%	
Total		**2.15e-01**	100.00%	**17.46%**
Backlight				
BOD	treatment	3.00e-03	54.50%	
Iron	treatment	8.33e-05	1.51%	
Lead	treatment	8.33e-07	0.02%	
Mercury	treatment	8.33e-08	<0.01%	
Nickel	treatment	3.33e-06	0.06%	
Nitrogen	treatment	1.00e-03	18.17%	
Oil & grease	treatment	8.33e-05	1.51%	
Suspended solids	treatment	1.33e-03	24.22%	

Table 2-60. LCD manufacturing stage water outputs

Material	Disposition	Quantity (kg/ functional unit)	% of process group total	% of grand total
Process Group				
Total		**5.50e-03**	100.00%	**0.45%**
PWB				
Copper (+1 & +2)	treatment	4.28e-05	85.71%	
Lead cmpds	treatment	7.14e-06	14.29%	
Total		**5.00e-05**	100.00%	**0.00%**
Japanese grid				
Sulfate ion (-4)	surface water	2.93e-03	97.46%	
Suspended solids	surface water	7.63e-05	2.54%	
Total		**3.01e-03**	100.00%	**0.24%**
U.S. grid				
Sulfate ion (-4)	treatment	1.32e-04	97.46%	
Suspended solids	treatment	3.45e-06	2.54%	
Total		**1.36e-04**	100.00%	**0.01%**
Fuels				
Acids (H+)	surface water	1.76e-08	<0.01%	
Adsorbable organic halides	surface water	1.82e-11	<0.01%	
Aluminum (+3)	surface water	6.88e-06	<0.01%	
Ammonia ions	surface water	1.33e-03	0.18%	
Aromatic hydrocarbons	surface water	4.25e-09	<0.01%	
Barium cmpds	surface water	1.36e-08	<0.01%	
BOD	surface water	9.12e-03	1.23%	
Cadmium cmpds	surface water	1.42e-11	<0.01%	
Chloride ions	surface water	2.65e-01	35.77%	
Chromium (III)	surface water	3.49e-09	<0.01%	
Chromium (VI)	surface water	3.49e-09	<0.01%	
COD	surface water	7.71e-02	10.42%	
Copper (+1 & +2)	surface water	2.84e-10	<0.01%	
Cyanide (-1)	surface water	1.99e-11	<0.01%	
Dissolved organics	surface water	4.67e-08	<0.01%	
Dissolved solids	surface water	2.01e-05	<0.01%	
Fluorides (F-)	surface water	1.76e-06	<0.01%	
Halogenated matter (organic)	surface water	5.67e-12	<0.01%	
Hydrocarbons, remaining unspeciated	surface water	1.70e-05	<0.01%	
Iron (+2 & +3)	surface water	1.73e-08	<0.01%	
Lead cmpds	surface water	5.67e-11	<0.01%	
Mercury compounds	surface water	6.52e-14	<0.01%	
Metals, remaining unspeciated	surface water	4.72e-04	0.06%	
Nickel cmpds	surface water	2.84e-11	<0.01%	
Nitrate	surface water	2.97e-06	<0.01%	
Other nitrogen	surface water	7.66e-10	<0.01%	
Phenol	surface water	1.75e-04	0.02%	
Phosphates	surface water	2.83e-08	<0.01%	

Table 2-60. LCD manufacturing stage water outputs

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group				
Polycyclic aromatic hydrocarbons	surface water	6.81e-11	<0.01%	
Salts (unspecified)	surface water	7.84e-05	0.01%	
Sodium (+1)	surface water	3.41e-01	46.05%	
Sulfate ion (-4)	surface water	4.36e-06	<0.01%	
Sulfide	surface water	9.86e-09	<0.01%	
Suspended solids	surface water	4.14e-02	5.59%	
TOCs	surface water	4.25e-08	<0.01%	
Toluene	surface water	6.24e-10	<0.01%	
Waste oil	surface water	4.87e-03	0.66%	
Zinc (+2)	surface water	1.40e-09	<0.01%	
Total		**7.40e-01**	100.27%	**60.02%**
Grand Total		**1.23e+00**		**100.00%**

Table 2-61. LCD manufacturing stage hazardous waste outputs

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group				
Monitor/module				
Mercury	recycling/reuse	2.00e-06	<0.01%	
Waste metals, unspecified	recycling/reuse	1.17e-03	0.03%	
Waste acids, unspecified	recycling/reuse	3.24e-02	0.76%	
Waste acid (mainly HF)	recycling/reuse	5.69e-01	13.30%	
Waste acid (mainly HF)	treatment	1.36e-01	3.17%	
Unspecified sludge	land (other than landfill)	3.09e-02	0.72%	
Thinner, unspecified	treatment	5.40e-01	12.62%	
Tetramethyl ammonium hydroxide	recycling/reuse	1.42e-01	3.33%	
Sodium sulfate	recycling/reuse	2.44e-01	5.72%	
Rinse, unspecified	recycling/reuse	4.67e-02	1.09%	
Remover, unspecified	recycling/reuse	8.84e-02	2.07%	
Remover, unspecified	treatment	3.03e-01	7.08%	
Phosphoric acid	landfill	1.44e-02	0.34%	
Nitric acid	landfill	3.43e-04	0.01%	
Isopropyl alcohol	recycling/reuse	1.69e-01	3.95%	
Isopropyl alcohol	treatment	1.91e+00	44.75%	
Ferric chloride	recycling/reuse	1.37e-02	0.32%	
Acetone	treatment	2.77e-02	0.65%	
Acetic acid	landfill	4.46e-03	0.10%	
Total		**4.28e+00**	100.00%	**92.11%**
Panel components				
Spent solvents (F003 waste)	treatment	2.74e-04	0.24%	
Flammable liquids (F003 waste)	treatment	9.13e-04	0.80%	
Acid waste (D002 waste)	treatment	1.19e-03	1.04%	
Spent solvent (with halogenated materials)	treatment	1.55e-02	13.63%	
Spent solvent (non-halogenated)	treatment	4.66e-02	40.89%	
HCFC-225cb	recycling/reuse	3.11e-05	0.03%	
HCFC-225ca	recycling/reuse	3.11e-05	0.03%	
Waste solvent (photoresist)	recycling/reuse	2.05e-02	18.00%	
Waste solvent (photoresist)	treatment	2.17e-02	19.05%	
Waste acid (chrome mixed acid)	recycling/reuse	7.18e-03	6.29%	
Total		**1.14e-01**	100.00%	**2.46%**
LCD glass				
Waste Batch (Ba, Pb) (D008 waste)	landfill	6.55e-05	8.18%	
Waste acid (mostly 3% HCl solution)	recycling/reuse	1.82e-04	22.74%	
Hydrofluoric acid	landfill	8.24e-05	10.29%	
Chrome liquid waste (D007 waste)	recycling/reuse	4.54e-04	56.70%	
Chrome debris (D007 waste)	treatment	6.83e-06	0.85%	
Barium debris (D008 waste)	landfill	9.91e-06	1.24%	
Total		**8.01e-04**	100.00%	**0.02%**

Table 2-61. LCD manufacturing stage hazardous waste outputs

Material	Disposition	Quantity (kg/ functional unit)	% of process group total	% of grand total
Process Group				
Backlight				
Hazardous waste, unspecified	recycling/reuse	1.42e-02	67.68%	
Hazardous waste, unspecified	treatment	6.80e-03	32.31%	
Waste glass, with mercury	landfill	1.05e-10	<0.01%	
Waste CCFL, with mercury	treatment	8.17e-10	<0.01%	
Waste CCFL, with lead	treatment	8.17e-08	<0.01%	
Silver	landfill	2.72e-09	<0.01%	
Chromium	landfill	1.52e-06	0.01%	
Total		**2.11e-02**	100.00%	**0.45%**
PWB				
PWB-Waste cupric etchant	recycling/reuse	9.93e-02	49.42%	
PWB-Solder dross	recycling/reuse	2.96e-02	14.72%	
PWB-Route dust	recycling/reuse	5.31e-03	2.64%	
PWB-Lead contaminated waste oil	treatment	5.14e-03	2.56%	
PWB-Decontaminating debris	treatment	6.85e-03	3.41%	
Hazardous waste, unspecified	treatment	5.48e-02	27.26%	
Total		**2.01e-01**	100.00%	**4.33%**
Fuels				
Hazardous waste, unspecified	landfill	**2.97e-02**		**0.64%**
Grand Total		**4.64e+00**		**100.00%**

Table 2-62. LCD manufacturing stage solid waste outputs

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group				
Monitor/module				
Isopropyl alcohol	treatment	1.03e-02	0.33%	
LCD panel waste	landfill	2.43e-02	0.77%	
Printed wiring board (PWB)	landfill	7.50e-03	0.24%	
Remover, unspecified	treatment	3.09e-02	0.98%	
Unspecified sludge	recycling/reuse	8.46e-01	26.79%	
Unspecified sludge	treatment	5.73e-02	1.82%	
Unspecified solid waste	recycling/reuse	2.02e-02	0.64%	
Waste acid (containing F and detergents)	landfill	2.70e-01	8.56%	
Waste acids, unspecified	treatment	1.05e-01	3.32%	
Waste alkali, unspecified	recycling/reuse	3.23e-01	10.24%	
Waste LCD glass	landfill	2.06e-01	6.52%	
Waste LCD glass	recycling/reuse	7.20e-01	22.80%	
Waste metals, unspecified	recycling/reuse	2.93e-03	0.09%	
Waste oil	treatment	1.61e-02	0.51%	
Waste plastic from LCD modules	recycling/reuse	7.40e-02	2.35%	
Waste plastic from LCD modules	treatment	4.03e-01	12.77%	
Waste plastics from LCD monitor	landfill	4.05e-02	1.28%	
Total		**3.16e+00**	100.00%	**25.07%**
Panel components				
Isopropyl alcohol	recycling/reuse	2.53e-02	11.75%	
Polyester resin	recycling/reuse	3.20e-02	14.84%	
Unspecified solid waste	treatment	1.10e-02	5.09%	
Used silica gel	landfill	6.22e-04	0.29%	
Waste alkali (color filter developer, unspecified)	recycling/reuse	8.91e-02	41.37%	
Waste LCD glass	landfill	5.74e-02	26.66%	
Total		**2.15e-01**	100.00%	**1.71%**
LCD glass				
abrasive sludge	recycling/reuse	1.95e-03	32.61%	
acid absorbent	landfill	3.77e-06	0.06%	
blasting media	landfill	1.70e-05	0.28%	
Cinders from LCD glass mfg	landfill	3.83e-04	6.40%	
Cobalt nitrate	treatment	2.83e-06	0.05%	
Diesel fuel	treatment	1.88e-06	0.03%	
Dust	treatment	1.59e-04	2.65%	
LCD glass EP dust	landfill	4.77e-05	0.80%	
LCD glass EP dust	recycling/reuse	2.32e-04	3.88%	
LCD glass, unspecified	landfill	1.13e-03	18.83%	
Nickel nitrate	treatment	2.83e-06	0.05%	
Oily rags & filter media	landfill	1.51e-05	0.25%	
Oily rags & filter media	recycling/reuse	1.88e-06	0.03%	

Table 2-62. LCD manufacturing stage solid waste outputs

Material	Disposition	Quantity (kg/ functional unit)	% of process group total	% of grand total
Process Group				
parts cleaner solvent	recycling/reuse	3.77e-06	0.06%	
Plating process sludge	landfill	1.52e-05	0.25%	
Potassium Carbonate	landfill	1.53e-04	2.55%	
sludge (calcium fluoride, CaF2)	recycling/reuse	8.13e-04	13.59%	
Sludge from LCD glass mfg	landfill	4.06e-05	0.68%	
Sodium Carbonate	landfill	1.53e-04	2.55%	
Unspecified sludge	landfill	3.56e-04	5.95%	
Waste alkali, unspecified	treatment	1.95e-06	0.03%	
Waste LCD glass	landfill	8.70e-05	1.45%	
Waste oil	treatment	3.03e-04	5.07%	
Waste refractory	landfill	1.13e-04	1.89%	
Total		**5.98e-03**	100.00%	**0.05%**
Backlight				
Broken CCFL	landfill	2.69e-07	<0.01%	
Cardboard	treatment	1.82e-05	0.34%	
Polyethylene, foamed	treatment	9.99e-04	18.50%	
Polyethylene/polypropylene waste	treatment	2.72e-03	50.45%	
Unspecified nonhazardous waste	recycling/reuse	1.26e-04	2.32%	
Waste backlight casing (PC)	landfill	1.46e-05	0.27%	
Waste backlight light guide (PMMA)	landfill	1.52e-03	28.12%	
Total		**5.40e-03**	100.00%	**0.04%**
PWB				
PWB-Drill dust	landfill	6.59e-03	0.36%	
Unspecified solid waste	recycling/reuse	1.91e-01	10.53%	
Unspecified solid waste	treatment	1.62e+00	89.11%	
Total		**1.81e+00**	100.00%	**14.40%**
Japanese grid				
Coal waste	landfill	2.18e+00	61.12%	
Dust/sludge	landfill	8.42e-01	23.59%	
Fly/bottom ash	landfill	5.45e-01	15.28%	
Total		**3.57e+00**	100.00%	**28.34%**
U.S. grid				
Coal waste	landfill	9.85e-02	61.10%	
Dust/sludge	landfill	3.81e-02	23.63%	
Fly/bottom ash	landfill	2.46e-02	15.27%	
Total		**1.61e-01**	100.00%	**1.28%**
Fuels				
Aluminum scrap	recycling/reuse	8.77e-06	<0.01%	
Aluminum scrap, Wabash 319	recycling/reuse	2.37e-08	<0.01%	
Bauxite residues	landfill	5.87e-04	0.02%	
FGD sludge	landfill	1.09e-02	0.30%	
Mineral waste	landfill	1.26e-04	<0.01%	

Table 2-62. LCD manufacturing stage solid waste outputs

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group				
Mixed industrial (waste)	landfill	4.83e-02	1.32%	
Non toxic chemical waste (unspecified)	landfill	2.95e-05	<0.01%	
Slag and ash	landfill	3.40e+00	92.69%	
Slag and ash	recycling/reuse	3.49e-02	0.95%	
Unspecified solid waste (incinerated)	treatment	6.44e-04	0.02%	
Unspecified waste	landfill	1.72e-01	4.70%	
Total		**3.66e+00**	100.00%	**29.10%**
Grand Total		**1.26e+01**		**100.00%**

Table 2-63. LCD manufacturing stage radioactive waste outputs

Material	**Disposition**	**Quantity (kg/ functional unit)**	**% of process group total**	**% of grand total**
Process Group				
Japanese grid				
Low-level radioactive waste	landfill	3.71e-04	76.93%	
Uranium, depleted	landfill	1.11e-04	23.07%	
Total		**4.82e-04**	100.00%	**99.09%**
U.S. grid				
Low-level radioactive waste	landfill	3.40e-06	76.93%	
Uranium, depleted	landfill	1.02e-06	23.07%	
Total		**4.42e-06**	100.00%	**0.91%**
Grand Total		**4.87e-04**		**100.00%**

Table 2-64. LCD manufacturing stage radioactivity outputs

Material	Disposition	Quantity (Bq/ functional unit)	% of process group total	% of grand total
Process Group				
Japanese grid				
Antimony-124 (isotope)	treatment	1.67e+00	<0.01%	
Antimony-125 (isotope)	treatment	6.63e+00	<0.01%	
Argon-41 (isotope)	air	3.37e+03	0.03%	
Barium-140 (isotope)	treatment	1.23e-01	<0.01%	
Bromine-89 (isotope)	air	3.90e-04	<0.01%	
Bromine-90 (isotope)	air	1.59e-04	<0.01%	
Cesium-134 (isotope)	air	1.07e-02	<0.01%	
Cesium-134 (isotope)	treatment	4.45e+00	<0.01%	
Cesium-137 (isotope)	air	8.08e-02	<0.01%	
Cesium-137 (isotope)	treatment	6.69e+00	<0.01%	
Chromium-51 (isotope)	air	2.11e-01	<0.01%	
Chromium-51 (isotope)	treatment	8.02e+00	<0.01%	
Cobalt-57 (isotope)	air	5.68e-04	<0.01%	
Cobalt-57 (isotope)	treatment	1.94e-01	<0.01%	
Cobalt-58 (isotope)	air	7.26e-03	<0.01%	
Cobalt-58 (isotope)	treatment	7.90e+01	<0.01%	
Cobalt-60 (isotope)	air	5.46e-02	<0.01%	
Cobalt-80 (isotope)	treatment	2.07e+01	<0.01%	
Iodine-131 (isotope)	air	2.55e-01	<0.01%	
Iodine-131 (isotope)	treatment	3.70e+00	<0.01%	
Iodine-132 (isotope)	air	5.18e-02	<0.01%	
Iodine-132 (isotope)	treatment	1.40e+00	<0.01%	
Iodine-133 (isotope)	air	2.37e+02	<0.01%	
Iodine-133 (isotope)	treatment	1.59e+00	<0.01%	
Iodine-134 (isotope)	air	2.68e-01	<0.01%	
Iodine-135 (isotope)	air	1.35e-02	<0.01%	
Iodine-135 (isotope)	treatment	1.14e+00	<0.01%	
Iron-55 (isotope)	treatment	1.89e+01	<0.01%	
Iron-59 (isotope)	treatment	9.70e-01	<0.01%	
Krypton-85 (isotope)	air	5.59e+03	0.06%	
Krypton-85M (isotope)	air	2.71e+02	<0.01%	
Krypton-85M (isotope)	treatment	5.00e+00	<0.01%	
Krypton-87 (isotope)	air	1.01e+02	<0.01%	
Krypton-88 (isotope)	air	4.73e+02	<0.01%	
Lanthanum-140 (isotope)	treatment	1.32e-01	<0.01%	
Manganese-54 (isotope)	air	3.00e-03	<0.01%	
Manganese-54 (isotope)	treatment	5.29e+00	<0.01%	
Molybdenum-99 (isotope)	treatment	9.98e+06	98.42%	
Niobium-95 (isotope)	air	1.19e-04	<0.01%	
Niobium-95 (isotope)	treatment	1.36e+00	<0.01%	
Rubidium-88 (isotope)	air	1.11e+00	<0.01%	

Table 2-64. LCD manufacturing stage radioactivity outputs

Material	Disposition	Quantity (Bq/ functional unit)	% of process group total	% of grand total
Process Group				
Ruthenium-103 (isotope)	treatment	1.67e-01	<0.01%	
Silver-110M (isotope)	air	3.56e-06	<0.01%	
Silver-110M (isotope)	treatment	1.94e+00	<0.01%	
Sodium-24 (isotope)	treatment	2.96e-01	<0.01%	
Strontium-89 (isotope)	treatment	3.20e-01	<0.01%	
Strontium-90 (isotope)	treatment	7.52e-02	<0.01%	
Strontium-95 (isotope)	treatment	8.29e-01	<0.01%	
Sulfur-136 (isotope)	treatment	1.78e-01	<0.01%	
Technetium-99M (isotope)	air	1.60e-05	<0.01%	
Technetium-99M (isotope)	treatment	1.16e-01	<0.01%	
Tin-113 (isotope)	treatment	1.84e-01	<0.01%	
Tritium-3 (isotope)	air	7.90e+03	0.08%	
Tritium-3 (isotope)	treatment	5.91e+04	0.58%	
Xenon-131M (isotope)	air	4.56e+02	<0.01%	
Xenon-131M (isotope)	treatment	6.08e+01	<0.01%	
Xenon-133 (isotope)	air	4.37e+03	0.04%	
Xenon-133 (isotope)	treatment	9.34e+03	0.09%	
Xenon-133M (isotope)	air	6.58e+04	0.65%	
Xenon-133M (isotope)	treatment	7.65e+01	<0.01%	
Xenon-135 (isotope)	air	2.48e+03	0.02%	
Xenon-135 (isotope)	treatment	6.97e+01	<0.01%	
Xenon-135M (isotope)	air	4.74e+01	<0.01%	
Xenon-138 (isotope)	air	1.57e+02	<0.01%	
Zinc-85 (isotope)	treatment	8.92e-02	<0.01%	
Zirconium-95 (isotope)	air	3.08e-04	<0.01%	
Total		**1.01e+07**	100.00%	**99.09%**
U.S. grid				
Antimony-124 (isotope)	treatment	1.53e-02	<0.01%	
Antimony-125 (isotope)	treatment	6.09e-02	<0.01%	
Argon-41 (isotope)	air	3.09e+01	0.03%	
Barium-140 (isotope)	treatment	1.13e-03	<0.01%	
Bromine-89 (isotope)	air	3.58e-06	<0.01%	
Bromine-90 (isotope)	air	1.45e-06	<0.01%	
Cesium-134 (isotope)	air	9.82e-05	<0.01%	
Cesium-134 (isotope)	treatment	4.09e-02	<0.01%	
Cesium-136 (isotope)	treatment	1.75e-03	<0.01%	
Cesium-137 (isotope)	air	7.41e-04	<0.01%	
Cesium-137 (isotope)	treatment	6.13e-02	<0.01%	
Chromium-51 (isotope)	air	1.94e-03	<0.01%	
Chromium-51 (isotope)	treatment	7.36e-02	<0.01%	
Cobalt-57 (isotope)	air	5.21e-06	<0.01%	
Cobalt-57 (isotope)	treatment	1.78e-03	<0.01%	

Table 2-64. LCD manufacturing stage radioactivity outputs

Material	Disposition	Quantity (Bq/ functional unit)	% of process group total	% of grand total
Process Group				
Cobalt-58 (isotope)	air	6.65e+00	<0.01%	
Cobalt-58 (isotope)	treatment	7.25e-01	<0.01%	
Cobalt-60 (isotope)	air	5.01e-04	<0.01%	
Cobalt-80 (isotope)	treatment	1.90e-01	<0.01%	
Iodine-131 (isotope)	air	2.34e-03	<0.01%	
Iodine-131 (isotope)	treatment	3.39e-02	<0.01%	
Iodine-132 (isotope)	air	4.75e-04	<0.01%	
Iodine-132 (isotope)	treatment	1.28e-02	<0.01%	
Iodine-133 (isotope)	air	2.17e+00	<0.01%	
Iodine-133 (isotope)	treatment	1.45e-02	<0.01%	
Iodine-134 (isotope)	air	2.46e-03	<0.01%	
Iodine-135 (isotope)	air	1.24e-04	<0.01%	
Iodine-135 (isotope)	treatment	1.04e-02	<0.01%	
Iron-55 (isotope)	treatment	1.73e-01	<0.01%	
Iron-59 (isotope)	treatment	8.90e-03	<0.01%	
Krypton-85 (isotope)	air	5.13e+01	0.06%	
Krypton-85M (isotope)	air	2.48e+00	<0.01%	
Krypton-85M (isotope)	treatment	4.58e-02	<0.01%	
Krypton-87 (isotope)	air	9.25e-01	<0.01%	
Krypton-88 (isotope)	air	4.34e+00	<0.01%	
Lanthanum-140 (isotope)	treatment	1.21e-03	<0.01%	
Manganese-54 (isotope)	air	2.75e-05	<0.01%	
Manganese-54 (isotope)	treatment	4.85e-02	<0.01%	
Molybdenum-99 (isotope)	treatment	9.15e+04	98.41%	
Niobium-95 (isotope)	air	1.09e-06	<0.01%	
Niobium-95 (isotope)	treatment	1.25e-02	<0.01%	
Rubidium-88 (isotope)	air	1.02e-02	<0.01%	
Ruthenium-103 (isotope)	treatment	1.53e-03	<0.01%	
Silver-110M (isotope)	air	3.26e-08	<0.01%	
Silver-110M (isotope)	treatment	1.78e-02	<0.01%	
Sodium-24 (isotope)	treatment	2.72e-03	<0.01%	
Strontium-89 (isotope)	treatment	2.93e-03	<0.01%	
Strontium-90 (isotope)	treatment	6.90e-04	<0.01%	
Strontium-95 (isotope)	treatment	7.60e-03	<0.01%	
Sulfur-136 (isotope)	treatment	1.64e-03	<0.01%	
Technetium-99M (isotope)	air	1.47e-07	<0.01%	
Technetium-99M (isotope)	treatment	1.06e-03	<0.01%	
Tin-113 (isotope)	treatment	1.68e-03	<0.01%	
Tritium-3 (isotope)	air	7.25e+01	0.08%	
Tritium-3 (isotope)	treatment	5.42e+02	0.58%	
Xenon-131M (isotope)	air	4.18e+00	<0.01%	
Xenon-131M (isotope)	treatment	5.58e-01	<0.01%	

Table 2-64. LCD manufacturing stage radioactivity outputs

Material	**Disposition**	**Quantity (Bq/ functional unit)**	**% of process group total**	**% of grand total**
Process Group				
Xenon-133 (isotope)	air	6.04e+02	0.65%	
Xenon-133 (isotope)	treatment	8.57e+01	0.09%	
Xenon-133M (isotope)	air	4.01e+01	0.04%	
Xenon-133M (isotope)	treatment	7.02e-01	<0.01%	
Xenon-135 (isotope)	air	2.28e+01	0.02%	
Xenon-135 (isotope)	treatment	6.39e-01	<0.01%	
Xenon-135M (isotope)	air	4.35e-01	<0.01%	
Xenon-138 (isotope)	air	1.44e+00	<0.01%	
Zinc-85 (isotope)	treatment	8.18e-04	<0.01%	
Zirconium-95 (isotope)	air	2.82e-06	<0.01%	
Total		**9.30e+04**	100.00%	**0.91%**
Fuels				
Radioactive substance (unspecified)	air	4.44e+01	99.08%	
Radioactive substance (unspecified)	surface water	4.11e-01	0.92%	
Total		**4.48e+01**	100.00%	**0.00%**
Grand Total		**1.02e+07**		**100.00%**

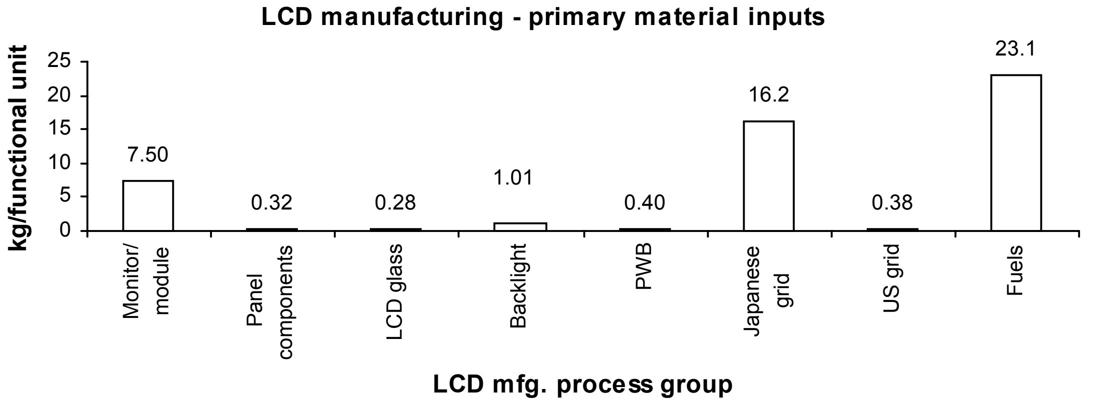

Figure 2-51. LCD manufacturing primary material inputs

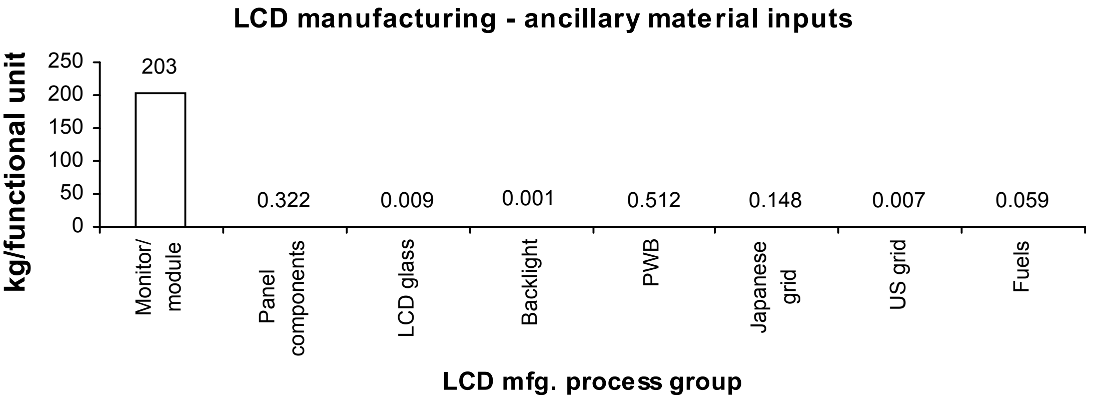

Figure 2-52. LCD manufacturing ancillary material inputs

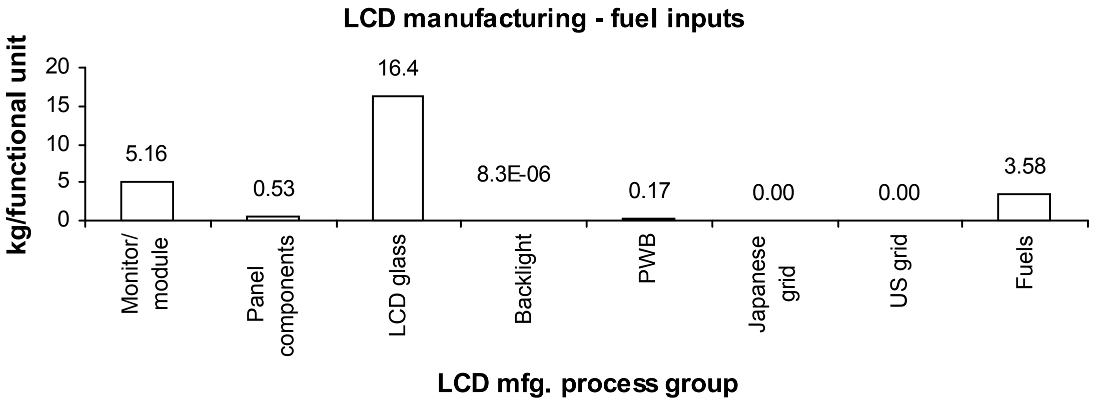

Figure 2-53. LCD manufacturing fuel inputs

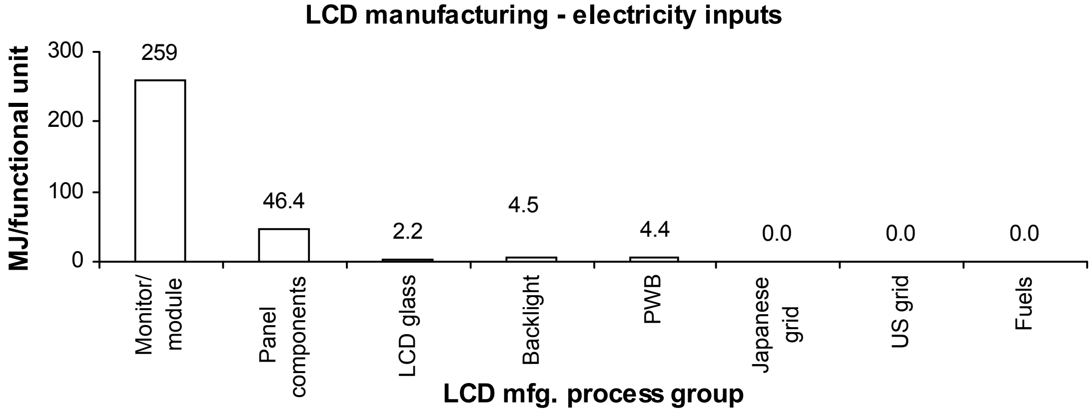

Figure 2-54. LCD manufacturing electricity inputs

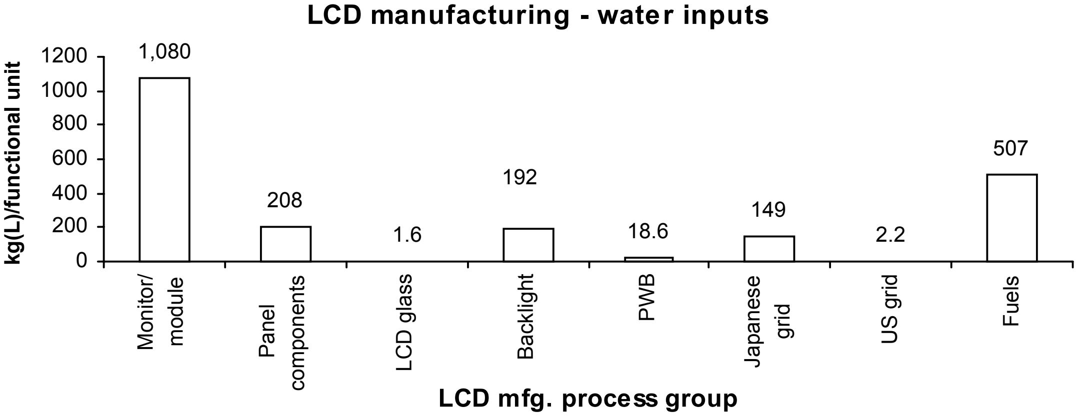

Figure 2-55. LCD manufacturing water inputs

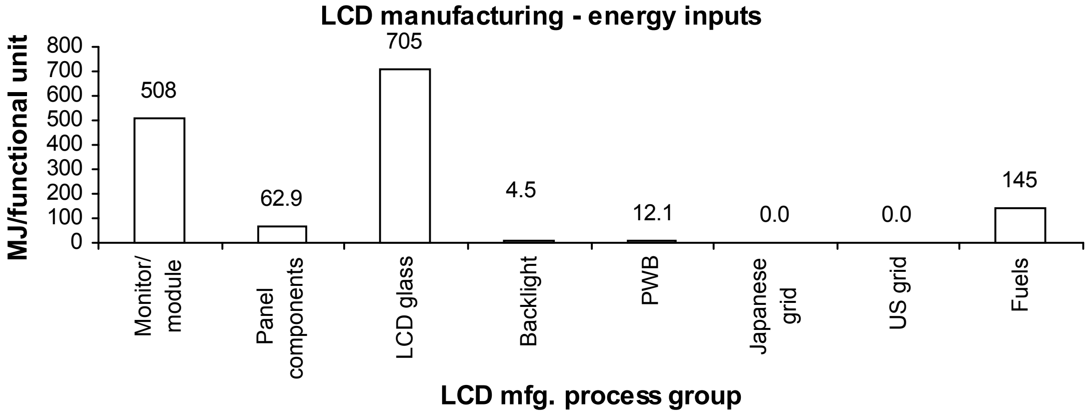

Figure 2-56. LCD manufacturing energy inputs

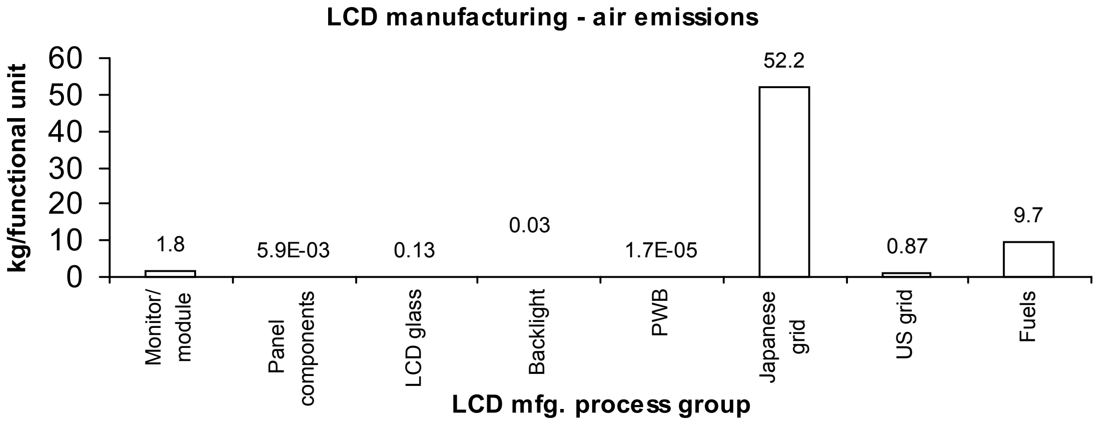

Figure 2-57. LCD manufacturing air pollutant outputs

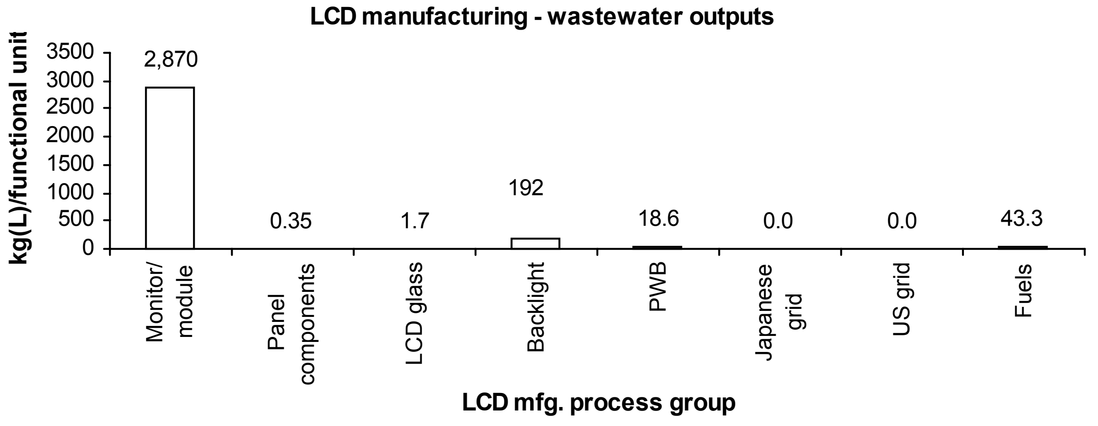

Figure 2-58. LCD manufacturing wastewater outputs

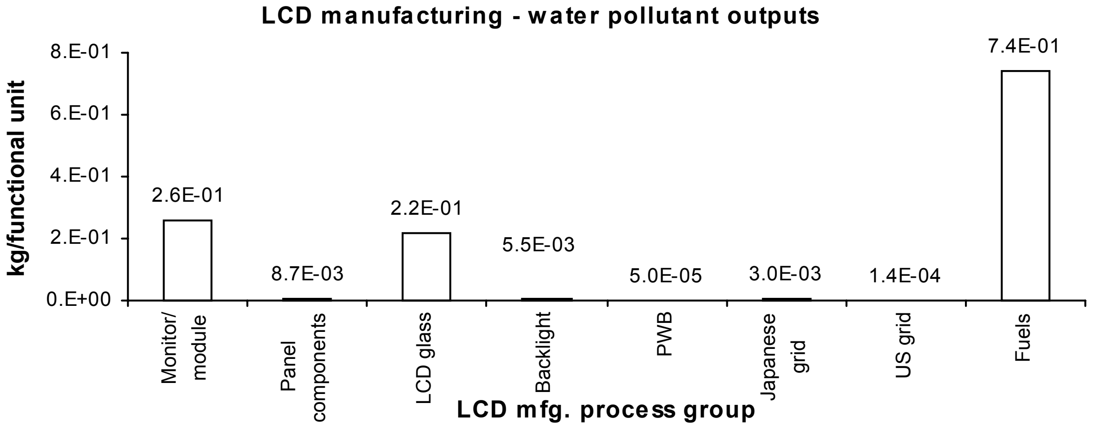

Figure 2-59. LCD manufacturing water pollutant outputs

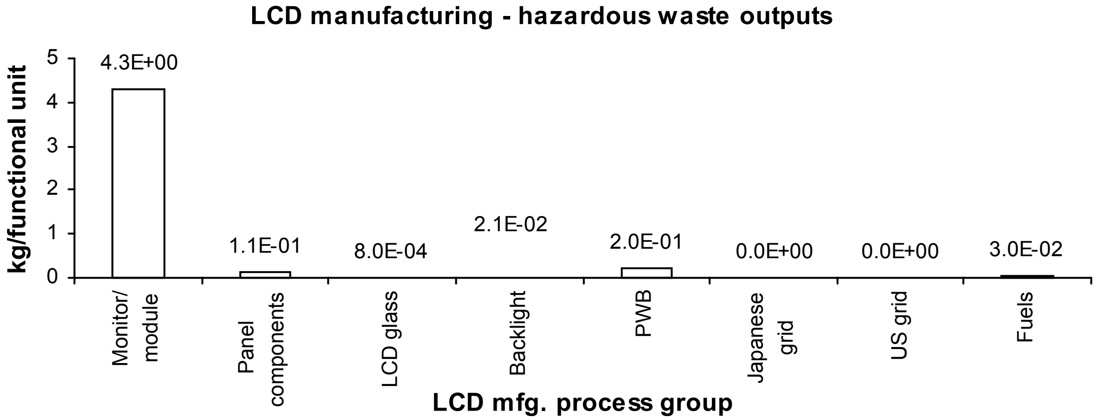

Figure 2-60. LCD manufacturing hazardous waste outputs

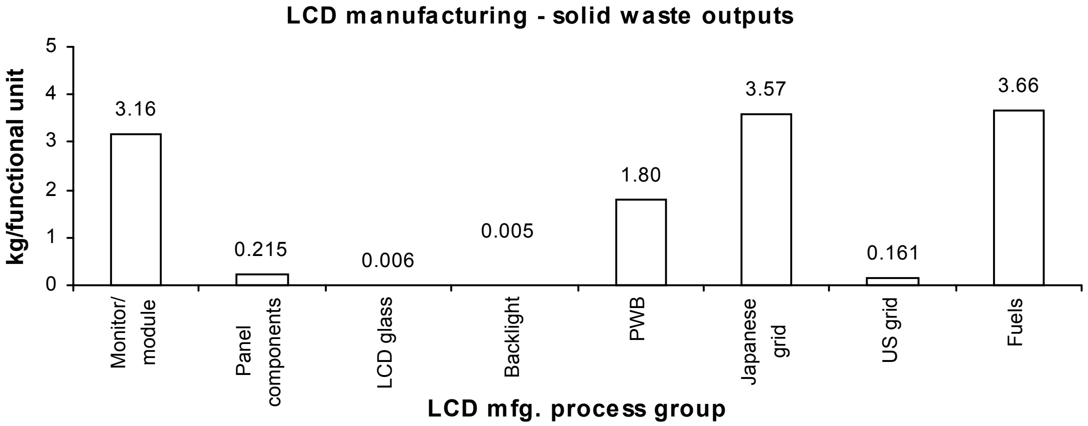

Figure 2-61. LCD manufacturing solid waste outputs

Of the total 49 kg of primary materials per functional unit in the manufacturing stage, the fuels production contributes the greatest (23.1 kg/functional unit), followed by the Japanese electric grid (16.2 kg/functional unit) (Figure 2-51 and Table 2-56). Nearly all (203 out of 204 kg/functional unit) of the ancillary materials used during manufacturing are from the monitor/module process group (Figure 2-52 and Table 2-57). Liquified natural gas (LNG) constitutes about 96% (194 kg/functional unit) of the total ancillary materials in the monitor/module process group. As stated earlier, this is not used to calculate energy impacts.

Of the utility inputs, electricity and water inputs were greatest in the monitor/module manufacturing processes; fuels were greatest in the LCD glass manufacturing process group (Figures 2-53, 2-54, and 2-55). Sixty-three percent of the fuel inputs are from the LCD glass manufacturing process group. Within that group, the use of LPG clearly dominates at about 16.2 kg/functional unit (over 99% of the LCD glass fuel inputs) (Table 2-58).[6] The monitor/module manufacturing fuel inputs are about 20% of the total manufacturing fuel inputs (5.2 kg/functional unit). About 259 MJ/functional unit of electricity in the LCD manufacturing stage are from the monitor/module processes[7], or 82% of all manufacturing electricity (Figure 2-54). The total energy, which converts fuel mass into energy and adds that to the electrical energy, is greatest in the LCD glass manufacturing processes and contributes 705 MJ/functional unit to the 1,440 MJ/functional unit in the manufacturing stage (Figure 2-56). Water inputs are most significant in the monitor/module manufacturing process, contributing 1,080 kg (or liter)/functional unit (Figure 2-55), which is 50% of all the manufacturing water inputs. The fuels production and panel components process groups contribute about 24% and 10% to the water manufacturing inputs, respectively.

For outputs from the manufacturing stage, the mass of air emissions are dominated by the generation of electricity (Figure 2-57). Individual material (pollutant) contributions for each process group are presented in Table 2-59. Wastewater outputs (i.e., the volume or mass of wastewater released) are greatest for the monitor/module manufacturing processes (92%) (Figure 2-58), but only 21% of the chemical pollutants in the wastewater streams come from those processes (Figure 2-59). Table 2-60 shows the individual contributions from each material.

Hazardous wastes from the LCD manufacturing stage dominated over other life-cycle stages, and within the manufacturing stage, the monitor/module processes had the greatest hazardous waste outputs by mass (4.3 kg/functional unit) (Figure 2-60). The greatest contributors by mass are isopropyl alcohol (a total of 2.1 kg/functional unit, or 49% of all wastes from the monitor/module manufacturing processes) (Table 2-61). These wastes, however, are recycled and although they are a large portion of the inventory, they will not affect the impact assessment (to be presented in Chapter 3) as they are not directly released to the environment.

Solid wastes generated during the manufacturing stage were only about 21% of the overall solid wastes generated throughout the LCD life-cycle, as was shown earlier in

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[6] Note: An industry participant questioned the large fuel contribution reported here; however, further discussions with industry supported that no valid reason could justify removing these data. Glass energy inputs are evaluated in a sensitivity analysis (see Section 2.7.3 and 3.4).

[7] This amount of electricity is consistent with the industry participant that expressed doubt in the large fuel energy contribution and subsequent overall energy use amount in module manufacturing.

Figure 2-48. Within the manufacturing stage, the fuels production, Japanese grid and monitor/module manufacturing process groups are all major contributors to the solid waste outputs (Figure 2-61). The individual material contributions are provided in Table 2-62.

Radioactive waste and radioactivity are directly related to the electricity generation process and therefore, only the Japanese and U.S. electric grid processes generate these outputs in the manufacturing stage. Tables 2-63 and 2-64 show that more radioactive wastes and radioactivity are from the Japanese electric grid. This is a result of more manufacturing processes being in Japan, as modeled in this project, as well as the greater fraction of nuclear power in the Japanese electric grid.

2.7.2 Relative Data Quality

Sections 2.2 through 2.6 (and associated appendices) discuss the data quality and data limitations for each life-cycle stage. Several factors contribute to the overall quality for an entire life-cycle stage. For example, the manufacturing stage includes several different processes that were collected from several different companies. The quality of one data set from one company may be very different from that of another company. Relative data quality estimates have been made for each life-cycle stage, including electricity generation, which is included in more than one life-cycle stage (Table 2-65). In addition, transportation data quality is listed in Table 2-65, although it has been excluded from the analysis due to the very low data quality.

Table 2-65. Relative data quality

Life-cycle stage	Relative data quality
Upstream	Moderate
Manufacturing	Moderate to high
Use	Moderate to high
EOL	Low to moderate
Electricity generation	High
Transportation	Very low

2.7.3 Sensitivity Analyses

The inventory results presented above in Section 2.7.1 are the "baseline" results in this study. The baseline scenario includes the parameters/assumptions presented in the methodologies for the effective life scenario. However, due to assumptions and uncertainties in this LCA, as in any LCA, sensitivity analyses on the baseline results have been conducted. Four areas have been identified where sensitivity analyses were most warranted:

- use stage lifespan assumptions;
- glass manufacturing energy inputs;
- LCD monitor/module manufacturing energy inputs, and
- LCD EOL disposition assumptions.

Selected sensitivity analyses were chosen based on the data with either the greatest uncertainties or with a large uncertainty and a major contributor to the inventory results. The matrix in Table

2-66 shows the different sensitivity analyses or scenarios that are considered in the impact assessment results. Discussions of the sensitivity analyses for manufactured life (use stage), glass manufacturing energy inputs, LCD monitor manufacturing energy inputs, and LCD EOL inventories follow in this section. Complete inventories of each sensitivity analysis scenario are not presented; however, the effects determined in the LCIA results of the sensitivity analyses are shown in Chapter 3 (see Section 3.4).

Table 2-66. List of sensitivity analysis scenarios

Monitor type	**Sensitivity analysis scenario**
Baseline analyses (for reference)	
CRT	Effective life scenario with average glass energy inputs (all glass manufacturing energy data used)
LCD	Effective life scenario with average glass energy inputs (all glass manufacturing energy data used) and outliers in the LCD module manufacturing energy data removed
Sensitivity analyses	
CRT	Manufactured life scenario same as baseline except lifespan is based on manufactured life instead of effective life, which results in some revised functional equivalency calculations (see Section 2.7.3.1 below)
LCD	Manufactured life scenario same as baseline except lifespan is based on manufactured life, which results in some revised functional equivalency calculations (see Section 2.7.3.1 below)
CRT	Modified glass energy scenario same as baseline except comparatively high glass manufacturing energy inputs are removed
LCD	Modified glass energy scenario same as baseline except comparatively high glass manufacturing energy inputs are removed
LCD	Modified LCD module energy scenario same as baseline except LCD monitor/ module manufacturing energy outliers are included in the average
LCD	Modifed LCD EOL scenario same as baseline except LCD EOL dispositions are modified

2.7.3.1 Manufactured life scenario

To address uncertainties in the use stage lifespan assumptions, we applied the manufacturing life scenario to the CRT and LCD life-cycle profiles. (See Section 2.4 for a discussion of the product use stage and the differences in the “effective life” versus “manufactured life” life span assumptions.) Recall that the LCD manufactured life (45,000 hours) is 3.6 times greater than the CRT manufactured life (12,500 hours). In an LCA, comparisons are made based on functional equivalency. Therefore, if one monitor will operate for a longer period of time than another, impacts should be based on an equivalent use. Thus, based on equivalent use periods, under the manufactured life scenario 3.6 CRTs would need to be manufactured for every LCD. This was incorporated into the profile analysis for the comparative manufactured life LCA. Similarly, on average, 1.4 LCD backlights (which can be cost-effectively replaced) will be needed during the manufactured lifetime of an LCD monitor. This was also incorporated into the profile. Thus, the following modifications were made:

- change the CRT electricity input in the use stage from 635 kWh (2,286 MJ) to 788 kWh (2,837 MJ); [8]
- change the LCD electricity input in the use stage from 237 kWh (853 MJ) to 1,035 kWh (3,726 MJ);
- increase the manufacturing of CRTs by a factor of 3.6 to account for the functional equivalency of CRTs and LCDs. This was done by increasing the functional unit (22 kg CRT monitor) by a factor of 3.6, which equates to manufacturing 3.6 times more CRTs than in the baseline case; and
- increase the manufacturing of the LCD backlight lamp by a factor of 1.4 to account for the functional equivalency of LCDs and CRTs. This was done by increasing the backlight lamp mass (0.0023 kg), which is an input to the backlight unit assembly process, by a factor of 1.4.

Note that functional equivalency modification requires that the manufactured life scenario results be used only when comparing the CRT and LCD. These results cannot be accurately used to compare EL to ML for CRT or LCD. LCIA results of the sensitivity analysis are presented in Chapter 3.

2.7.3.2 Modified glass energy scenario

In the second case, the energy input values for CRT glass manufacturing (and consequently LCD glass manufacturing) were considered uncertain due to the large discrepancy in fuel and electricity values among the individual data sets. The baseline case uses the average of the data supplied and confirmed by the companies who supplied the data. However, because one set of data was significantly higher, that one set of data was removed from the profile for the sensitivity analysis. (A statistical evaluation of the glass manufacturing data for outliers could not be conducted because there were not enough data sets.)

In the baseline scenario, the averaged primary data from manufacturers of total energy to produce a kilogram of CRT or LCD glass was 1,560 MJ (433 kWh) of energy, with only 0.3% of that as electrical energy. The sensitivity analysis scenario assumes 16.3 MJ (4.5 kWh) per kilogram of glass produced, with approximately 30% as electrical energy. The majority of the fuel energy in the baseline scenario was from LPG. The energy consumption values can be compared to estimates for the entire glass industry, which includes the more prevalent general flat glass, as well as speciality glasses, such as CRT and LCD glass. In a report of the Glass Technology Roadmap Workshop (Energetics Inc. 1997), it was estimated that in practice, about 1.1 MJ of energy are required to melt a kilogram of glass; and electrical energy contributes approximately 13% of the total process energy requirements from glass production, as reported in 1994. Although this does not translate into energy requirements for CRT or LCD glass, it suggests the baseline data collected for this analysis may be inflated. Therefore, the sensitivity

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[8] This represents the electricity use for a 12,500 hour life span. This figure is then multiplied by a factor of 3.6 in the functional equivalency calculations (see third bullet, below).

analysis uses revised energy input values for glass production, but it is also not known whether these values represent the true energy requirements for CRT and LCD glass production. The sensitivity analysis is considered a lower bound of energy requirements for monitor glass production.

2.7.3.3 Modified LCD module energy scenario

LCD monitor/module manufacturing energy was another area of relatively large uncertainty and variability in the inventory data. The CDP received seven sets of LCD monitor/module manufacturing data from five companies in Japan and two in Korea. Of these, the manufacturing energy data from one company in Korea was incomplete and could not be used. For the remaining six data sets, total energy inputs ranged from 330 MJ to 7,310 MJ, with a mean and standard deviation of 2,269 MJ and 2,906 MJ, respectively. Given the wide variability in the data and large standard deviation, CDP researchers evaluated the data for outliers by breaking the total energy data points into quartile ranges. Minor outliers are then those within a certain range of multipliers beyond the middle 50 percent of the distribution. That is, the interquartile range (IQR) (i.e., the range of values representing the middle 50 percent) multiplied by 1.5 is the lower bound of the minor outlier and the IQR times three is the upper bound of the minor outlier. Anything beyond IQR times three is a major outlier. Using this approach, one data set was found to be a minor outlier and another was found to be a major outlier. These outliers were excluded from the averages used in the baseline analysis, but included in the averages used in the LCD monitor/module manufacturing energy sensitivity analysis.

Table 2-67 summarizes the energy inputs for the LCD monitor/module manufacturing process group under the baseline and modified LCD module energy scenarios. Note that total energy inputs are approximately 4.5 times lower under the baseline scenario. However, because of the different types of energy (fuel and electricity) employed by different manufacturers, the mean electric energy is higher for the baseline than the modified energy scenario.

2.7.3.4 LCD End-of-life dispositions

Finally, because very few desktop LCDs have reached their end of life, and usually only if they have been damaged in some way, very little is known about the percentage of LCDs that are remanufactured, recycled, landfilled or incinerated. In the baseline scenario, it was assumed that a certain proportion of monitors go to each EOL disposition. As the functional unit in this study is one monitor, we used those proportions to represent the probability that one monitor would go to the respective disposition. To address uncertainties in the allocation of disposition percentages, a sensitivity analysis was conducted with a different set of final disposition numbers. Details and assumptions for the sensitivity analysis are provided in Appendix I. Table 2-68 presents the distribution of LCD EOL dispositions assumed under the baseline and modifed EOL dispositions scenarios. LCIA results for the sensitivity analysis are presented in Section 3.4.

Table 2-67. Energy inputs to the LCD monitor/module manufacturing process group under the baseline and modified energy scenarios

	Total energy (MJ per monitor)	Electric energy (MJ per monitor)	Fuel energy (MJ per monitor)	% electric energy	% fuel energy
Baseline (excludes two outlier data sets from the means used in the inventory)					
Range	333 to 934	199 to 359	48 to 695	25 to 88	12 to 75
Mean	508	259	249	60	40
Standard deviation	284	68	300	27	27
Modified Energy (includes two outlier data sets in the means used in the inventory)					
Range	333 to 7,317	125 to 359	48 to 7,146	2 to 88	12 to 98
Mean	2,274	222	2052	10	90
Standard deviation	2,906	79	2,956	36	36

Table 2-68. Distribution of LCD EOL dispositions in the baseline and modified EOL scenarios

Disposition	Baseline	Modified
Incineration	15%	15%
Recycling	15%	0%
Remanufacturing	15%	40%
Hazardous waste landfill	5%	5%
Solid waste landfill	50%	40%

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Chapter 3

LIFE-CYCLE IMPACT ASSESSMENT

Within LCA, the LCI is a well established methodology; however, LCIA methods are less well defined and continue to evolve (Barnthouse *et al.*, 1997; Fava *et al.*, 1993). For toxicity impacts in particular, there are some methods being applied in practice (e.g., toxicity potentials, critical volume, and direct valuation) (Guinee *et al.*, 1996; ILSI, 1996; Curran, 1996), while others are in development. However, there is currently no general consensus among the LCA community as to one method over another. LCIA sophistication has also been discussed in efforts to determine the appropriate level of analytical sophistication for various types of decision making requirements (Bare *et al.*, 1999) or one that adequately addresses toxicity impacts.

Section 3.1 of this chapter presents the University of Tennessee (UT) LCIA methodology, which takes a more detailed approach to chemical toxicity impacts than some methods currently being used. Section 3.1 also discusses data sources, data quality, and the limitations and uncertainties in the LCIA methodology. The UT methodology calculates life-cycle impact category indicators for a number of impact categories, including several traditional LCA impact categories (e.g., global warming, stratospheric ozone depletion, photochemical smog, and energy consumption). Furthermore, the method calculates relative category indicators for potential chronic human health, aquatic ecotoxicity, and terrestrial ecotoxicity impacts in order to address interest in human and ecological toxicity and to fill a common gap in LCIAs. Work conducted for Saturn Corporation and the EPA Office of Research and Development by the UT Center for Clean Products and Clean Technologies has provided the basis for much of this methodology (Swanson, 2001).

Section 3.2 of this chapter describes the data management and analysis software used to calculate LCIA results. Section 3.3 presents the baseline LCIA results for both the CRT and the LCD. Baseline results are presented by impact category and include a discussion of the specific limitations and uncertainties in each category. Section 3.4 presents sensitivity analyses of the baseline results.

3.1 METHODOLOGY

In its simplest form, LCIA is the evaluation of potential impacts to any system as a result of some action. LCIAs generally classify the consumption and loading data from the inventory stage to various impact categories. Characterization methods are then used to quantify the magnitude of the contribution that loading or consumption could have in producing the associated impact. LCIA does not seek to determine actual impacts, but rather to link the data gathered from the LCI to impact categories and to quantify the relative magnitude of contribution to the impact category (Fava *et al.*, 1993; Barnthouse *et al.*, 1997). Further, impacts in different impact categories are generally calculated based on differing scales and therefore cannot be directly compared.

Conceptually, there are three major phases of LCIA, as defined by the Society of Environmental Toxicology and Chemistry (SETAC) (Fava *et al.*, 1993):

- **Classification** - The process of assignment and initial aggregation of data from inventory studies to impact categories (e.g., greenhouse gases or ozone depletion compounds).
- **Characterization** - The analysis and estimation of the magnitudes of potential impacts for each impact category, derived through application of specific impact assessment tools. In the CDP, "impact scores" are calculated for inventory items that have been classified into various impact categories and then aggregated into life-cycle impact category indicators.
- **Valuation** - The assignment of relative values or weights to different impacts and their integration across impact categories to allow decision makers to assimilate and consider the full range of relevant impact scores across impact categories.

The international standard for life cycle impact assessment, ISO 14042, considers classification and characterization to be mandatory elements of LCIA. Valuation or weighting is an optional element to be included depending on the goals and scope of the study. The CDP addresses the first two LCIA steps and leaves the valuation step to industry or others. In addition, further qualitative risk screening of selected materials is conducted beyond the traditional LCIA "characterization" phase in Chapter 4. The methodologies for life-cycle impact classification and characterization are described in Sections 3.1.1 and 3.1.2, respectively. Sections 3.1.3 and 3.1.4 address data sources and data quality, and limitations and uncertainties associated with the LCIA methodology.

3.1.1 Classification

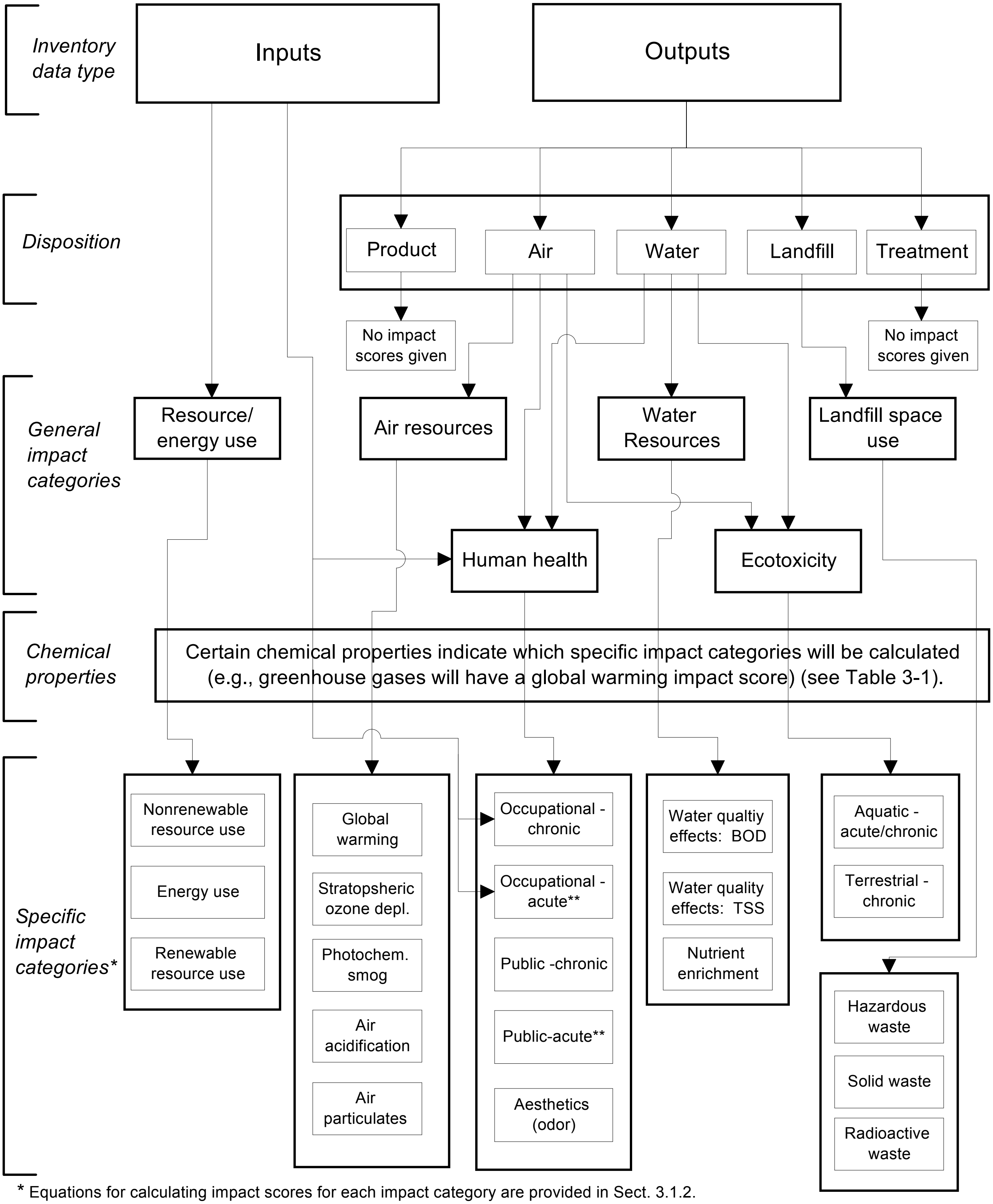
In the first step of classification, impact categories of interest are identified in the scoping phase of the LCA. The categories to be included in the CDP LCIA are listed below:

- Natural Resource Impacts
  - renewable resource use
  - nonrenewable materials use/depletion
  - energy use
  - solid waste landfill use
  - hazardous waste landfill use
  - radioactive waste landfill use
- Abiotic Ecosystem Impacts
  - global warming
  - stratospheric ozone depletion
  - photochemical smog
  - acidification
  - air quality (particulate matter loading)
  - water eutrophication (nutrient enrichment)
  - water quality (biological oxygen demand [BOD] and total suspended solids [TSS])
  - radioactivity

- Potential Human Health and Ecotoxicity Impacts
  - chronic human health effects (occupational and public)
  - aesthetic impacts (odor)
  - aquatic ecotoxicity
  - terrestrial ecotoxicity

The second step of classification is assigning inventory inputs or outputs to applicable impact categories. Classification depends on whether the inventory item is an input or output, what the disposition of the output is, and in some cases the material properties for a particular inventory item. Figure 3-1 shows a conceptual model of classification for the CDP. Table 3-1 presents the inventory types and material properties used to define which impact category will be applicable to an inventory item. One inventory item may have multiple properties and therefore would have multiple impacts. For example, methane is both a global warming gas and has the potential to create photochemical oxidants (smog formation).

Output inventory items from a process may have varying dispositions, such as direct release (to air, water or land), treatment, or recycle/reuse. Outputs with direct release dispositions are classified into impact categories for which impacts will be calculated in the characterization phase of the LCIA. Outputs sent to treatment are considered inputs to a treatment process and impacts are not calculated until direct releases from that process occur. Similarly, outputs to recycle/reuse are considered inputs to previous processes and impacts are not directly calculated for outputs that go to recycle/reuse. Figure 3-1 graphically depicts the relationships between inventory type, dispositions, and impact categories. Note that a product is also an output of a process; however, product outputs are not used to calculate any impacts. Once impact categories for each inventory item are classified, life-cycle impact category indicators are quantitatively estimated through the characterization step.



* Equations for calculating impact scores for each impact category are provided in Sect. 3.1.2.

** Excluded from the scope of the CDP; however, included in the UT Life-Cycle Design Toolkit.

Note, radioactivity (not depicted in this figure) is classified for radioactive isotope outputs to air, water or landfill.

Figure 3-1. Impact classification conceptual model

Table 3-1. Inventory types and properties for classifying inventory items into impact categories

Inventory Type		Chemical/Material Properties	Impact Category
Input	Output		
Natural Resource Impacts			
material, water	----	renewable	renewable resource use
material, fuel	----	nonrenewable	nonrenewable resource use/depletion
electricity, fuel	----	energy	energy use
----	solid waste to landfill	RCRA [a] - defined nonhazardous waste (or other country-specific definitions)	solid waste landfill use
----	hazardous waste to landfill	RCRA [a] - defined hazardous waste (or other country-specific definitions)	hazardous waste landfill use
----	radioactive waste to landfill	radioactive waste	radioactive waste landfill use
Abiotic Ecosystem Impacts			
----	air	global warming gases	global warming
----	air	ozone depleting substances	stratospheric ozone depletion
----	air	substances that can be photochemically oxidized	photochemical smog
----	air	substances that react to form hydrogen ions (H+)	acidification
----	air	air particulates (PM_{10}, TSP) [a]	air quality (air particulates)
----	water	substances that contain available nitrogen or phosphorus	water eutrophication (nutrient enrichment)
----	water	BOD [a]	water quality: BOD
----	water	TSS [a]	water quality: TSS
---	radioactivity to air, water, or land	radioactive substance (isotope)	radioactivity
Human Health and Ecotoxicity			
material	----	toxic material	chronic human health effects - occupational
----	air, water	toxic material	chronic human health effects - public
----	air	odorous material	aesthetic impacts (odor)
----	water	toxic material	aquatic ecotoxicity
----	air, water	toxic material	terrestrial ecotoxicity

[a] Acronyms: Resource Conservation and Recovery Act (RCRA); particulate matter with average aerodynamic diameter less than 10 micrometers (PM_{10}); total suspended particulates (TSP); biological oxygen demand (BOD); total suspended solids (TSS).

3.1.2 Characterization

The characterization step of LCIA includes the conversion and aggregation of LCI results to common units within an impact category. Different assessment tools are used to quantify the magnitude of potential impacts, depending on the impact category. Three types of approaches are used in the characterization method for the CDP:

- **Loading** - An impact score is based on the inventory amount.
- **Equivalency** - An impact score is based on the inventory amount weighed by a certain effect, equivalent to a reference chemical.
    - *Full equivalency* - all substances are addressed in a unified, technical model.
    - *Partial equivalency* - a subset of substances can be converted into equivalency factors.
- **Scoring of inherent properties** - An impact score is based on the inventory amount weighed by a score representing a certain effect for a specific material (e.g., toxicity impacts are weighed using a toxicity scoring method).

Table 3-2 lists the characterization approach used with each impact category. The loading approach either uses the direct inventory amount to represent the impact or slightly modifies the inventory amount to change the units into a meaningful loading estimate. Two examples are nonrenewable resource depletion and landfill use. Use of nonrenewable resources are directly estimated as the mass (loading) of that material consumed (input amount). Use of landfill space applies the mass loading of an output of hazardous, nonhazardous, or radioactive waste and converts that loading into a volume to estimate the amount of landfill space consumed.

The equivalency method uses equivalency factors that exist for certain impact categories. Equivalency factors are values that provide a relative measure or weighting that relate an inventory output amount to some impact category relative to a certain chemical. For example, to relate an atmospheric release to the global warming impact category, chemical-specific global warming potential (GWP) equivalency factors are used. GWPs are a measure of the possible warming effect on the earth's surface arising from the emission of a gas relative to carbon dioxide (CO_2). They are based on atmospheric lifetimes and radiative forcing of different greenhouse gases.

The scoring of inherent properties method is applied to impact categories that may have different effects for the same amount of various chemicals, but for which equivalency factors do not exist or are not widely accepted. The scores are meant to normalize the inventory data to provide measures of potential impacts. Scoring methods are employed for the human and ecological toxicity impact categories, based on the CHEMS-1 method described by Swanson et al. (1997), and presented below. The scoring method provides a hazard value (HV) for each potentially toxic material, which is then multiplied by the inventory amount to calculate the toxicity impact score. The aesthetics category directly applies an inherent chemical property (i.e., odor threshold concentration), but does not convert that value into a relative score, or HV.

Using the various approaches, the UT LCIA method calculates impact scores for each inventory item for each applicable impact category. Impact scores are therefore based on either a direct measure of the inventory amount or some modification (e.g., equivalency or scoring) of that amount based on the potential effect the inventory item may have on a particular impact category. Impact scores are then aggregated within each impact category to calculate the various life-cycle impact category indicators.

Inventory amounts are identified on a functional unit basis and then used to calculate impact scores. For each inventory item, an individual score is calculated for each applicable impact category. The equations presented in the subsections that follow calculate impacts for individual inventory items that could later be aggregated as defined by the user. Impact scores represent relative and incremental changes rather than absolute effects or threshold levels.

Table 3-2. LCIA characterization approaches for the CDP

Impact Category	Characterization Approach
Natural Resource Impacts	
Renewable resource use	loading
Nonrenewable materials use/depletion	loading
Energy use	loading
Solid waste landfill use	loading
Hazardous waste landfill use	loading
Radioactive waste landfill use	loading
Abiotic Ecosystem Impacts	
Global warming	equivalency (full)
Stratospheric ozone depletion	equivalency (full)
Photochemical smog	equivalency (partial)
Acidification	equivalency (full)
Air quality (particulate matter)	loading
Water eutrophication (nutrient enrichment)	equivalency (partial)
Water quality (BOD, TSS)	loading
Radioactivity	loading
Human Health and Ecotoxicity	
Chronic human health effects - occupational	scoring of inherent properties
Chronic human health effects - public	scoring of inherent properties
Aesthetic impacts (odor)	application of inherent properties
Aquatic ecotoxicity	scoring of inherent properties
Terrestrial ecotoxicity	scoring of inherent properties

3.1.2.1 Renewable and nonrenewable resource use

Natural resources are materials that are found in nature in their basic form rather than being manufactured (e.g., water, minerals, petroleum and wood). Renewable (or flow) resources, which are those that can be regenerated, are typically biotic resources (e.g., forest products, other plants or animals) and water. Nonrenewable (or stock) resources are abiotic, such as mineral ore or fossil fuels. Both of these natural resource impacts are calculated using the loading approach. Renewable and nonrenewable resource consumption impacts use direct consumption values (i.e., material mass) from the inventory.

Renewable resource impact scores are based on the following process inputs in the LCI: primary, ancillary, water, and fuel inputs of renewable materials. To calculate the loading-based impact scores, the following equation is used:

$$(IS_{RR})_i = [Amt_{RR} \ x \ (1 - RC)]_i$$

where:

IS_{RR} equals the impact score for use of renewable resource *i* (kg) per functional unit;

Amt_{RR} equals the inventory input amount of renewable resource *i* (kg) per functional unit; and

RC equals the fraction recycled content (post industrial and post consumer) of resource *i*.

In the CDP LCI, most manufacturers that provided primary data did not report recycled content nor was the recycled content available for material inventories from secondary sources. Therefore, to calculate the impact score for use of renewable resources the recycled content (RC) was assumed to be zero.

Depletion of materials, which results from the extraction of renewable resources faster than they are renewed, may occur but is not specifically modeled or identified in the renewable resource impact score. For the nonrenewable materials use/depletion category, depletion of materials results from the extraction of nonrenewable resources. Nonrenewable resource impact scores are based on the amount of primary, ancillary, and fuel inputs of nonrenewable materials. To calculate the loading-based impact scores the following equation is used:

$$(IS_{NRR})_i = [Amt_{NRR} \ x \ (1 - RC)]_i$$

where:

IS_{NRR} equals the impact score for use of nonrenewable resource *i* (NRR) (kg) per functional unit;

Amt_{NRR} equals the inventory input amount of nonrenewable resource *i* (kg) per functional unit; and

RC equals the fraction recycled content (post industrial and post consumer) of resource *i*.

Due to the lack of data on the recycled content of nonrenewable resources, RC was assumed to be zero.

3.1.2.2 Energy use

General energy consumption is used as an indicator of potential environmental impacts from the entire energy generation cycle. Energy use impact scores are based on *fuel* and *electricity* inputs. The impact category indicator is the sum of electrical energy inputs and fuel energy inputs. Fuel inputs are converted from mass to energy units using the fuel's heat value (H) and the density (D), presented in Appendix K, Table K-1. The impact score is calculated by:

$$(IS_E)_i = Amt_{Ei} \text{ or } [Amt_F \, x \, (H / D)]_i$$

where:

IS_E	equals the impact score for energy use (MJ) per functional unit;
Amt_E	equals the inventory input amount of electrical energy used (MJ) per functional unit;
Amt_F	equals the inventory input amount of fuel used (kg) per functional unit;
H	equals the heat value of fuel *i* (MJ/L); and
D	equals the density of fuel *i* (kg/L).

This category addresses energy *use* only. The emissions from energy production are outputs from the energy production process and are classified to applicable impact categories, depending on the disposition and chemical properties of the outputs (see Classification Section 3.1.1).

3.1.2.3 Landfill use

Landfill impacts are calculated using solid, hazardous, or radioactive waste outputs to land as volume of landfill space consumed. Solid waste landfill use pertains to the use of suitable and designated landfill space as a natural resource where municipal waste or construction debris is accepted. A solid waste landfill impact score is calculated using solid waste outputs disposed of in a solid waste (nonhazardous) landfill. Impact characterization is based on the volume of solid waste, determined from the inventory mass amount of waste and material density of each specific solid waste type:

$$(IS_{SWL})_i = (Amt_{SW} / D)_i$$

where:

IS_{SWL}	equals the impact score for solid waste landfill (SWL) use for waste *i* (m^3) per functional unit;
Amt_{SW}	equals the inventory output amount of solid waste *i* (kg) per functional unit; and
D	equals density of waste *i* (kg/m^3).

Hazardous waste landfill use pertains to the use of suitable and designated landfill space as a natural resource where hazardous waste, as designated and regulated under the Resource Conservation and Recovery Act, is accepted. For non-US activities, equivalent hazardous or special waste landfills are considered for this impact category. Impact scores are characterized from hazardous waste outputs with a disposition of landfill. Impact characterization is based on the volume of hazardous waste, determined from the inventory mass amount of waste and material density of each specific hazardous waste type:

$$(IS_{HWL})_i = (Amt_{HW} / D)_i$$

where:

IS_{HWL}	equals the impact score for hazardous waste landfill (HWL) use for waste *i* (m^3) per functional unit;
Amt_{HW}	equals the inventory output amount of hazardous waste *i* (kg) per functional unit; and
D	equals density of waste *i* (kg/m^3).

Radioactive waste pertains to the suitable and designated landfill space as a natural resource that accepts radioactive waste. Impacts are characterized from radioactive waste outputs with a disposition of landfill. Impact characterization is based on the volume of radioactive waste, determined from the inventory mass amount of waste and material density of each specific waste.

$$(IS_{RWL})_i = (Amt_{RW}/D)_i$$

where:

IS_{RWL}	equals the impact score for radioactive waste landfill (RWL) use for waste *i* (m^3) per functional unit;
Amt_{RW}	equals the inventory output amount of radioactive waste *i* (kg) per functional unit; and
D	equals density of waste *i* (kg/m^3).

3.1.2.4 Global warming impacts

The build up CO_2 and other greenhouse gases in the atmosphere may generate a "greenhouse effect" of rising temperature and climate change. Global warming potential (GWP) refers to the warming (relative to CO_2) that chemicals contribute to this effect by trapping the earth's heat. The impact scores for global warming (global climate change) effects are calculated using the mass of a global warming gas released to air modified by a GWP equivalency factor. The GWP equivalency factor is an estimate of a chemical's atmospheric lifetime and radiative forcing that may contribute to global climate change compared to the reference chemical CO_2. Therefore, GWPs are in units of CO_2 equivalents. GWPs have been published for known global warming chemicals within differing time horizons. The LCIA methodology being presented in this memorandum uses GWPs having effects in the 100-year time horizon. Although LCA does not necessarily have a temporal component of the inventory, these impacts are expected to be far enough into the future that releases occurring throughout the life cycle of a computer monitor would be within the 100-year time frame. Appendix K, Table K-2 presents a current list of GWPs as identified by the Intergovernmental Panel on Climate Change (IPCC) (Houghton et al., 1996). Global warming impact scores are calculated for any chemicals in the LCI that are found in Appendix K, Table K-2. The equation to calculate the impact score for an individual chemical is as follows:

$$(IS_{GW})_i = (EF_{GWP} \times Amt_{GG})_i$$

where:

IS_{GW} equals the global warming impact score for greenhouse gas chemical *i* (kg CO_2 equivalents) per functional unit;

EF_{GWP} equals the GWP equivalency factor for greenhouse gas chemical *i* (CO_2 equivalents, 100 year time horizon) (Appendix K, Table K-2); and

Amt_{GG} equals the inventory output amount of greenhouse gas chemical *i* released to air (kg) per functional unit.

3.1.2.5 Stratospheric ozone depletion

The stratospheric ozone layer filters out harmful ultraviolet radiation from the sun. Chemicals such as chlorofluorocarbons, if released to the atmosphere, may result in ozone-destroying chemical reactions. Stratospheric ozone depletion refers to the release of chemicals that may contribute to this effect. Impact scores are based on the identity and amount of ozone depleting chemicals released to air. Currently identified ozone depleting chemicals are those with ozone depletion potentials (ODPs), which measure the change in the ozone column in the equilibrium state of a substance compared to the reference chemical chlorofluorocarbon (CFC)-11 (Heijungs *et al.*, 1992; CAAA, 1990). The list of ODPs that are used in this methodology are provided in Appendix K, Table K-3. The individual chemical impact score for stratospheric ozone depletion impacts is based on the ODP and inventory amount of the chemical:

$$(IS_{OD})_i = (EF_{ODP} \times Amt_{ODC})_i$$

where:

IS_{OD} equals the ozone depletion impact score for chemical *i* (kg CFC-11 equivalents) per functional unit;

EF_{ODP} equals the ODP equivalency factor for chemical *i* (CFC-11 equivalents) (Appendix K, Table K-3); and

Amt_{ODC} equals the amount of ozone depleting chemical *i* released to air (kg) per functional unit.

3.1.2.6 Photochemical smog

Photochemical oxidants are produced in the atmosphere from sunlight reacting with hydrocarbons and nitrogen oxides. At higher concentrations they may cause or aggravate health problems, plant toxicity, and deterioration of certain materials. Photochemical oxidant creation potential (POCP) refers to the release of chemicals that may contribute to this effect. The POCP is based on simulated trajectories of tropospheric ozone production with and without volatile organic carbons (VOCs) present. The POCP is a measure of a specific chemical compared to the reference chemical ethene (Heijungs *et al.*, 1992). The list of chemicals with POCPs to be used in this methodology are presented in Appendix K, Table K-4. As shown in Table 3-2, photochemical smog impacts are based on partial equivalency because some chemicals cannot be converted into POCP equivalency factors. For example, nitrogen oxides do not have a POCP. However, VOCs are assumed to be the limiting factor and if VOCs are present, there is a potential impact. Impact scores are based on the identity and amount of chemicals with POCP equivalency factors released to the air and the chemical-specific equivalency factor:

$$(IS_{POCP})_i = (EF_{POCP} \; x \; Amt_{POC})_i$$

where:

IS_{POCP}	equals the photochemical smog impact score for chemical *i* (kg ethene equivalents) per functional unit;
EF_{POCP}	equals the POCP equivalency factor for chemical *i* (ethene equivalents) (Appendix K, Table K-4); and
Amt_{POC}	equals the amount of smog-creating chemical *i* released to the air (kg) per functional unit.

3.1.2.7 Acidification

This refers to the release of chemicals that may contribute to the formation of acid precipitation. Impact characterization is based on the amount of a chemical released to air that would cause acidification and the acidification potentials (AP) equivalency factor for that chemical. The AP equivalency factor is the number of hydrogen ions that can theoretically be formed per mass unit of the pollutant being released compared to sulfur dioxide (SO_2) (Heijungs *et al.*, 1992; Hauschild and Wenzel, 1997). Appendix K, Table K-5 lists the AP values that will be used as the basis of calculating acidification impacts. The impact score is calculated by:

$$(IS_{AP})_i = (EF_{AP} \; x \; Amt_{AC})_i$$

where:

IS_{AP}	equals the impact score for acidification for chemical *i* (kg SO_2 equivalents) per functional unit;
EF_{AP}	equals the AP equivalency factor for chemical *i* (SO_2 equivalents) (Appendix K, Table K-5); and
Amt_{AC}	equals the amount of acidification chemical *i* released to the air (kg) per functional unit.

3.1.2.8 Air particulates

This refers to the release and build up of particulate matter primarily from combustion processes. Impact scores are based on particulate release amounts [particulate matter with average aerodynamic diameter less than 10 micrometers (PM_{10})] to the air. This size of particulate matter is most damaging to the respiratory system. Impact characterization is simply based on the inventory amount of particulates released to air. This loading impact score is calculated by:

$$IS_{PM} = Amt_{PM}$$

where:

IS_{PM}	equals impact score for particulates (kg PM_{10}) per functional unit, and

Amt_{PM} equals the inventory output amount of particulate release (PM_{10}) to the air (kg) per functional unit.

In this equation, PM_{10} is used to estimate impacts. However, if only total suspended particulates (TSP) data are available, these data may be used. Note that using TSP data is an overestimation of $PM_{10,}$ which only refers to the fraction of particulates in the size range below 10 micrometers. A common conversion factor (TSP to PM_{10}) is not available because the fraction of PM_{10} varies depending on the type of particulates.

3.1.2.9 Water eutrophication

Eutrophication (nutrient enrichment) impacts to water are based on the identity and concentrations of eutrophication chemicals released to surface water after treatment. Equivalency factors for eutrophication have been developed assuming nitrogen (N) and phosphorus (P) are the two major limiting nutrients of importance to eutrophication. Therefore, the partial equivalencies are based on the ratio of N to P in the average composition of algae ($C_{106}H_{263}O_{110}N_{16}P$) compared to the reference compound phosphate (PO_4^{3-}) (Heijungs *et al.*, 1992; Lindfors *et al.*, 1995). If the wastewater stream is first sent to a publicly owned treatment works (POTW), treatment is considered as a separate process and the impact score would be based on releases from the POTW to surface waters. Impact characterization is based on eutrophication potentials (EP) (Appendix K, Table K-6) and the inventory amount:

$$(IS_{EUTR})_i = (EF_{EP} \text{ x } Amt_{EC})_i$$

where:

IS_{EUTR} equals the impact score for regional water quality impacts from chemical *i* (kg phosphate equivalents) per functional unit;

EF_{EP} equals the EP equivalency factor for chemical *i* (phosphate equivalents) (Appendix K, Table K-6); and

Amt_{EC} equals the inventory output mass (kg) of chemical *i* per functional unit of eutrophication chemical in a wastewater stream released to surface water after any treatment, if applicable.

3.1.2.10 Water quality

Water quality impacts are characterized as surface water impacts due to releases of wastes causing oxygen depletion and increased turbidity. Two water quality impact scores are calculated based on the biological oxygen demand (BOD) and total suspended solids (TSS) in the wastewater streams released to surface water. The impact scores are based on releases to surface water following any treatment. Using a loading characterization approach, impact characterization is based on the amount of BOD and TSS in a wastewater stream. The water quality score equations for each are presented below:

$$(IS_{BOD})_i = (Amt_{BOD})_i$$

and

$$(IS_{TSS})_i = (Amt_{TSS})_i$$

where:

IS_{BOD}	equals the impact score for BOD water quality impacts for waste stream *i* (kg) per functional unit;
Amt_{BOD}	equals the inventory output amount of BOD in wastewater stream *i* released to surface waters (kg) per functional unit;
IS_{TSS}	equals the impact score for TSS water quality impacts for waste stream *i* (kg) per functional unit; and
Amt_{TSS}	equals the inventory amount of TSS in wastewater stream *i* released to surface waters (kg) per functional unit.

3.1.2.11 Radioactivity

Radioactivity inventoried as the quantity of an isotope released to the environment is considered in the radioactivity impact category. These outputs, such as those from the generation of nuclear energy, can be air, water, or land releases. The radioactivity impact is a direct loading score measured in Bequerels of radioactivity, and calculated as follows:

$$(IS_{rad})_i = (Amt_{rad})_i$$

where:

IS_{rad}	equals the impact score for radioactivity of isotope *i* (Bq) per functional unit; and
Amt_{rad}	equals the inventory amount of radioactivity of isotope *i* (Bq) per functional unit.

While this impact category uses a loading approach, further refinement of this impact score calculation in the future could use radioactivity dose conversion factors, which convert radioactivity quantities (e.g., Bq) into human doses equivalents (e.g., sievert or rem).

3.1.2.12 Potential human health impacts

Human health impacts are defined in the context of life-cycle assessment as relative measures of potential adverse health effects to humans. Human health impact categories included in the scope of this LCA are chronic (repeated dose) effects, which include noncarcinogenic and carcinogenic effects, and aesthetics (although not a health effect *per se*, aesthetics pertains to human welfare). Chronic human health effects to both workers and the public are considered. Quantitative measures of consumer impacts are not included in this LCIA methodology because there are no direct outputs quantified in the LCI from the use stage of a computer monitor. The CDP does, however, quantify indirect outputs from energy consumption (i.e., pollutants released from energy production). In addition, Appendix L qualitatively discusses direct consumer impacts, such as electromagnetic radiation or eye strain.

The chemical characteristic that classifies inventory items to the human health effects (and ecotoxicity) categories is toxicity. Toxic chemicals were identified by searching lists of toxic chemicals [e.g., Toxic Release Inventory (TRI)] and if needed, toxicity databases [e.g., Hazardous Substances Data Bank (HSDB)], and Registry of Toxic Effects of Chemical Substances (RTECS), or other literature. Upon review by the EPA DfE Workgroup (see Appendix C), several materials in the CDP inventory were excluded from the toxic list if they are generally accepted as nontoxic. The EPA DfE Workgroup also reviewed the list of chemicals that were included in this project as potentially toxic. The list of potentially toxic chemicals is provided in Appendix K, Table K-8, and chemicals that were excluded from the toxic list that appear in the CDP inventory are presented in Appendix K, Table K-9.

Human (and ecological) toxicity impact scores are calculated based on a chemical scoring method modified from CHEMS-1 found in Swanson *et al.* (1997). To calculate impact scores, chemical-specific inventory data are required. Any chemical that is assumed to be potentially toxic is given a toxicity impact score. If toxicity data are unavailable for a chemical, a mean default toxicity score is given. This is described in further detail below. Ecological toxicity is presented in Section 3.1.2.13.

Chronic human health effects are potential human health effects occurring from repeated exposure to toxic agents over a relatively long period of time (i.e., years). These effects could include carcinogenicity, reproductive toxicity, developmental effects, neurotoxicity, immunotoxicity, behavioral effects, sensitization, radiation effects, chronic effects to other specific organs or body systems (e.g., blood, cardiovascular, respiratory, kidney and liver effects). Impact categories for chronic health effects are divided into worker and public impacts. Occupational impact scores are based on inventory inputs and public impact scores are based on inventory outputs.

Chronic occupational health effects

This refers to potential health effects to workers, including cancer, from long-term repeated exposure to toxic or carcinogenic agents in an occupational setting. For possible occupational impacts, the identity and amounts of materials/constituents as input to a process are used. The inputs represent potential exposures and we could assume that a worker would continue to work at a facility and incur exposures over time. However, the inventory is based on manufacturing one monitor and does not truly represent chronic exposure. Therefore, the chronic health effects impact score is more a ranking of the potential of a chemical to cause chronic effects than a prediction of actual effects.

Chronic occupational health effects scores are based on the identity of toxic chemicals (or chemical ingredients) found in primary and ancillary inputs from materials processing and manufacturing life-cycle stages. The distinction between pure chemicals and mixtures is made implicitly, if possible, by specifying component ingredients of mixtures in the inventory.

The chronic human health impact scores are calculated using hazard values (HVs) for carcinogenic and for noncarcinogenic effects. The former HV uses cancer slope factors or cancer weight of evidence (WOE) classifications assigned by EPA and/or the International Agency for Research on Cancer (IARC) when no slope factor exists. If both an oral and inhalation slope factor exist, the slope factor representing the larger hazard is chosen. Where no slope factor is available for a chemical, but there is a WOE classification, the WOE is used to designate default hazard values as follows: EPA WOE Groups D (not classifiable) and E (noncarcinogen) and IARC Groups 3 (not classifiable) and 4 (probably not carcinogenic) are given a hazard value of zero. All other WOE classifications (known, probable, and possible human carcinogen) are given a default HV of 1 (representative of a mean slope factor) (Table 3-3). Similarly, materials for which no cancer data exist, but are designated as potentially toxic, are also given a default value of 1.

Table 3-3. Hazard values for carcinogenicity weight-of-evidence if no slope factor is available

EPA Classification	IARC Classification	Description	Hazard Value
Group A	Group 1	known human carcinogen	1
Group B1	Group 2A	Probable human carcinogen (limited human data)	1
Group B2	N/A	Probable human carcinogen (from animal data)	1
Group C	Group 2B	Possible human carcinogen	1
Group D	Group 3	Not classifiable	0
Group E	Group 4	Noncarcinogenic or probably not carcinogenic	0

N/A: not applicable.

The cancer hazard value for chronic occupational health effects is the greater of the following:

$$\textit{oral}: \quad (HV_{CA_{oral}})_i = \frac{oral\ SF_i}{oral\ SF_{mean}}$$

$$\textit{inhalation}: \quad (HV_{CA_{inhalation}})_i = \frac{inhalation\ SF_i}{inhalation\ SF_{mean}}$$

where:

HV_{CAoral}	equals the cancer oral hazard value for chemical *i* (unitless);
$oral\ SF_i$	equals the cancer oral slope factor for chemical *i* (mg/kg-day);
$oral\ SF_{mean}$	equals the geometric mean cancer slope factor of all available slope factors (0.71 mg/kg-day);
$HV_{CAinhalation}$	equals the cancer inhalation hazard value for chemical *i* (unitless);
$inhalation\ SF_i$	equals the cancer inhalation slope factor for chemical *i* $(mg/kg\text{-}day)^{-1}$; and
$inhalation\ SF_{mean}$	equals the geometric mean cancer inhalation slope factor of all available inhalation slope factors (1.70 $mg/kg\text{-}day)^{-1}$.

The oral and inhalation slope factor mean values are the geometric means of a set of chemical data presented in Appendix K, Table K-10.

The noncarcinogen HV is based on either no-observed-adverse-effect levels (NOAELs) or lowest-observed-adverse-effect levels (LOAELs). The noncarcinogen HV is the greater of the

$$\textit{oral}: \quad (HV_{NC_{oral}})_i = \frac{1/(oral\ NOAEL_i)}{1/(oral\ NOAEL_{mean})}$$

inhalation and oral HV:

$$\textit{inhalation}: \quad (HV_{NC_{inhalation}})_i = \frac{1/(inhal\ NOAEL_i)}{1/(inhal\ NOAEL_{mean})}$$

where:

$HV_{NC\ oral}$	equals the noncarcinogen oral hazard value for chemical *i* (unitless);
$oralNOAEL_i$	equals the oral NOAEL for chemical *i* (mg/kg-day);
$oralNOAEL_{mean}$	equals the geometric mean oral NOAEL of all available oral NOAELs (11.88 mg/kg-day);
$HV_{NC\ inhalation}$	equals the noncarcinogen inhalation hazard value for chemical *i* (unitless);
$inhalNOAEL_i$	equals the inhalation NOAEL for chemical *i* (mg/m^3); and
$inhalNOAEL_{mean}$	equals the geometric mean inhalation NOAEL of all available inhalation NOAELs (68.67 mg/kg-day).

The oral and inhalation NOAEL mean values are the geometric means of a set of chemical data presented in Appendix K, Table K-8. If LOAEL data are available instead of NOAEL data, the LOAEL divided by 10 is used to substitute for the NOAEL. The most sensitive endpoint is used if there are multiple data for one chemical.

The sum of the carcinogen and noncarcinogen HVs for a particular chemical is multiplied by the applicable inventory input to calculate the impact score:

$$(IS_{CHO})_i = [(HV_{CA} + HV_{NC},)\ x\ Amt_{TCinput}]_i$$

where:

IS_{CHO}	equals the impact score for chronic occupational health effects for chemical *i* (tox-kg) per functional unit;
HV_{CA}	equals the hazard value for carcinogenicity for chemical *i*;
HV_{NC}	equals the hazard value for chronic noncancer effects for chemical *i*; and
$Amt_{TCinput}$	equals the amount of toxic inventory input (kg) per functional unit for chemical *i.*

Chronic public health effects

For chronic public health effects, the impact score represents a surrogate for potential health effects to residents living near a facility, including cancer, from long-term repeated exposure to toxic or carcinogenic agents. Impact scores are based on the identity and amount of toxic chemical outputs with dispositions to air and water.[1] As stated above, inventory items do not truly represent long-term exposure; instead, impacts are relative toxicity weightings of the inventory.

The scores for impacts to the public differ from the occupational impacts in that inventory outputs are used as opposed to inventory inputs. Note that this basic screening level scoring does not incorporate the fate and transport of the chemicals. The chronic public health effects impact score is calculated as follows:

$$(IS_{CHP})_i = [(HV_{CA} + HV_{NC}) \times Amt_{TCoutput}]_i$$

where:

IS_{CHP} equals the impact score for chronic human health effects to the public for chemical *i* (tox-kg) per functional unit; and

$Amt_{TCoutput}$ equals the amount of toxic inventory output of chemical *i* to air and water (kg) per functional unit.

Aesthetic impacts (odor)

This refers to impacts that detract from the quality of the local environment from a human perspective. Characterization in this project is based on odor. Impact scores are based on the identity and amount of odor-causing chemicals (Heijungs *et al.*, 1992; EPA 1992), released to the air and their odor threshold value (OTV) (Heijungs *et al.*, 1992) (Appendix K, Table K-7). This approach does not score chemicals as is done for toxic chemicals. The OTV is specific to a chemical, but does not use an equivalency factor that is based on a reference chemical or a hazard value based on a mean OTV. In this case, the OTV is a concentration which, when divided into the mass output of a chemical, results in an impact score in units of volume of malodorous air:

$$(IS_{AS})_i = (Amt_{OC} / OTV)_i$$

where:

IS_{AS} equals the aesthetics impact score for chemical *i* (m^3 malodorous air) per functional unit;

Amt_{OC} equals the amount of odor-causing output for chemical *i* released to air (mg) per functional unit; and

OTV equals the odor threshold value for chemical *i* (mg/m^3) (Appendix K, Table K-10).

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[1] Disposition could be to groundwater. For example, a landfill model could have releases that go to groundwater.

Note that this impact assessment methodology determines the volume of malodorous air created if there is no dilution. In reality, many of the air releases reported in the LCI may occur at concentrations below the chemical's odor threshold.

3.1.2.13 Ecotoxicity

Ecotoxicity refers to effects of chemical outputs on nonhuman living organisms. Impact categories include ecotoxicity impacts to aquatic and terrestrial ecosystems.

Aquatic toxicity

Toxicity measures for fish are used to represent potential adverse effects to organisms living in the aquatic environment from exposure to a toxic chemical. Impact scores are based on the identity and amount of toxic chemicals as outputs to surface water. Impact characterization is based on CHEMS-1 acute and chronic hazard values for fish (Swanson *et al.*, 1997) combined with the inventory amount. Both acute and chronic impacts are combined into the aquatic toxicity term. The hazard values (HVs) for acute and chronic toxicity are based on LC_{50} and NOAEL toxicity data, respectively, mostly from toxicity tests in fathead minnows (*Pimephales promelas*) (Swanson *et al.*, 1997). The acute fish HV is calculated by:

$$(HV_{FA})_i = \frac{1/(LC_{50})_i}{1/(LC_{50})_{mean}}$$

where:

HV_{FA}	equals the hazard value for acute fish toxicity for chemical *i* (unitless);
LC_{50i}	equals the lethal concentration to 50% of the exposed fish population for chemical *i*; and
LC_{50mean}	equals the geometric mean LC_{50} of available fish LC_{50} values in Appendix K, Table K-8 (23.45 mg/L).

The chronic fish HV is calculated by:

$$(HV_{FC})_i = \frac{1/NOAEL_i}{1/NOAEL_{mean}}$$

where:

HV_{FC}	equals the hazard value for chronic fish toxicity for chemical *i*;
$NOAEL_i$	equals the no observed adverse affect level for fish for chemical *i*; and
$NOAEL_{mean}$	equals the geometric mean NOAEL of available fish NOAEL values in Appendix K, Table K-7 (3.90 mg/L).

The aquatic toxicity impact score is calculated as follows:

$$(IS_{AQ})_i = [(HV_{FA} + HV_{FC}) \text{ x } Amt_{TCoutput,water}]_i$$

where:

IS_{AQ} equals the impact score for aquatic ecotoxicity for chemical *i* (tox-kg) per functional unit; and

$Amt_{TCoutput,water}$ equals the toxic inventory output amount of chemical *i* to water (kg) per functional unit.

Terrestrial toxicity

Toxicity measures for mammals (primarily rodents) are used to represent potential adverse effects to organisms living in the terrestrial environment from exposure to a toxic chemical. Impact scores are based on the identity and amount of toxic chemicals as outputs to air and surface water. Impact characterization is based on chronic toxicity hazard values combined with the inventory amount. The terrestrial toxicity impact score is based on the same noncancer chronic data used for human health because underlying data are from the same mammal studies (see Section 2.1.2.12 for the HV_{NC} term). The cancer hazard value was not included in the terrestrial impact score as it is based on ranking for potential human carcinogenicity. The terrestrial toxicity impact score is as follows:

$$(IS_{TER})_i = (HV_{NC} \text{ x } Amt_{TCoutput})_i$$

where:

IS_{TER} equals the impact score for terrestrial toxicity for chemical *i* (tox-kg) per functional unit; and

$Amt_{TCoutput}$ equals the toxic inventory output amount of chemical *i* (kg) per functional unit.

3.1.2.14 Summary of impact score equations

Table 3-4 summarizes the impact categories, associated impact score equations, and the input or output data required for calculating natural resource impacts. Each of these characterization equations are loading estimates.

Table 3-4. Summary of natural resources impact scoring

Impact Category	Impact Score Approach	Data Required from Inventory (per functional unit)	
		Inputs	**Outputs**
Use of renewable resources	$IS_{RR} = Amt_{RR} \times (1 - RC)$	Material mass (kg) (e.g., water)	none
Use/depletion of nonrenewable materials	$IS_{NRR} = Amt_{NRR} \times (1 - RC)$	Material mass (kg)	none
Energy use, general energy consumption	$IS_E = Amt_E$ or $(Amt_F \times H/D)$	Energy (MJ) (electricity, fuel)	none
Solid waste landfill use	$IS_{SWL} = Amt_{SW} / D$	none	solid waste mass (kg) and density (i.e., volume, m^3)
Hazardous waste landfill use	$IS_{HWL} = Amt_{HW} / D$	none	hazardous waste mass (kg) and density (i.e., volume, m^3)
Radioactive waste landfill use	$IS_{RWL} = Amt_{RW} / D$	none	radioactive waste mass (kg) and density (i.e., volume, m^3)

Abbreviations: RC = recycled content; H = heat value of fuel *i*; D = density of fuel *i*.

The term abiotic ecosystem refers to the nonliving environment that supports living systems. Table 3-5 presents the impact categories, impact score equations, and inventory data requirements for abiotic environmental impacts to atmospheric resources.

Table 3-5. Summary of atmospheric resource impact scoring

Impact Category	Impact Score Approach	Data Required from Inventory (per functional unit)	
		Inputs	**Outputs**
Global warming	$IS_{GW} = EF_{GWP} \times Amt_{GG}$	none	amount of each greenhouse gas chemical released to air
Stratospheric ozone depletion	$IS_{OD} = EF_{ODP} \times Amt_{ODC}$	none	amount of each ozone depleting chemical released to air
Photochemical smog	$IS_{POCP} = EF_{POCP} \times Amt_{POC}$	none	amount of each smog-creating chemical released to air
Acidification	$IS_{AP} = EF_{AP} \times Amt_{AC}$	none	amount of each acidification chemical released to air
Air quality (particulate matter)	$IS_{PM} = Amt_{PM}$	none	amount of particulates: PM_{10} or TSP released to air [a]

[a] Assumes PM_{10} and TSP are equal; however, using TSP will overestimate PM_{10}.

Table 3-6 presents the impact categories, impact score equations, and required inventory data for abiotic environmental impacts to water resources.

Table 3-6. Summary of water resource impact scoring

Impact Category	Impact Score Approach	Data Required from Inventory (per functional unit)	
		Inputs	**Outputs**
Water eutrophication	$IS_{EUTR} = EF_{EP} \times Amt_{EC}$	none	amount of each eutrophication chemical released to water
Water quality (BOD)	$IS_{BOD} = Amt_{BOD}$	none	amount of BOD in each wastewater stream released to surface water
Water quality (TSS)	$IS_{TSS} = Amt_{TSS}$	none	amount of suspended solids (TSS) in each wastewater stream released to surface water

Table 3-7 summarizes the human health and ecotoxicity impact scoring approaches. The impact categories, impact score equations, the type of inventory data, and the chemical properties required to calculate impact scores are presented. The human health effects and ecotoxicity impact scores are based on the scoring of inherent properties approach to characterization.

Table 3-7. Summary of human health and ecotoxicity impact scoring

Impact Category	Impact Score Equations	Data Required from Inventory (per functional unit)		Chemical Properties Data Required
		Inputs	**Outputs**	
Chronic human health effects - occupational	$IS_{CHO} = (HV_{CA} + HV_{NC}) \times Amt_{TCinput}$	mass of each primary and ancillary toxic chemical	none	WOE or SF and/or mammal NOAEL or LOAEL
Chronic human health effects - public	$IS_{CHP} = (HV_{CA} + HV_{NC}) \times Amt_{TCoutput}$	none	mass of each toxic chemical released to air and surface water	WOE or SF and/or mammal NOAEL or LOAEL
Aesthetic impacts (odor)	$IS_{AS} = Amt_{OC} / OTV$	none	mass of odorous chemicals released to air	human odor threshold values
Aquatic toxicity	$IS_{AQ} = (HV_{FA} + HV_{FC}) \times Amt_{TCoutput,water}$	none	mass of each toxic chemical released to surface water	fish LC_{50} and/or fish NOAEL
Terrestrial toxicity	$IS_{TER} = HV_{NC} \times Amt_{TCoutput}$	none	mass of each toxic chemical released to air or surface water	mammal NOAEL

3.1.2.15 Aggregation of impact scores

Individual impact scores are calculated for inventory items for a certain impact category and can be aggregated by inventory item (e.g., a certain chemical), process, life-cycle stage, or entire product profile. For example, global warming impacts can be calculated for one inventory item (e.g., CO_2 releases), for one process that could include contributions from several inventory items (e.g., electricity generation), for a life-cycle stage that may consist of several process steps (e.g., product manufacturing), or for an entire profile (e.g., a CRT desktop monitor over its life).

The following example illustrates how impacts are calculated. If two toxic chemicals [e.g., toluene and benzo(a)pyrene] are included in a waterborne release to surface water from Process A, impact scores would be calculated for the following impact categories (based on the classification shown in Table 3-1):

- Chronic public health effects;
- Aquatic toxicity; and
- Terrestrial toxicity.

Despite the output types being waterborne releases, the water eutrophication and water quality impact categories are not applicable here because the chemical properties criteria in Table 3-1 are not met. That is, these chemicals do not contain N or P and are not themselves wastewater streams.

Using chronic public health effects as an example, impact scores are then calculated for each chemical as follows:

$$IS_{CHP:toluene} = (HV_{CA:toluene} + HV_{NC:toluene}) \text{ x } Amt_{TCoutput:toluene}$$
$$IS_{CHP:benzo(a)pyrene} = (HV_{CA:benzo(a)pyrene} + HV_{NC:benzo(a)pyrene}) \text{ x } Amt_{TCoutput:benzo(a)pyrene}$$

Table 3-8 presents toxicity data for the example chemicals from Appendix K, Table K-8. Using benzo(a)pyrene as an example, the hazard values are calculated as follows:

Table 3-8. Toxicity data used in example calculations

Chemical	Cancer		Chronic noncancer effects	
	Weight of evidence	**Slope factor (SF) (mg/kg-day)$^{-1}$**	**Oral (mg/kg-day)**	**Inhalation (mg/m^3)**
Toluene	D, 3	none	100[b]	411.1[b]
Benzo(a)pyrene	B2, 2A	3.1[a] 7.3[c]	no data	no data

[a] inhalation SF

[b] NOAEL

[c] oral SF

Cancer effects:

$$oral: \quad (HV_{CA_{oral}})_i = \frac{oral\ SF_i}{oral\ SF_{mean}}$$

$HV_{CAoral:benzo(a)pyrene}$ $= 7.3\ (mg/kg\text{-}day)^{-1} \div 0.71\ (mg/kg\text{-}day)^{-1}$
$= 10.3$

$$inhalation: \quad (HV_{CA_{inh}})_i = \frac{inhalation\ SF_i}{inhalation\ SF_{mean}}$$

$HV_{CAinhalation:benzo(a)pyrene}$ $= 3.1\ (mg/kg\text{-}day)^{-1} \div 1.7\ (mg/kg\text{-}day)^{-1}$
$= 1.82$

Thus, the cancer HV is 10.3, the greater of the two values.

Noncancer effects:

Since no data are available for noncancer effects, a default HV of one is assigned, representative of mean toxicity.

Total HV:

Thus the total hazard value for benzo(a)pyrene is given by:

$HV_{benzo(a)pyrene}$ $= HV_{CA} + HV_{NC}$
$= 10.3 + 1$
$= 11.3$

Similarly, the HV for toluene is found to be 0.12. Given the following hypothetical output amounts:

$Amt_{TC\text{-}O:TOLUENE}$ = 1.3 kg of toluene per functional unit
$Amt_{TC\text{-}O:BENZO(A)PYRENE}$ = 0.1 kg of benzo(a)pyrene per functional unit

the resulting impact scores are as follows:

$IS_{CHP\text{-}W:TOLUENE}$ = 0.12 x 1.3 = 0.16 tox-kg of toluene per functional unit
$IS_{CHP\text{-}W:BENZO(A)PYRENE}$ = 11.3 x 0.1 = 1.13 tox-kg of benzo(a)pyrene per functional unit

If these were the only outputs from Process A relevant to chronic public health effects, the total impact score for this impact category for Process A would be:

$$\begin{aligned} IS_{CHP:PROCESS\_A} &= IS_{CHP\text{-}W:TOLUENE} + IS_{CHP\text{-}W:BENZO(A)PYRENE} \\ &= 0.16 + 1.13 \\ &= 1.29 \text{ tox-kg per functional unit for Process A.} \end{aligned}$$

If the product system Y contained three processes altogether (Processes A, B, and C), and the impact scores for Process B and C were 2.5 and 3.0, respectively, impact scores would be added together to yield a total impact score for the product system relevant to chronic public health effects:

$$\begin{aligned} IS_{CHP:PROFILE\_Y} &= IS_{CHP:PROCESS\_A} + IS_{CHP:PROCESS\_B} + IS_{CHP:PROCESS\_C} \\ &= 1.29 + 2.5 + 3.0 \\ &= 6.8 \text{ tox-kg per functional unit for Profile Y.} \end{aligned}$$

An environmental profile would then be the sum of all the processes within that profile for each impact category.

3.1.3 Data Sources and Data Quality

Data that are used to calculate impacts are from: (1) equivalency factors or parameters used to identify hazard values; and (2) LCI items. Equivalency factors and data used to develop hazard values, which have been presented in this methodology, include GWP, ODP, POCP, AP, EP, WOE, SF, mammalian LOAEL/NOAEL, OTV, fish LC_{50}, and fish NOAEL. Published lists of the chemical-specific parameter values exist for GWP, ODP, POCP, AP, EP and OTV (see Appendix K). The other parameters may exist for a large number of chemicals and several data sources must be searched to identify the appropriate parameter values. Priority is given to peer-reviewed databases (e.g., HEAST, IRIS, HSDB), then other databases (e.g., RTECS), other studies or literature, and finally estimation methods [e.g., structure-activity relationships (SARs) or quantitative structure-activity relationships (QSARs)]. The specific toxicity data that are used in the CDP are presented in Appendix K, Table K-8. The sources of each parameter presented in this report, and the basis for their values, are presented in Table 3-9. Data quality is affected by the type of data source (e.g., primary versus secondary data), the currency of the data, and the accuracy and precision of the data, and will depend on the source. The sources and quality of the LCI data used to calculate impact scores were discussed in Chapter 2. Data sources and data quality for each impact category are discussed further in Section 3.3, Baseline LCIA Results.

3.1.4 Limitations and Uncertainties

This section summarizes some of the limitations and uncertainties in LCIA methodology, in general. Specific limitations and uncertainties in each impact category are discussed in Section 3.3 with the baseline LCIA results.

The purpose of an LCIA is to evaluate the *relative potential* impacts of a product system for various impact categories. There is no intent to measure the *actual* impacts or provide spatial or temporal relationships linking the inventory to specific impacts. The LCIA is intended to provide a screening-level evaluation of impacts. More detailed characterization of exposure and toxicity has been conducted on selected materials for the CDP in Chapter 4.

Table 3-9. Data sources for equivalency factors and hazard values

Parameter	Basis of Parameter Values	Source
Global warming potential (GWP)	atmospheric lifetimes and radiative forcing compared to CO_2	Houghton *et al.*, 1996
Ozone depletion potential (ODP)	the change in the ozone column in the equilibrium state of a substance compared to CFC-11	Heijungs *et al.*, 1992; CAAA, 1990
Photochemical oxidant creation potential (POCP)	simulated trajectories of ozone production with and without VOCs present compared to ethene	Heijungs *et al.*, 1992
Acidification potential (AP)	number of hydrogen ions that can theoretically be formed per mass unit of the pollutant being released compared to SO_2	Heijungs *et al.*, 1992; Hauschild and Wenzel, 1997
Nutrient enrichment/eutrophication potential (EP)	ratio of N to P in the average composition of algae ($C_{106}H_{263}O_{110}N_{16}P$) compared to phosphate (PO_4^{3-})	Heijungs *et al.*, 1992; Lindfors *et al.*, 1995
Weight-of-evidence (WOE)	classification of carcinogenicity by EPA or IARC based on human and/or animal toxicity data	EPA, 1999; IARC, 1998
Slope factor (SF)	measure of an individual's excess risk or increased likelihood of developing cancer if exposed to a chemical, based on dose-response data	IRIS and HEAST as cited in Risk Assessment Information System (RAIS) online database
Mammalian: Lowest observed adverse effect level / No observed adverse effect level (LOAEL/NOAEL)	mammalian (primarily rodent) toxicity studies	IRIS, HEAST and various literature sources provided by EPA contractor
Fish lethal concentration to 50% of the exposed population (LC_{50})	fish (primarily fathead minnow) toxicity studies	Various literature sources and Ecotox database
Fish NOAEL	fish (primarily fathead minnow) toxicity studies	Literature sources and Ecotox database
Odor threshold value (OTV)	measured odor thresholds in humans	EPA, 1992

In addition to lacking temporal or spatial relationships and providing only relative impacts, LCA is also limited by the availability and quality of the inventory data. Data collection can be very time consuming and expensive. Confidentiality issues may also inhibit the availability of primary data.

Uncertainties are inherent in each parameter described in Table 3-9 and the reader is referred to each source for more information on associated uncertainties. For example, toxicity data require extrapolations from animals to humans and from high to low doses (for chronic effects) and can have a high degree of uncertainty.

Uncertainties also are inherent in chemical ranking and scoring systems, such as the scoring of inherent properties approach used for human health and ecotoxicity effects. In particular, systems that do not consider the fate and transport of chemicals in the environment can contribute to misclassifications of chemicals with respect to risk. Also, uncertainty is introduced where it was assumed that all chronic endpoints are equivalent, which is likely not the case. In addition, when LOAELs were not available but NOAELs were, a factor of ten was applied to the NOAEL to estimate the LOAEL, introducing uncertainty. The human health and ecotoxicity impact characterization methods presented here are screening tools that cannot substitute for more detailed risk characterization methods. However, it should be noted that in LCA, chemical toxicity is often not considered at all. This methodology is an attempt to consider chemical toxicity where it is often ignored.

Uncertainty in the inventory data depends on the responses to the data collection questionnaires and other limitations identified during inventory data collection. These uncertainties are carried into impact assessment. In this LCA, there was uncertainty in the inventory data, which included but was not limited to the following:

- missing individual inventory items,
- missing processes or sets of data,
- measurement uncertainty,
- estimation uncertainty,
- allocation uncertainty/working with aggregated data, and
- unspeciated chemical data.

The goal definition and scoping process helped reduce the uncertainty from missing data, although it is certain that some (missing data) still exist. As far as possible, the remaining uncertainties were reduced primarily through quality assurance/quality control measures (e.g., performing systematic double-checks of all calculations on manipulated data). The limitations and uncertainties in the inventory data were discussed further in Chapter 2.

3.2 DATA MANAGEMENT AND ANALYSIS SOFTWARE

The inventory and chemical characteristics data for the CDP are stored in a database within a software package developed by UT, using the Microsoft Visual FoxPro application programming language, under a cooperative agreement with the EPA Office of Research and Development. The software package calculates impact scores based on the stored inventory and chemical data and on the appropriate formulas for each impact category, as presented in Section 3.1.

3.3 BASELINE LCIA RESULTS

This section presents the baseline LCIA results calculated using the impact assessment methodology presented in Section 3.1. As noted in the section on baseline LCI results (Section 2.7.1), the baseline scenario meets the following conditions:

- uses the effective life use stage scenario (e.g., use stage calculations are based on the actual amount of time a monitor is used by one or multiple users before it reaches its final disposition);
- uses the average value of all the energy inputs from the primary data for glass manufacturing;
- removes two outliers from the primary data for energy inputs during LCD panel/module manufacturing and then uses the average of the remaining energy inputs;
- excludes transportation in the manufacturing stage, but includes any transportation embedded in upstream data sets;
- includes the manufacturing processes of materials used as fuels (e.g., natural gas, fuel oil) in the manufacturing stage instead of in the upstream, materials processing stage. In cases where materials normally considered to be fuels are used as ancillary materials, their manufacturing processes are included with other upstream processes; and
- assumes LCD glass manufacturing processes use the same amounts of energy as CRT glass manufacturing per kilogram of glass produced.

Section 3.3.1 summarizes the baseline life cycle impact category indicators for both the CRT and LCD. Sections 3.3.2 through 3.3.14 present a breakdown of the impact category indicators by life-cycle stage, list the materials that contribute 99% of the total for both monitor types, and discuss limitations and uncertainties in each impact category. Each of the tables in this report shows the top contributors to the impacts because the complete tables, which are provided in Appendix J, are often lengthy. Section 3.3.15 summarizes the top contributors to each impact category, and Appendix M presents complete LCIA results.

3.3.1 Summary of Baseline LCIA Results

Table 3-10 presents the baseline CRT and LCD LCIA indicator results for each impact category, calculated using the impact assessment methodology presented in Section 3.1. The indicator results presented in the table are the result of the characterization step of LCIA methodology where LCI results are converted to common units and aggregated within an impact category. Note that the impact category indicator results are in a number of different units and therefore can not be summed or compared across impact categories. Note also that the CDP LCIA methodology does not perform the optional LCIA steps of normalization (calculating the magnitude of category indicator results relative to a reference value), grouping (sorting and possibly ranking of indicators), or weighting (converting and possibly aggregating indicator results across impact categories). Ranking and weighting, in particular, are subjective steps that depend on the values of the different individuals, organizations, or societies performing the analysis. Since the CDP involves a variety of stakeholders from different geographic regions and with different values, these more subjective steps were intentionally excluded from the CDP LCIA methodology.

Table 3-10. Baseline life-cycle impact category indicators[a]

Impact category	**Units per monitor**	**CRT**	**LCD**
Renewable resource use	kg	**1.31E+04**	2.80E+03
Nonrenewable resource use	kg	**6.68E+02**	3.64E+02
Energy use	MJ	**2.08E+04**	2.84E+03
Solid waste landfill use	m^3	**1.67E-01**	5.43E-02
Hazardous waste landfill use	m^3	**1.68E-02**	3.61E-03
Radioactive waste landfill use	m^3	**1.81E-04**	9.22E-05
Global warming	kg-CO_2 equivalents	**6.95E+02**	5.93E+02
Ozone depletion	kg-CFC-11 equivalents	2.05E-05[b,c]	1.37E-05[b]
Photochemical smog	kg-ethene equivalents	**1.71E-01**	1.41E-01
Acidification	kg-SO_2 equivalents	**5.25E+00**	2.96E+00
Air particulates	kg	**3.01E-01**	1.15E-01
Water eutrophication	kg-phosphate equivalents	4.82E-02	**4.96E-02**
Water quality, BOD	kg	**1.95E-01**	2.83E-02
Water quality, TSS	kg	**8.74E-01**	6.15E-02
Radioactivity	Bq	**3.85E+07**[d]	1.22E+07[d]
Chronic health effects, occupational	tox-kg	**9.34E+02**	6.96E+02
Chronic health effects, public	tox-kg	**1.98E+03**	9.02E+02
Aesthetics (odor)	m^3	**7.58E+06**	5.04E+06
Aquatic toxicity	tox-kg	2.25E-01	**5.19E+00**
Terrestrial toxicity	tox-kg	**1.97E+03**	8.94E+02

[a] Bold indicates the larger value within an impact category when comparing the CRT and LCD.

[b] Several of the substances included in this category were phased out of production by January 1, 1996. Excluding phased out substances decreases the CRT ozone depletion indicator to 1.09E-05 kg CFC-11 equivalents per monitor and the LCD ozone depletion indicator to 1.18E-05 kg CFC-11 equivalents per monitor. These ozone depletion indicators are probably more representative of the CDP temporal boundaries and current operating practices. See Section 3.3.6 for details.

[c] Although the CRT indicator appears larger than the LCD indicator, uncertainties in the inventory make it difficult to determine which monitor has the greater value. Therefore, this value is not shown in bold.

[d] Radioactivity impacts are being driven by radioactive releases from nuclear fuel reprocessing in France, which are included in the electricity data in some of the upstream, materials processing data sets. See Section 3.3.12 for details.

As shown in the table, under the baseline conditions the CRT indicators are greater than the LCD indicators in the following categories: renewable resource use, nonrenewable resource use, energy use, solid waste landfill use, hazardous waste landfill use, radioactive waste landfill use, global warming, photochemical smog, acidification, air particulates, biological oxygen demand (BOD), total suspended solids (TSS), radioactivity, chronic public health effects, chronic occupational health effects, aesthetics, and terrestrial toxicity. The LCD indicators are greater than the CRT indicators in the following categories: water eutrophication and aquatic toxicity. In addition, as noted in Table 3-10, the CRT ozone depletion indicator is greater than that of the LCD when phased out substances are left in the CRT and LCD inventories. However, if phased out substances are removed from the CRT and LCD inventories, the LCD ozone depletion indicator would exceed that of the CRT.

A number of the impact results for both monitor types, and for the CRT in particular, are being driven by a few data points with relatively high uncertainty. Therefore, sensitivity analyses of the baseline results are presented in Section 3.4.

3.3.2 Renewable and Nonrenewable Resource Use

3.3.2.1 Renewable resource use

Figure 3-2 presents the CRT and LCD impact category indicators for renewable resource use by life-cycle stage, based on the impact assessment methodology presented in Section 3.1.2.1. Tables M-1 and M-2 in Appendix M present complete renewable resource results for the CRT and LCD, respectively. A renewable resource is one that is being replenished at a rate greater than or equal to its rate of depletion. Note that several of the resources listed in the Appendix and in the tables that follow are not renewable or can not be replenished, *per se*, but are considered renewable since they can be restored or are present in nearly infinite, non-depletable amounts. For example, water is typically considered a renewable resource since it can be restored to potable quality and is therefore being "replenished" at a rate greater than or equal to its rate of depletion. However, current trends toward shortages of potable water suggest that water might be more appropriately classified as a nonrenewable resource.

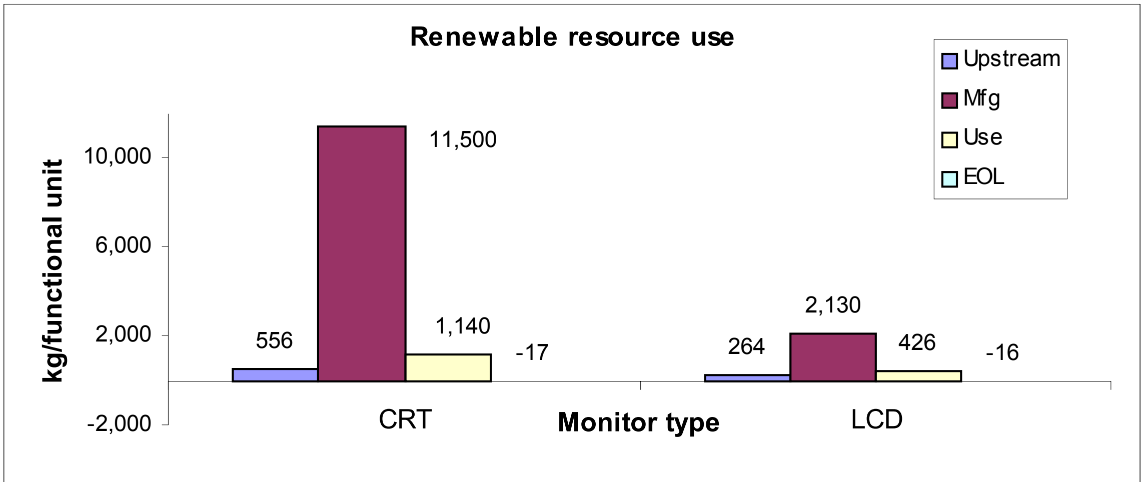

Figure 3-2. Renewable resource use impacts by life-cycle stage

As shown in Figure 3-2, the baseline life-cycle impact category indicator for renewable resource use is 13,100 kg per monitor for the CRT and 2,800 kg per monitor for the LCD. Both the CRT and LCD renewable resource use results are dominated by the manufacturing life-cycle stage, with manufacturing accounting for 87% and 76% of the CRT and LCD totals, respectively.

Table 3-11 presents the life-cycle inventory items that contribute to the top 99% of the CRT renewable resource use total. It also lists the LCI data type (primary, secondary, or model/secondary). As shown in Table 3-11, water used in the production of LPG clearly dominates the CRT renewable resource use impact score. LPG is primarily used as an energy source in CRT glass manufacturing, indicating that the glass/frit process group is ultimately the greatest contributor to the CRT renewable resource use impact score. Other significant contributors include water used to produce electricity in the United States during the use of the monitor, water used in CRT tube manufacturing, and water used in the production of steel. The LCI data for LPG production and steel manufacturing are from secondary sources, while the LCI data for the U.S. electric grid are based on the model developed by the CDP for the amount of electricity consumed by a CRT during use combined with data from secondary sources on the inputs and outputs from U.S. power plants. CRT tube manufacturing LCI data are primary data collected by the CDP.

Table 3-11. Top 99% of the CRT renewable resource use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LPG production	Water	Secondary	79%
Use	U.S. electric grid	Water	Model/secondary	8.7%
Manufacturing	CRT tube manufacturing	Water	Primary	6.2%
Materials processing	Steel production, cold-rolled, semi-finished	Water	Secondary	3.6%
Manufacturing	Japanese electric grid	Water	Model/secondary	0.34%
Manufacturing	PWB manufacturing	Water	Primary	0.32%

* Column may not add to 99% due to rounding.

Table 3-12 presents the inventory items contributing to the top 99% of the LCD renewable resource use total and the LCI data types (primary, secondary, or model/secondary). As shown in the table, water used in LCD module/monitor manufacturing is the greatest contributor to the LCD renewable resource use impact score. Other significant contributors include water used in the production of LPG, water used by the U.S. electric grid during the use life-cycle stage, and water used in steel production. It is LCD glass manufacturing that consumes the LPG responsible for the high LCD renewable resource use score. The LCI data for LCD module manufacturing are primary data collected by the CDP. LPG production and steel manufacturing are from secondary sources, while the LCI data for the U.S electric grid are based on the model developed by the CDP for the amount of electricity consumed by an LCD during the use stage combined with data from secondary sources.

Table 3-12. Top 99% of the LCD renewable resource use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LCD module/monitor mfg.	Water	Primary	38%
Manufacturing	LPG production	Water	Secondary	18%
Use	U.S. electric grid	Water	Model/secondary	15%
Materials processing	Steel production (cold-rolled, semi-finished)	Water	Secondary	8.2%
Manufacturing	LCD panel components	Water	Primary	6.4%
Manufacturing	Backlight	Water	Primary	6.8%
Manufacturing	Japanese electric grid	Water	Model/secondary	5.3%
Manufacturing	PWB Manufacturing	Water	Primary	0.66%

* Column may not add to 99% due to rounding.

3.3.2.2 Nonrenewable resource use

Figure 3-3 presents the CRT and LCD impact category indicators for nonrenewable resource use by life-cycle stage, based on the impact assessment methodology presented in Section 3.1.2.1. Tables M-3 and M-4 in Appendix M present complete nonrenewable resource results for the CRT and LCD, respectively. The total nonrenewable resource use indicator was 668 kg per monitor for the CRT and 364 kg per monitor for the LCD. As shown in Figure 3-3, the CRT nonrenewable resource use results are dominated by the manufacturing life-cycle stage, which contributed 68% of the total. The LCD nonrenewable resource use score is dominated by the upstream materials processing stages, which contributed 69% of the total.

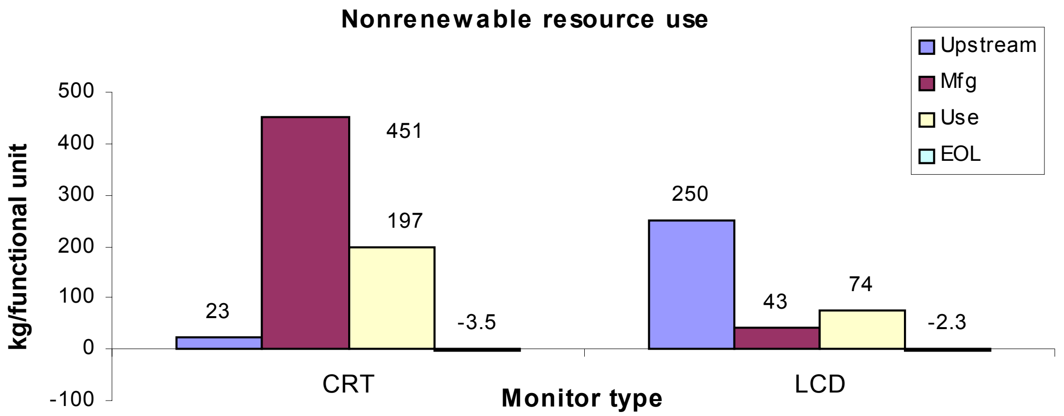

Figure 3-3. Nonrenewable resource use impacts by life-cycle stage

Table 3-13 presents the inventory items contributing to the top 99% of the CRT nonrenewable resource use impact score. It also lists the LCI data type (primary, secondary, or model/secondary). Similar to the renewable resource use LCIA results, the LPG production process, which mainly supports the CRT glass manufacturing process, clearly dominates the CRT nonrenewable resource use impact score. Petroleum used to make LPG is the non-renewable resource being consumed by the LPG production process in the greatest amounts, followed by natural gas, and coal. Note that the LPG actually consumed during CRT glass manufacturing does not appear in the nonrenewable resource use results. This is because it was accounted for in the nonrenewable resource use score for the LPG production process when it was extracted from the ground.

Fuels (coal and natural gas) consumed by the U.S. electric grid during monitor use are also among the greatest contributors to the CRT nonrenewable resource use impact scores. The LCI data for LPG production are from secondary sources, while the LCI data for the U.S. electric grid are based on the model developed by the CDP for the amount of electricity consumed by a CRT during use combined with data from secondary sources on the inputs and outputs from U.S. power plants.

Table 3-13. Top 99% of the CRT nonrenewable resource use impact score

Life-cycle stage	Process group	Material*	LCI data type	Contribution to impact score*
Manufacturing	LPG production	Petroleum (in ground)	Secondary	56%
Use	U.S. electric grid	Coal, average (in ground)	Model/secondary	27%
Manufacturing	LPG production	Natural gas (in ground)	Secondary	6.7%
Use	U.S. electric grid	Natural gas	Model/secondary	2.1%
Manufacturing	LPG production	Coal, average (in ground)	Secondary	2.0%
Materials processing	Steel production, cold-rolled, semi-finished	Iron Ore	Secondary	0.99%
Materials processing	Steel production, cold-rolled, semi-finished	Coal, average (in ground)	Secondary	0.60%
Manufacturing	Fuel oil #6 production	Petroleum (in ground)	Secondary	0.58%
Use	U.S. electric grid	Petroleum (in ground)	Model/secondary	0.57%
Manufacturing	Natural gas production	Natural gas (in ground)	Secondary	0.51%
Manufacturing	U.S. electric grid	Coal, average (in ground)	Model/secondary	0.43%
Manufacturing	Japanese electric grid	Coal, average (in ground)	Model/secondary	0.34%
Materials processing	Aluminum production	Bauxite	Secondary	0.20%
Manufacturing	Japanese electric grid	Petroleum (in ground)	Model/secondary	0.19%
Materials processing	Polycarbonate production	Natural gas (in ground)	Secondary	0.19%
Manufacturing	Japanese electric grid	Natural gas	Model/secondary	0.19%

* Column may not add to 99% due to rounding.

Table 3-14 presents the inventory items contributing to the top 99% of the LCD non-renewable resource use impact score. In this case, the impact score is dominated by the natural gas extracted to produce natural gas in the upstream, materials processing life-cycle stage. Liquified natural gas (LNG) from this production process is used as an ancillary material in the LCD module/monitor manufacturing process group, indicating LCD module/monitor manufacturing is ultimately responsible for this non-renewable resource use. However, only one of the seven companies that provided data for the LCD module/monitor manufacturing process group reported this use of LNG. Note that the actual use of LNG in the LCD module/manufacturing process group does not appear in the nonrenewable resource results. Similar to the LPG results discussed above for the CRT, this is because it has been accounted for in the natural gas production process results.

Other primary contributors to this impact score include coal used to produce electricity for the U.S. electric grid, and petroleum used to produce LPG. The LCI data for all of the primary contributors to the LCD non-renewable resource use score were either from secondary sources or CDP models combined with secondary sources.

Table 3-14. Top 99% of the LCD nonrenewable resource use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Materials processing	Natural gas production	Natural gas (in ground)	Secondary	65%
Use	U.S. electric grid	Coal, average (in ground)	Model/secondary	18%
Manufacturing	LPG production	Petroleum (in ground)	Secondary	4.9%
Manufacturing	Japanese electric grid	Coal, average (in ground)	Model/secondary	2.1%
Manufacturing	Natural gas production	Natural gas (in ground)	Secondary	1.5%
Use	U.S. electric grid	Natural gas	Model/secondary	1.4%
Manufacturing	Japanese electric grid	Petroleum (in ground)	Model/secondary	1.2%
Manufacturing	Japanese electric grid	Natural gas	Model/secondary	1.2%
Materials processing	Steel production (cold-rolled, semi-finished)	Iron ore	Secondary	0.89%
Manufacturing	LPG production	Natural gas (in ground)	Secondary	0.59%
Materials processing	Steel production (cold-rolled, semi-finished)	Coal (in ground)	Secondary	0.54%
Materials processing	Natural gas production	Coal (in ground)	Secondary	0.45%
Use	U.S. electric grid	Petroleum (in ground)	Model/secondary	0.39%

*Column may not add to 99% due to rounding

3.3.2.3 Limitations and uncertainties

The renewable and nonrenewable resource use results presented here are based on the mass of a material consumed. Depletion of renewable materials, which results from the extraction of renewable resources faster than they are renewed, may occur but is not specifically modeled or identified in the renewable resource impact scores. This may be particularly important for water, which, while considered a renewable resource, is in shorter and shorter supply as world population grows and more of the world’s water resources become degraded. For the nonrenewable materials use category, depletion of materials results from the extraction of nonrenewable resources. However, the impact scores do not directly relate consumption rates to the earth's ability to sustain that consumption.

The CRT and LCD impact scores for renewable resource use, and the CRT impact score for nonrenewable resources use, are being driven by the fuels consumed during CRT or LCD glass manufacturing. However, as discussed in Section 2.3.3.3, there is a high degree of variability in the three sets of CRT glass manufacturing energy data received by the CDP. Furthermore, as discussed in Section 2.3.3.1, LCD glass manufacturing data were developed from the CRT data because no companies were willing to supply the LCD data. Therefore, glass energy use inputs are uncertain for both the CRT and the LCD and were the subject of a sensitivity analysis, discussed in Section 3.4.

The LCD impact score for nonrenewable resource use is being driven by LNG used as an ancillary material during LCD module/monitor manufacturing. However, only one LCD module/monitor manufacturer reported using LNG as an ancillary material, which was confirmed by CDP researchers in follow-up communications. Given the fact that only one of seven manufacturers reported the ancillary use of LNG, the LCD nonrenewable resource use indicator may not be representative of the industry as a whole. If we remove this application of LNG from the LCD inventory, the LCD nonrenewable resource result is reduced by 66%, from 364 kg per monitor to 125 kg per monitor.

Inventory data for most of the materials contributing 99% of the CRT and LCD impact scores come from secondary sources, and were not developed specifically for the CDP. The limitations and uncertainties associated with secondary data sources are summarized in Section 2.2.2. Table 3-15 looks more closely at the LPG and natural gas production geographic and temporal boundaries. These are the production processes that are driving a large part of the CRT and LCD resources use indicators. As shown in the table, most of the LPG and natural gas production data are for the United States, although the LPG data set includes some data from other countries. Both data sets rely on several different sources and have different temporal boundaries. In particular, LPG production data are less recent, and may not accurately reflect current production practices. All of these factors create some inconsistencies among the data sets and reduce the data quality when used for the purposes of the CDP. However, this is a common difficulty with LCA, which often uses data from secondary sources to avoid the tremendous amount of time and resources required to collect all the needed data.

Table 3-15. LPG and natural gas production geographic and temporal boundaries

Production Process	Location	Source	Year
LPG production	Mainly U.S., but includes some other countries	Seven sources cited	1983 to 1993
Natural gas production	U.S.	Six sources cited	1987 to 1998

3.3.3 Energy Use

Figure 3-4 presents the CRT and LCD impact results for energy use by life-cycle stage, based on the impact assessment methodology presented in Section 3.1.2.2. Tables M-5 and M-6 in Appendix M list complete energy use results for the CRT and LCD, respectively. The total indicator for this impact category was 20,800 MJ per monitor for the CRT, and 2,840 MJ per monitor for the LCD.

CRTs generally are assumed to have greater life-cycle energy use impacts than the LCDs due to the high energy requirements in the use stage. This is borne out by the results in Figure 3-4, which show that CRT energy consumption during use is roughly 2.7 times that of the LCD. However, contrary to expectations, CRT energy use impacts are driven by the manufacturing life-cycle stage, which contributes about 88% of the total score. The use stage, which was expected to be responsible for a large amount of energy consumption impacts, only contributes about 11% of the total score. LCD energy consumption impacts are also largest in the manufacturing life-cycle stage which accounts for almost 51% of the impacts in this category. Both the use and upstream (materials processing) life-cycle stages are also significant contributors to LCD life-cycle energy use, accounting for 30 and 22%, respectively. Note that the sum of the upstream, manufacturing, and use life-cycle stages is greater than 100% due to an energy credit for incineration with energy recovery at the end of a monitor's useful life.

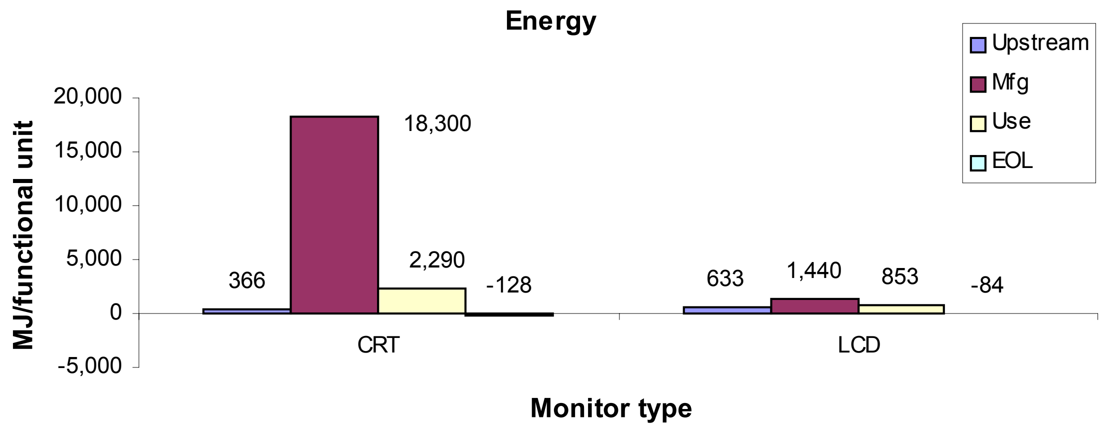

Figure 3-4. Energy impacts by life-cycle stage

3.3.3.1 Major contributors to the CRT energy use results

Table 3-16 presents the life-cycle inventory items contributing to the top 99% of the CRT energy use results and the LCI data type (primary, secondary, or model/secondary). As shown in the table, LPG used in the glass/frit process group, primarily from CRT glass manufacturing, clearly dominates the CRT energy use result, followed by electricity consumed during use of a CRT monitor, and natural gas, petroleum, and coal consumed during LPG production. Since LPG is used primarily as an energy source during CRT glass manufacturing, most of the sum of the glass/frit manufacturing and LPG production energy use impacts—roughly 87% of the CRT life-cycle energy use impacts—can be attributed to the CRT glass manufacturing process.

Table 3-16. Top 99% of the CRT energy use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	Glass/frit manufacturing	Liquified petroleum gas	Primary	72%
Use	CRT monitor use	Electricity	Model/secondary	11%
Manufacturing	LPG production	Natural gas (in ground)	Secondary	10%
Manufacturing	LPG production	Petroleum (in ground)	Secondary	2.0%
Manufacturing	LPG production	Coal, average (in ground)	Secondary	1.4%
Manufacturing	CRT tube manufacturing	Fuel oil #6	Primary	0.72%
Manufacturing	Glass/frit manufacturing	Natural gas	Primary	0.26%
Manufacturing	Glass/frit manufacturing	Fuel oil # 2	Primary	0.24%
Manufacturing	Glass/frit manufacturing	Electricity	Primary	0.23%
Manufacturing	CRT tube manufacturing	Natural gas	Primary	0.18%
Materials processing	Polycarbonate production	Natural gas (in ground)	Secondary	0.16%
Manufacturing	LPG production	Uranium (U, ore)	Secondary	0.16%
Manufacturing	CRT tube manufacturing	Electricity	Primary	0.15%
Manufacturing	Glass/frit manufacturing	Electricity	Primary	0.13%

*Column may not add to 99% due to rounding.

3.3.3.2 Major contributors to the LCD energy use results

Table 3-17 lists the inventory items contributing to the top 99% of the LCD life-cycle energy use results. Electricity consumed during use of the LCD monitor by the consumer is the single largest contributor to LCD energy use impacts, closely followed by LPG utilized to produce LCD glass. Other major contributors include natural gas consumed during natural gas production, electricity and LNG used as a fuel during LCD monitor/module manufacturing, and natural gas consumed during LPG production. Note that the LNG used as an ancillary material in LCD module/monitor manufacturing is not included in the LCD energy use impact calculations since it is not used as a source of energy. However, natural gas used as an energy source to produce the LNG is included (the third item listed in the table).

Table 3-17. Top 99% of the LCD energy use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	LCD monitor use	Electricity	Model/ secondary	30%
Manufacturing	LCD glass manufacturing	Liquified petroleum gas	Primary	25%
Materials processing	Natural gas production	Natural gas (in ground)	Secondary	14%
Manufacturing	LCD module/monitor mfg.	Electricity	Primary	8.9%
Manufacturing	LCD module/monitor mfg.	Liquified natural gas	Primary	5.8%
Manufacturing	LPG production	Natural gas (in ground)	Secondary	3.4%
Manufacturing	LCD panel components	Electricity	Primary	1.4%
Manufacturing	LCD module/monitor mfg.	Natural gas	Primary	1.3%
Materials processing	Natural gas production	Coal (in ground)	Secondary	1.3%
Materials processing	Natural gas production	Petroleum (in ground)	Secondary	0.89%
Manufacturing	LCD module/monitor mfg.	Liquified petroleum gas	Primary	0.88%
Manufacturing	LPG production	Petroleum (in ground)	Secondary	0.69%
Materials processing	Polycarbonate production	Natural gas (in ground)	Secondary	0.67%
Manufacturing	LPG production	Coal (in ground)	Secondary	0.51%
Manufacturing	LCD module/monitor mfg.	Kerosene	Primary	0.46%
Materials processing	PMMA sheet production	Petroleum (in ground)	Secondary	0.42%
Materials processing	PMMA sheet production	Natural gas (in ground)	Secondary	0.41%
Materials processing	Steel production (cold-rolled, semi-finished)	Petroleum (in ground)	Secondary	0.36%
Materials processing	Steel production (cold-rolled, semi-finished)	Natural gas (in ground)	Secondary	0.35%
Manufacturing	Natural gas production	Natural gas (in ground)	Secondary	0.32%
Materials processing	PMMA sheet production	Electricity	Secondary	0.32%
Materials processing	Steel production (cold-rolled, semi-finished)	Electricity	Secondary	0.31%
Manufacturing	LCD module/monitor mfg.	Fuel oil # 4	Primary	0.31%
Materials processing	Styrene-butadiene copolymer production	Natural gas (in ground)	Secondary	0.29%
Materials processing	Aluminum production	Coal (in ground)	Secondary	0.29%

*Column may not add to 99% due to rounding.

3.3.3.3 Limitations and uncertainties

Some of the limitations and uncertainties in the energy use indicators are similar to those in the renewable and nonrenewable resource use categories. First, as discussed in Section 3.3.1.1, the energy data for both CRT and LCD glass manufacturing are uncertain due to the variability in the primary glass data received by the CDP from three glass manufacturers. Glass manufacturing energy data are the subject of a sensitivity analysis in Section 3.4. Second, data for LPG production and natural gas production, which are among the largest contributors to the energy use indicators, are from secondary sources and are therefore subject to the limitations and uncertainties associated with secondary data (see Section 2.2.2 and 3.3.1.1). Not counting the use stage data, note that about 14% of the CRT energy use impacts shown in Table 3-16, above, are from secondary sources, compared to about 24% of the LCD energy use impacts (Table 3-17).

The amount of electricity consumed during use of a monitor was modeled by the CDP from secondary sources on the amount of electricity consumed during different power modes and the amount of time a monitor spends in each mode. Data quality for the effective life scenario (the baseline scenario presented here) is considered to be excellent, based on the source and quality information detailed in Appendix H and discussed in Sections 2.4.2 and 2.4.3.

3.3.4 Landfill Use

3.3.4.1 Solid waste landfill use

Figure 3-5 presents the CRT and LCD LCIA results for the solid waste landfill use impact category, based on the impact assessment methodology presented in Section 3.1.2.3. Tables M-7 and M-8 in Appendix M present complete results for the CRT and LCD, respectively. Life-cycle solid waste landfill use was 0.17 m^3 for the CRT and 0.054 m^3 for the LCD. The solid waste landfill indicators for both monitor types are dominated by waste disposal during the use stage—which contributes 59% of the total for the CRT and 68% for the LCD—primarily from wastes generated as a by-product of electricity production. Both monitor types have negative solid waste impact scores during the end-of-life stage. This is due to an energy credit from incineration processes, which offsets some of the solid waste impacts from electricity generation.

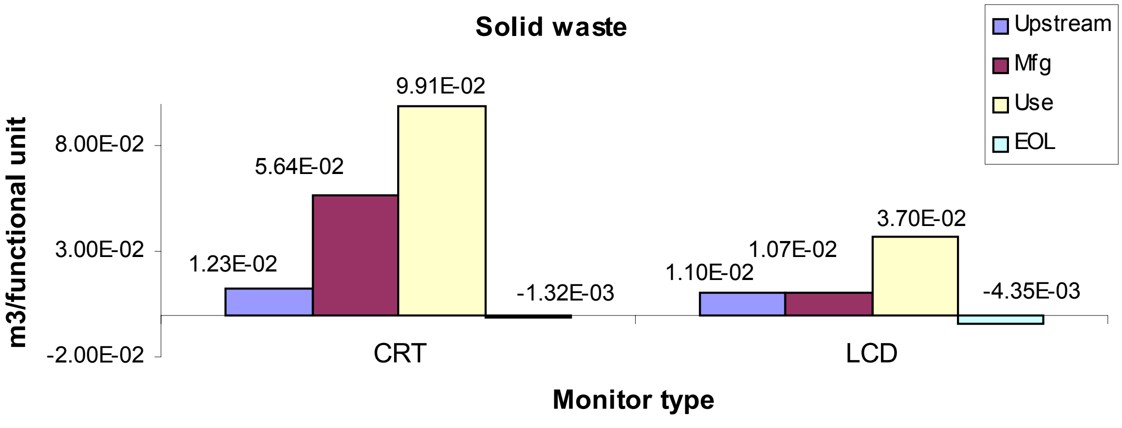

Figure 3-5. Solid waste impacts by life-cycle stage

Table 3-18 presents the materials that contribute to the top 99% of the CRT solid waste landfill use impact score. Note that the material contributions actually add to greater than 100% due to the energy credit from incineration processes, discussed above. Coal waste from U.S. electricity production is the single largest contributor to CRT impacts in this impact category, followed by slag and ash from LPG production, and dust/sludge and fly bottom ash from U.S.

electricity production. Electricity is used to power the monitor during the use stage, while LPG is primarily used in the production of CRT glass during manufacturing. LPG production also results in an unspecified solid waste that contributes 4.5% of the CRT solid waste impact score, while the CRT glass/frit process group generates a wastewater treatment sludge that contributes 5% of the score. Thus, the CRT glass/frit process group contributes about 30% of the CRT solid waste impact score, either directly (as a result of the glass manufacturing process itself) or indirectly (from LPG production). Other processes that are significant contributors include steel production and the landfilling of a CRT at the end of its effective life. The latter value is based on the assumption that 25% of CRTs that have reached their end of life are disposed of in a solid waste landfill (see Section 2.5 and Appendix I).

Table 3-18. Top 99% of the CRT solid waste landfill use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Coal waste	Model/secondary	38%
Manufacturing	LPG production	Slag and ash	Secondary	21%
Use	U.S. electric grid	Dust/sludge	Model/secondary	12%
Use	U.S. electric grid	Fly bottom ash	Model/secondary	10%
Materials processing	Steel production, cold-rolled, semi-finished	Unspecified solid waste	Secondary	6.6%
End-of-Life	CRT landfilling	EOL CRT monitor, landfilled	Primary	5.0%
Manufacturing	LPG production	Unspecified waste	Secondary	4.5%
Manufacturing	CRT glass/frit mfg.	Waste water treatment sludge	Primary	4.4%

*Column adds to greater than 100% due to a credit from incineration with energy recovery during the EOL life-cycle stage.

CRT glass manufacturing data were collected specifically for the CDP, while data for other process groups were either modeled by the CDP from secondary sources (e.g., U.S. electric grid data) or are entirely from secondary sources (e.g., LPG and steel production data). The mass and volume of CRT materials that are landfilled were developed for the CDP based on the mass reported in each inventory data set (collected as primary data) and the density of CRT materials assumed to be disposed of in a solid waste landfill. Note that the upstream inventories, which were derived from secondary sources (i.e., *Ecobilan*), include electricity generation within the materials manufacturing processes. These inventories do not include coal waste as an output, but list “slag and ash” as an output. The different inventories used in this project have varying nomenclature and some of the solid waste materials listed in the table may indeed overlap.

Table 3-19 presents the materials that contribute to the top 99% of the LCD solid waste landfill use results. Like the CRT solid waste results, the material contributions in the table are actually greater than 100% due to some negative values at end-of-life from an incinerator energy credit. Coal waste, dust/sludge, and fly/bottom ash from U.S. electricity during the use stage dominate the LCD solid waste impacts, contributing 68% of the impact score. Other significant contributors include the following: (1) an unspecified solid waste from producing steel used in the manufacture of the monitor, (2) slag and ash generated during the production of natural gas which is then used by one LCD module/monitor manufacturer as an ancillary material (LNG) during LCD module/monitor manufacture, (3) a wastewater treatment sludge from LCD module/monitor manufacturing, (4) coal waste from the generation of electricity in Japan during manufacturing, and (5) landfilling of non-hazardous or non-recovered components of the LCD at the end of its effective life. The latter value is based on the assumption that 50% of LCDs are sent to a solid waste landfill at the end of their effective lives.

Table 3-19. Top 99% of the LCD solid waste landfill use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Coal waste	Model/secondary	44%
Use	U.S. electric grid	Dust/sludge	Model/secondary	13%
Use	U.S. electric grid	Fly/bottom ash	Model/secondary	11%
Materials processing	Steel production, cold-rolled, semi-finished	Unspecified solid waste	Secondary	9.9%
Materials processing	Natural gas production	Slag and ash	Secondary	7.7%
Manufacturing	LCD monitor/module mfg.	Waste water treatment sludge	Primary	5.6%
Manufacturing	Japanese electric grid	Coal waste	Model/secondary	5.0%
End-of-Life	LCD landfilling	EOL LCD monitor, landfilled	Primary	3.5%

*Column adds to greater than 100% due to a credit from incineration with energy recovery during the EOL life-cycle stage.

LCI data for LCD monitor/module manufacturing were collected by the CDP, and LCD solid waste disposal volumes were estimated by the CDP based on the amounts and density of LCD materials assumed to be disposed of in a solid waste landfill. Like the CRT, data for other process groups either were modeled by the CDP from secondary data sources or came from secondary sources. As discussed above for the CRT, the materials processing inventories from secondary sources (i.e., *Ecobilan*) include electricity generation within the materials manufacturing processes. The different inventories used in this project have varying nomenclature and some of the solid waste materials listed in the table may indeed overlap.

3.3.4.2 Hazardous waste landfill use

Figure 3-6 presents the CRT and LCD LCIA results for the hazardous waste landfill use impact category, based on the impact assessment methodology presented in Section 3.1.2.3. Tables M-9 and M-10 (see Appendix M) present complete hazardous waste landfill use results for the CRT and LCD, respectively. Hazardous waste landfill use impacts are characterized from hazardous waste outputs with a disposition of landfill, which includes about 83% of the 9.46 kg of hazardous waste/functional unit generated by the CRT life cycle and about 27% of the 6.3 kg/functional unit generated by the LCD life cycle. This consumes approximately 0.017 m^3 of hazardous waste landfill space for the CRT and 0.036 m^3 for the LCD, based on the mass and densities of the various materials. The results for both monitor types are dominated by monitor disposal at the end of its effective life. Approximately 46% of CRTs and 5% of LCDs are assumed to be landfilled as hazardous waste (see Section 2.5 and Appendix I).

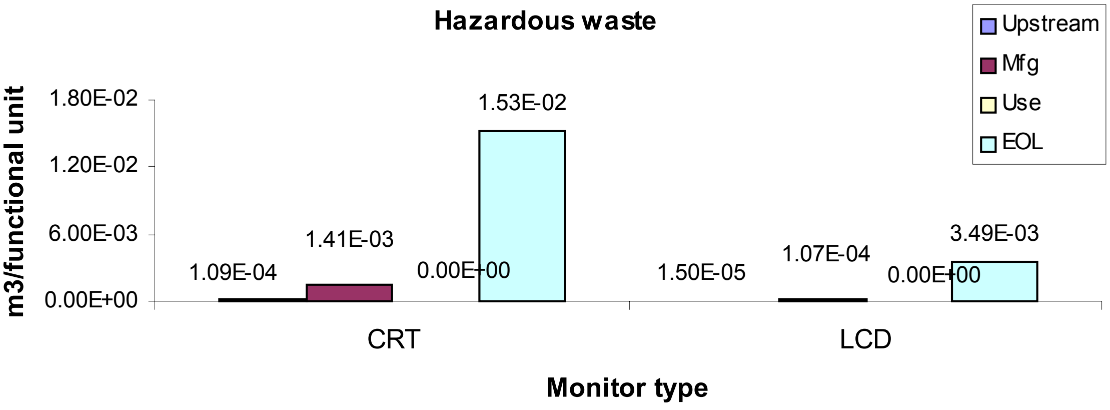

Figure 3-6. Hazardous waste impacts by life-cycle stage

Table 3-20 presents the materials that contribute to the top 99% of the CRT hazardous waste landfill use results. About 91% of the total hazardous waste landfill space consumed throughout the life-cycle of the CRT is from the amount of the monitor that is assumed to be disposed of as hazardous waste. The next largest contributor is an unspecified hazardous waste from LPG production. Most of this LPG is used to manufacture CRT glass. CRT outputs to a hazardous waste landfill at the end-of-life were estimated by the CDP. The LPG inventory is from secondary sources.

Table 3-20. Top 99% of the CRT hazardous waste landfill use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
End-of-Life	CRT landfilling	EOL CRT monitor, landfilled	Primary	91%
Manufacturing	LPG production	Hazardous waste	Secondary	8.1%

Table 3-21 lists the top contributors to the LCD hazardous waste landfill use results. LCD results are also dominated by landfilling of the LCD monitor at the end of its effective life, even though only 5% of LCDs are assumed to be landfilled. Other significant contributors include an unspecified hazardous waste from LPG production, and acetic acid from LCD monitor/module manufacturing. LPG is used in the manufacture of LCD glass. LCD outputs to a hazardous waste landfill at the end-of-life were estimated by the CDP. The LPG inventory is from secondary sources.

Table 3-21. Top 99% of the LCD hazardous waste landfill use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
End-of-Life	LCD landfilling	EOL LCD monitor, landfilled	Primary	97%
Manufacturing	LPG production	Hazardous waste	Secondary	1.8%
Manufacturing	LCD monitor/module mfg.	Acetic acid	Primary	0.88%

3.3.4.3 Radioactive waste landfill use

Figure 3-7 presents the CRT and LCD LCIA results for the radioactive waste landfill use impact category, based on the impact assessment methodology presented in Section 3.1.2.3. Tables M-11 and M-12 in Appendix M present complete results for the CRT and LCD, respectively. Life-cycle radioactive waste landfill use indicators for the CRT are 1.81E-04 m^3 per monitor for the CRT and 9.22E-05 m^3 per monitor for the LCD. As shown in the figure, CRT radioactive waste landfill impacts are dominated by radioactive waste disposal in the use stage, which contributes about 79% of the total impacts. This result is to be expected, given the relatively large amount of electricity consumed by a CRT during use and the associated radioactive waste from nuclear power plants. The use stage also contributes the greatest amount of LCD impacts (58%), but the manufacturing stage is also a significant contributor (33%) due to electricity consumed during manufacturing. LCD manufacturing electricity is linked to the Japanese electric grid, which derives 31% of its power from nuclear sources. By comparison, about 20% of the U.S. electric grid is powered by nuclear sources.

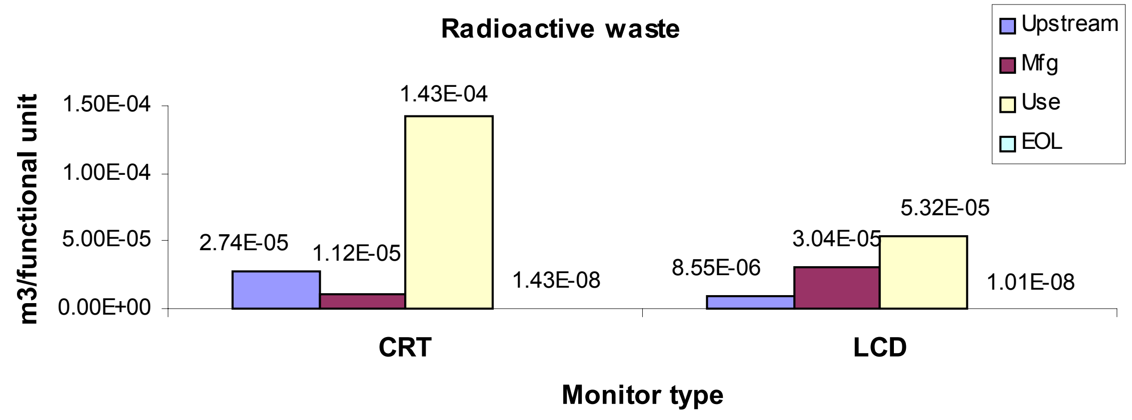

Figure 3-7. Radioactive waste impacts by life-cycle stage

Table 3-22 lists the materials that contribute to the top 99% of the CRT radioactive waste landfill use score and the LCI data type. Note that the LCI data for all of the materials in the table are from secondary sources or models. Low-level radioactive waste and depleted uranium from the U.S. electric grid are the radioactive materials being landfilled in the greatest quantities, followed by low-level radioactive waste from the production of steel used in the monitor. The latter radioactive waste is a byproduct of electricity production used in the manufacture of steel. It should be noted that the electricity generation data utilized in the steel inventory are from France (Glazebrook, 2001), where a large percentage of electricity is derived from nuclear sources. Therefore, these emissions may not be representative of emissions from steel production in some parts of Asia or in the United States. This issue is discussed further in the section on limitations and uncertainties, below.

Table 3-22. Top 99% of the CRT radioactive waste landfill use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Low-level radioactive waste	Model/secondary	61%
Use	U.S. electric grid	Uranium, depleted	Model/secondary	18%
Materials processing	Steel production, cold-rolled, semi-finished	Low-level radioactive waste	Secondary	9.0%
Manufacturing	Japanese electric grid	Low-level radioactive waste	Model/secondary	3.8%
Materials processing	Invar	Low-level radioactive waste	Secondary	2.6%
Materials processing	Ferrite manufacturing	Low-level radioactive waste	Secondary	2.5%
Manufacturing	Japanese electric grid	Uranium, depleted	Model/secondary	1.1%
Manufacturing	U.S. electric grid	Low-level radioactive waste	Model/secondary	0.97%

*Column may not add to 99% due to rounding.

Other significant contributors to the CRT radioactive waste score include low-level radioactive waste from electricity used in Japan during manufacturing, and low-level radioactive waste from invar and ferrite manufacturing. Invar is an alloy of nickel and iron. Like the steel data discussed above, the invar and ferrite manufacturing data also include emissions from electricity production. Finally, low-level radioactive waste from U.S. electricity consumed during the manufacturing stage contributes slightly less than 1% of the CRT radioactive waste landfill use impacts. The frit and PWB manufacturing processes consume this electricity. These are the only CRT components linked to the U.S. grid.

Table 3-23 lists the materials that contribute to the top 99% of the LCD radioactive waste landfill use results and the LCI data type. Note that LCI data for all of the primary contributors to this impact category are from secondary sources or modeled from secondary sources. Together, low-level radioactive waste and depleted uranium disposal from electricity consumed during use of the monitor account for about 57% of the LCD radioactive waste landfill use indicator, followed by low-level radioactive waste and depleted uranium disposal from electricity used during manufacturing (roughly 32%). Waste disposal from steel production is also a significant contributor at 8.7%. Like the CRT data discussed above, these emissions occur from electricity production in France and may not be representative of U.S. or some Asian practices.

Table 3-23. Top 99% of the LCD radioactive waste disposal impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Low-level radioactive waste	Model/secondary	44%
Manufacturing	Japanese electric grid	Low-level radioactive waste	Model/secondary	25%
Use	U.S. electric grid	Uranium, depleted	Model/secondary	13%
Materials processing	Steel production, cold-rolled, semi-finished	Low-level radioactive waste	Secondary	8.7%
Manufacturing	Japanese electric grid	Uranium, depleted	Model/secondary	7.5%

*Column may not add to 99% due to rounding.

3.3.4.4 Limitations and uncertainties

Landfill use pertains to the use of suitable and designated landfill space as a natural resource where the specified type of waste (solid, hazardous, or radioactive) is accepted. Landfill use impacts are characterized from solid, hazardous, or radioactive waste outputs with a disposition of landfill. Impact characterization is based on the volume of waste determined from the inventory mass amount of waste and materials density of each specific waste. Note that different countries may have different landfill designations for the final disposition of similar waste streams (e.g., a waste considered hazardous in the U.S. may be accepted in a solid waste landfill elsewhere). However, where possible, equivalent landfills (e.g., special waste landfills and hazardous waste landfills) were considered for these impact categories.

CRT and LCD impact results for the solid and radioactive waste landfill use categories were driven almost entirely by waste outputs reported in inventories from secondary sources. These inventories were not developed specifically for the CDP and therefore are subject to the limitations and uncertainties associated with secondary data (see Section 2.2.2 and 3.3.2). In particular, radioactive waste disposal from some of the upstream materials processing data may not be representative of conditions in the U.S. or parts of Asia. These data include emissions from electricity production within the materials inventory, which are the primary source of radioactive waste streams. For example, steel production data include the French electric grid, where a large percentage of the power supply comes from nuclear power plants. In addition, some of the upstream data may not be representative of current conditions, with steel production data covering the period from 1975 to 1990 and invar production data being from 1991.

CRT and LCD impact results for the hazardous waste landfill use category were dominated by monitor disposal at the end of their effective lives. Hazardous waste landfill disposal volumes were estimated based on the percent of monitors with hazardous waste landfilling as their final disposition, the monitor mass, and the material densities. However, data on the percentage of CRTs that are landfilled are not separated into hazardous and non-hazardous landfilling processes. Therefore, these percentages were estimated by the CDP, as described in Appendix I. Even less is known about the final disposition of LCDs, particulary since very few LCD desktop monitors have reached the end of their effective lives (and then, only if they have been damaged in some way). Therefore, the effect of different LCD EOL dispositions was evaluated in a sensitivity analysis (see Section 3.4.)

3.3.5 Global Warming

Figure 3-8 presents the CRT and LCD LCIA results for the global warming impact category, based on the impact assessment methodology presented in Section 3.1. Tables M-13 and M-14 in Appendix M list complete global warming results for the CRT and LCD, respectively. The life-cycle global warming indicators for the CRT and LCD were 695 and 593 kg of CO_2 equivalents per monitor, respectively. The CRT global warming indicators are driven by the use life-cycle stage, which contributes about 66% of the total. The manufacturing stage, which contributed 88% of the CRT energy consumption impacts, only contributes about 29% of the total global warming score. LCD global warming impacts, on the other hand, have the greatest contribution from the manufacturing life-cycle stage, which accounts for about 40% of the potential impacts in this category. Both the upstream (materials processing) and use life-cycle stages are also significant contributors to the LCD global warming results, accounting for 31% and 29% of the total, respectively.

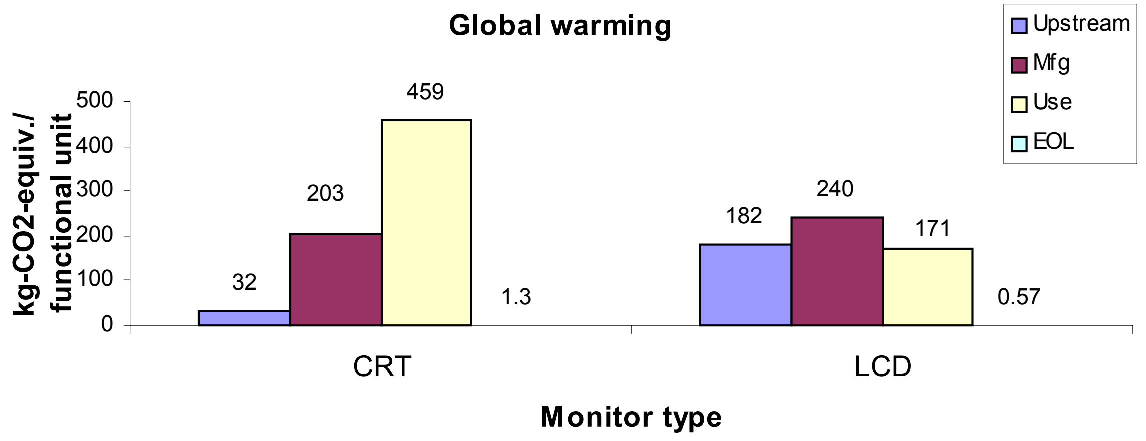

Figure 3-8. Global warming impacts by life-cycle stage

One might expect the distribution of global warming impacts across life-cycle stages to mirror those of energy consumption, as CO_2 is generally a large emission from electricity generation. However, as discussed in Section 3.3.3, CRT energy impacts are greatest in the manufacturing stage due to the large amounts of energy used to manufacture glass. Since the energy used in glass manufacturing is not only from electricity, but more so from other fuels (LPG, natural gas, and fuel oil), there is not a direct correlation between CRT global warming impacts and CRT energy impacts.

The distribution of LCD global warming impacts across life-cycle stages does mirror the distribution of LCD energy use impacts discussed in Section 3.3.3. However, as discussed below, the manufacturing stage global warming impacts for the LCD are being driven more by the use of sulfur hexafluoride (SF_6) in LCD monitor/module manufacturing than by the use of electricity.

3.3.5.1 Major contributors to the CRT global warming results

Table 3-24 presents the life-cycle inventory items contributing to the top 99% of the CRT global warming results and the LCI data type (primary, secondary, or model/secondary). As shown in the table, CRT global warming impacts are dominated by CO_2 emissions from electricity generation during use of the monitor, followed by CO_2 and methane emissions from producing LPG used as fuel in the CRT glass/frit process group. Together these three emissions contribute almost 89% of the CRT life-cycle global warming score. Carbon dioxide and methane emissions from a number of other processes also add to the CRT global warming score, as does nitrous oxide emissions from the LPG production process. It is likely that most of the CO_2 emissions from the materials processing life-cycle stage can be attributed to emissions from electricity generation or fuel combustion. As discussed in Section 2.2.2.1, the upstream materials processing inventories used in this study include data from electricity generation.

Note that almost all of the LCI data for global warming emissions are from secondary sources. This is because the CRT global warming results are dominated by CO_2 emissions from electricity generation, and electric grid data were either developed by the CDP from secondary sources or already included in the upstream, materials processing inventories from secondary sources.

Table 3-24. Top 99% of the CRT global warming impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Carbon dioxide	Model/secondary	64%
Manufacturing	LPG production	Carbon dioxide	Secondary	22%
Manufacturing	LPG production	Methane	Secondary	2.5%
Manufacturing	Japanese electric grid	Carbon dioxide	Model/secondary	2.2%
Use	U.S. electric grid	Methane	Model/secondary	1.9%
Materials processing	Steel production, cold-rolled, semi-finished	Carbon dioxide	Secondary	1.9%
Manufacturing	U.S. electric grid	Carbon dioxide	Model/secondary	1.0%
Manufacturing	LPG production	Nitrous oxide	Secondary	0.72%
Materials processing	Polycarbonate production	Carbon dioxide	Secondary	0.66%
Materials processing	Aluminum production	Carbon dioxide	Secondary	0.52%
End-of-Life	CRT incineration	Carbon dioxide	Secondary	0.51%
Manufacturing	CRT glass/frit mfg.	Carbon dioxide	Primary	0.40%
Materials processing	Invar	Carbon dioxide	Secondary	0.33%
Materials processing	Styrene-butadiene copolymer production	Carbon dioxide	Secondary	0.24%

*Column may not add to 99% due to rounding.

3.3.5.2 Major contributors to the LCD global warming results

Table 3-25 presents the life-cycle inventory items contributing to the top 99% of the LCD global warming results and the LCI data type (primary, secondary, or model/secondary). Sulfur hexafluoride used in LCD module manufacturing is the single largest contributor to LCD global warming impacts, followed by CO_2 emissions from electricity generation during the use stage, CO_2 and methane emissions from natural gas production, and CO_2 emissions from the generation of electricity used during manufacturing in Japan.

Table 3-25. Top 99% of the LCD global warming impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LCD monitor/module mfg.	Sulfur hexafluoride	Primary	29%
Use	U.S. electric grid	Carbon dioxide	Model/secondary	28%
Materials processing	Natural gas production	Carbon dioxide	Secondary	16%
Materials processing	Natural gas production	Methane	Secondary	12%
Manufacturing	Japanese electric grid	Carbon dioxide	Model/secondary	8.7%
Manufacturing	LPG production	Carbon dioxide	Secondary	1.2%
Materials processing	Steel production, cold-rolled, semi-finished	Carbon dioxide	Secondary	1.1%
Use	U.S. electric grid	Methane	Model/secondary	0.85%
Materials processing	PMMA sheet production	Carbon dioxide	Secondary	0.45%
Materials processing	Polycarbonate production	Carbon dioxide	Secondary	0.43%
Manufacturing	Natural gas production	Carbon dioxide	Secondary	0.35%
End-of-Life	LCD incineration	Carbon dioxide	Secondary	0.35%

*Column may not add to 99% due to rounding.

Sulfur hexafluoride is a potent global warming gas, with a global warming potential (GWP) equivalancy factor of 23,900 CO_2 equivalents (see Table K-2 in Appendix K). It is used as an etchant in a dry-etching process of amorphus silicon and SiNx films. The CO_2 and methane emissions from natural gas production can be attributed to the use of LNG as an ancillary material in LCD monitor/module manufacturing. However, as discussed in the section on non-renewable resource use (Section 3.3.2), only one LCD module manufacturer reported this use of LNG.

Carbon dioxide emissions (and, in one case, methane emissions) round out the remainder of the primary contributors to the LCD global warming indicator. Most of the carbon dioxide emissions occur from upstream processes and are due to electricity generation. With the exception of the SF_6 data, the LCI data for all of the top LCD global warming emissions are from secondary sources. Sulfur hexaflouride emissions data were developed by the CDP based on an emissions factor (0.45) applied to SF_6 inputs reported by LCD monitor/module manufacturers. The emissions factor is from the Intergovernmental Panel on Climate Change publication, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (Penman *et al.*, 2000.)

3.3.5.3 Limitations and uncertainties

Global warming potential (GWP) refers to the warming that emissions of certain gases may contribute by building up in the atmosphere and trapping the earth's heat. As discussed in Section 3.1.2.4, the LCIA methodology for global warming impacts uses published GWP equivalency factors having effects in the 100-year time horizon. These effects are expected to be far enough into the future that releases occurring throughout the life cycle of a computer monitor would be within the 100-year timeframe.

The effects of the buildup of global warming gases in the atmosphere is still the subject of scientific debate, but in 1995 the Intergovernmental Panel on Climate Change (IPCC), representing the consensus of most climate scientists worldwide, concluded that "... the balance of evidence...suggests that there is a discernible human influence on global climate (IPCC, 1995)." Other than the limitations and uncertainties inherent in predicting future effects, most of the limitations and uncertainties in the CRT and LCD global warming results have to do with the LCI data on greenhouse gas emissions, which occur primarily from electricity generation processes.

As noted above, the U.S. and Japan electric grid inventories used in the CDP were developed by the CDP, and electric grids used with upstream processes are embedded in the upstream inventories. U.S. electric grid emissions of CO_2 are based on data in the EPA publication, *National Air Quality and Emissions Trends Report, 1997* (EPA, 1998), which were the best data available when the electric grid inventory data was developed and are expected to be reasonably accurate. However, the Japanese electric grid inventory was derived from the U.S. inventory based on the mix of fuels used in Japan. Because Japanese power plants may employ different pollution control devices, use fuels of different quality, or other factors, their greenhouse gas emissions could actually be higher or lower than those reported in the inventory.

Similarly, the electric grid inventories embedded in upstream, materials processing inventories may have differing geographic and temporal boundaries or may be representative of older technologies. Therefore, actual emissions of greenhouse gases could be higher or lower than reported. This is a common limitation of LCAs, which must often rely on secondary data sources to avoid the considerable time and resources required to collect primary data for every process.

3.3.6 Stratospheric Ozone Depletion

Figure 3-9 presents the CRT and LCD LCIA results for the stratospheric ozone depletion impact category by life-cycle stage, based on the impact assessment methodology presented in Section 3.1.2.5. Note that most of the CRT ozone depletion impacts occur from the use stage (50%) and the upstream, materials processing stages (45%), while most of the LCD ozone depletion impacts occur from the manufacturing stage (63%). As will be shown later, this is important because upstream and use stage data are primarily from secondary data sources, whereas manufacturing data were collected by the CDP. Tables M-15 and M-16 in Appendix M list complete stratospheric ozone depletion results for the CRT and LCD, respectively.

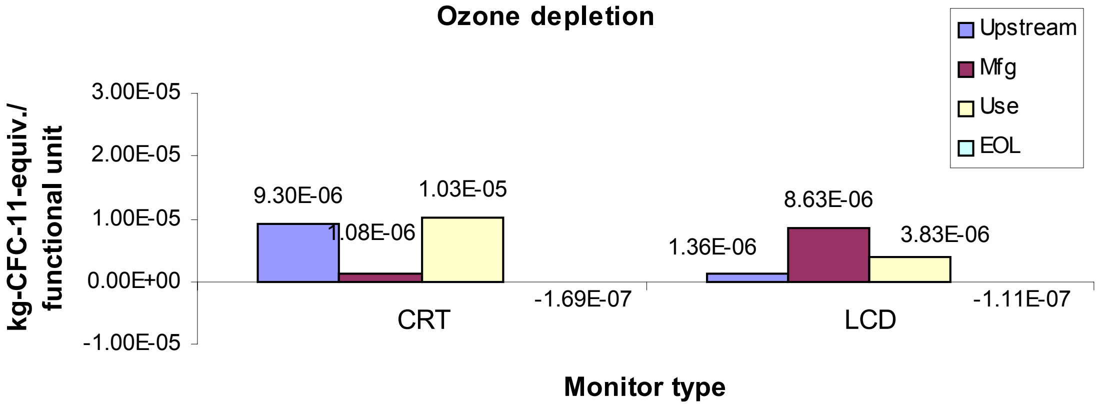

Figure 3-9. Ozone depletion impacts by life-cycle stage

The ozone depletion impact category indicator was 2.05E-05 kg of CFC-11 equivalents per monitor for the CRT and 1.37E-05 kg of CFC-11 equivalents per monitor for the LCD. However, for both the CRT and the LCD, many of the materials contributing to this impact category are listed as Class I ozone depleting substances in Title VI of the 1990 Clean Air Act Amendments, and therefore were required to be phased out of U.S. production by January 1, 1996. Production of these substances was also phased out in other developed countries under the Montreal Protocol and its Amendments and Adjustments, but continues today in some developing countries. An exception is bromomethane, which is a Class I substance that will not be completely phased out of production until 2005 (EPA, 2001a).

For a few of the phased out substances, a significant amount of inventory remained after production was phased out. However, most of these inventories are now exhausted, and Class I ozone depleting substances are rarely used by manufacturers in developed countries. If we delete the phased out substances from the CRT and LCD inventories, the CRT ozone depletion indicator is reduced 47% from 2.05E-05 to 1.09E-05 kg of CFC-11 equivalents per monitor, and the LCD result is reduced 14% from 1.37E-05 to 1.18E-05 kg of CFC-11 equivalents per monitor. These latter values are probably more representative of the temporal boundaries for primary data collected in the CDP LCA. Thus, when all data are included in the ozone depletion calculations, the CRT has a greater ozone depletion impact score than the LCD, but the results are switched (LCD greater than CRT) when phased out substances are removed from the inventory.

3.3.6.1 Major contributors to the CRT ozone depletion results

Table 3-26 lists the materials that contribute to the top 99% of the CRT life-cycle ozone depletion impact score and the LCI data type. Bromomethane emissions from electricity generated in the use stage are the single largest contributor to the CRT ozone depletion indicator, accounting for almost half of the total score. Most of the other materials in the table are emitted from materials production processes in the upstream, materials processing life-cycle stage. Exceptions are bromomethane emissions from the LPG production process (used to produce

LPG for the glass/frit process group), 1,1,1-trichloroethane emissions from electricity generation in the use stage, and bromomethane emissions from electricity used in manufacturing.

Table 3-26. Top 99% of the CRT stratospheric ozone depletion impact score

Life-cycle stage	**Process group**	**Material**	**LCI data type**	**Contribution to impact score**[a]
Use	U.S. electric grid	Bromomethane[b]	Model/secondary	49%
Materials processing	ABS production	HALON-1301[b]	Secondary	20%
Materials processing	Aluminum production	HALON-1301[b]	Secondary	14%
Materials processing	Invar	HALON-1301[b]	Secondary	5.9%
Manufacturing	LPG production	Bromomethane[b]	Secondary	3.7%
Materials processing	Lead	HALON-1301[b]	Secondary	2.6%
Materials processing	Steel production, cold-rolled, semi-finished	HALON-1301[b]	Secondary	2.0%
Use	U.S. electric grid	1,1,1-Trichloroethane[b]	Model/secondary	1.1%
Manufacturing	U.S. electric grid	Bromomethane[b]	Model/secondary	0.78%

[a] Column may not add to 99% due to rounding.

[b] Class I substance as listed in Title VI of the Clean Air Act Amendments.

Note that all of the materials listed in Table 3-26 are Class I ozone depleting substances. As discussed above, all of these substances except bromomethane were phased out of production by January 1, 1996. Note also that all of the LCI data for the materials in the table are from secondary sources. For both of these reasons, the LCI data for the materials in the table are highly uncertain. This is discussed further under limitations and uncertainties, below.

3.3.6.2 Major contributors to the LCD ozone depletion results

Table 3-27 lists the top contributors to the LCD life-cycle stratospheric ozone depletion indicator and the LCI data type. Together HCFC-225cb and HCFC 225ca used in the LCD panel components process group account for 59% of the LCD ozone depletion indicator. Note that HCFC 225cb and HCFC 225ca are Class II ozone depleting substances that are not scheduled for phaseout until 2015. [Under U.S. regulations and the Montreal Protocol and its Amendments and Adjustments these substances can not be produced or imported after 2015, except for use as refrigerants in equipment manufactured before January 1, 2020 (EPA, 2001b).] Also note that the impact scores for these materials are based on primary LCI data collected from manufacturers. Therefore, these data are considered to be more reliable than data for Phase I substances from secondary sources.

Table 3-27. Top 99% of the LCD stratospheric ozone depletion use impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score[a]
Manufacturing	LCD panel components	HCFC-225cb[b]	Primary	34%
Use	U.S. electric grid	Bromomethane[c]	Model/secondary	27%
Manufacturing	LCD panel components	HCFC-225ca[b]	Primary	25%
Materials processing	Aluminum production (virgin)	HALON-1301[c]	Secondary	7.8%
Manufacturing	Japanese electric grid	Bromomethane[c]	Model/secondary	3.1%
Materials processing	Steel production, cold-rolled, semi-finished	HALON-1301[c]	Secondary	1.4%

[a] Column may not add to 99% due to rounding.
[b] Class II substance as listed in Title VI of the Clean Air Act Amendments.
[c] Class I substance as listed in Title VI of the Clean Air Act Amendments.

Other significant contributors to the LCD ozone depletion score include bromomethane emissions from electricity generation in the United States and Japan, and halon emissions from upstream, materials processing stages. As noted above in the discussion of CRT ozone depletion results, the halons were phased out of production in 1996, which suggests that these data are not representative of current conditions. Bromomethane is still being produced, but bromomethane emissions data are also uncertain as will be discussed in the section on limitations and uncertainties, below.

3.3.6.3 Limitations and uncertainties

Both the CRT and LCD life-cycle stratospheric ozone depletion results are highly uncertain due to the inclusion of a number of Class I ozone depleting substances in inventories from secondary sources. As discussed above, except for bromomethane, developed countries that are parties to the Montreal Protocol and its Amendments and Adjustments phased out the production of Class I substances by 1996. To better assess the uncertainties in these results, Table 3-28 lists the geographic and temporal boundaries for the life-cycle inventories of the process groups listed in tables 3-26 and 3-27, above.

Table 3-28. Geographic and temporal boundaries of inventories contributing to the CRT and/or LCD ozone depletion indicator results

Process group	Geographic boundaries	Temporal boundaries
ABS production	Germany, Italy, Netherlands	1997
Aluminum production	Not provided	Not provided
Invar production	Multiple countries	1991 (nickel), Not provided (lead)
Japanese electric grid	U.S. and Japan[a]	1993[b]
LCD panel components	Japan	1998
Lead production	Not provided	Not provided
LPG production	Mainly U.S.	1983-1993
Steel production	Multiple countries	1975-1990
U.S. electric grid	U.S.	1993[b]

[a] Based on the U.S. electric grid inventory modified to account for the fuel mix used in Japan.

[b] Date of stack tests from which bromomethane emission factor was developed (from EPA Web site: Emission Factor Documentation for AP-42 Section 1.1: Bituminous and Subbituminous Coal Combustion. http://www.epa.gov/ttn/chief/ap42/ch01/bgdocs/b01s01.pdf.)

The most recent data are for LCD panel components manufacturing, which are primary data collected from manufacturers in Japan by the CDP and expected to be of better quality than older data from secondary sources. Data for ABS production are also fairly recent, dating from 1997. However, the temporal boundaries for most of the data are either not listed in the inventories, or pre-date the Class I substance production phase out. In addition, most of the data are from Europe and/or the United States, where very few Class I ozone depleting substances are currently used. Thus, we suspect that emissions of Class I substances reported in the inventories no longer occur, indicating that the CRT and LCD life-cycle impact results should be reduced to 2.05E-05 kg of CFC-11 equivalents per monitor for the CRT, and 1.37E-05 kg of CFC-11 equivalents per monitor for the LCD.

Bromomethane is a Class I ozone depleting substance that has not yet been phased out of production and is emitted during coal combustion to produce electricity. Bromoethane emissions from electricity production are estimated from an emission factor reported in AP-42, the EPA compilation of air pollutant emission factors (EPA, 1996). EPA (1996) provides an emission factor rating that is, “an overall assessment of how good a factor is, based on both the quality of the test(s) or information that is the source of the factor and on how well the factor represents the emission source.” The bromomethane emissions factor rating is “D,” or below average, indicating CDP data quality for bromomethane emissions from electricity generation is also below average.

In conclusion, it appears that most of the Class I substance emissions data are highly uncertain or of below average quality. Manufacturing data collected by the CDP, which includes emissions of Class II substances, are of better quality and expected to be more representative of current conditions. When all data are included in the ozone depletion calculations, the CRT has a greater ozone depletion impact score than the LCD. However, if we remove phased out substances from the inventory, the results are switched with the LCD having a greater score in this category than the CRT.

3.3.7 Photochemical Smog

Figure 3-10 presents the CRT and LCD LCIA results for the photochemical smog impact category by life-cycle stage. These results were calculated using the impact assessment methodology presented in Section 3.1.2.6. Tables M-17 and M-18 in Appendix M list complete results for the CRT and LCD, respectively. One 17" CRT monitor produces 0.171 kg of ethene equivalents throughout its life cycle, while a functionally equivalent 15" LCD monitor produces 0.141 of ethene equivalents. The CRT photochemical smog impact score is dominated by emissions during the manufacturing stage (71% of total); the LCD impact score is dominated by emissions during the upstream, materials processing stages (91% of total). However, as discussed below, it is fossil fuel production processes that emit the majority of smog forming emissions during the life-cycle of either monitor type. Both the CRT and LCD receive a slight credit on emissions of smog forming chemicals at the end of their effective lives due to energy recovery from incineration processes.

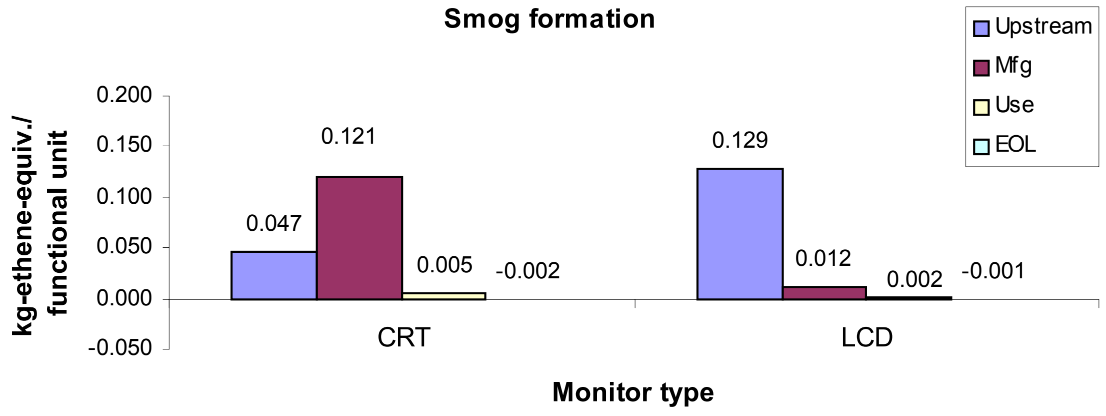

Figure 3-10. Smog formation impacts by life-cycle stage

<u>3.3.7.1 Major contributors to the CRT photochemical smog results</u>

Table 3-29 lists the materials that contribute to the top 99% of the CRT photochemical smog indicator result. The LPG production process alone, which emits various unspeciated hydrocarbons, benzene, aldehydes, ethane, and formaldehyde, accounts for almost 67% of CRT photochemical smog impacts. As noted earlier in the discussion of other impact category indicators, most of this LPG is used as a fuel source in CRT glass manufacturing. However, CRT glass energy data reported in the three data sets received by the CDP were highly variable and therefore the subject of a sensitivity analysis (see Section 3.4).

Other materials responsible for more than 1% of the CRT photochemical smog score include the following: (1) hydrocarbon (methane and nonmethane) emissions associated with steel production, (2) methane emissions from electricity generation during the use stage, (3) toluene emissions from CRT tube manufacturing, (4) nonmethane hydrocarbon emissions associated with ABS production, and (5) nonmethane hydrocarbon emissions associated with polycarbonate production. Note that the inventory for each upstream material (e.g., steel production, ABS production, etc.) contains data from the raw materials extraction, materials manufacture, and (usually) electricity generation processes. Therefore, hydrocarbon emissions associated with steel production, for example, could be from one of many individual processes, such as the steel production process itself, from fuels consumed during the mining of ore, or from the combustion of fuels as an energy source during steel manufacturing.

Table 3-29. Top 99% of the CRT photochemical smog impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LPG production	Hydrocarbons, unspeciated	Secondary	36%
Manufacturing	LPG production	Nonmethane hydrocarbons, unspeciated	Secondary	25%
Materials processing	Steel production, cold-rolled, semi-finished	Nonmethane hydrocarbons, unspeciated	Secondary	19%
Manufacturing	LPG production	Methane	Secondary	3.4%
Use	U.S. electric grid	Methane	Model/secondary	2.6%
Materials processing	Steel production, cold-rolled, semi-finished	Hydrocarbons, unspeciated	Secondary	2.0%
Manufacturing	LPG production	Benzene	Secondary	1.6%
Manufacturing	CRT tube mfg.	Toluene	Primary	1.3%
Materials processing	ABS production	Nonmethane hydrocarbons, unspeciated	Secondary	1.3%
Materials processing	Polycarbonate production	Nonmethane hydrocarbons, unspeciated	Secondary	1.1%
Materials processing	Aluminum production	Nonmethane hydrocarbons, unspeciated	Secondary	0.86%
Manufacturing	Natural gas production	Nonmethane hydrocarbons, unspeciated	Secondary	0.53%
Materials processing	ABS production	Nonmethane hydrocarbons, unspeciated	Secondary	0.41%
Manufacturing	LPG production	Aldehydes	Secondary	0.39%
Materials processing	Stryene-butadiene copolymer production	Hydrocarbons, remaining unspeciated	Secondary	0.39%
Materials processing	Invar	Nonmethane hydrocarbons, unspeciated	Secondary	0.32%
Manufacturing	Fuel oil #6 production	Hydrocarbons, unspeciated	Secondary	0.31%
Manufacturing	LPG production	Formaldehyde	Secondary	0.29%
Materials processing	Lead	Nonmethane hydrocarbons, unspeciated	Secondary	0.21%
Manufacturing	Fuel oil #6 production	Nonmethane hydrocarbons, unspeciated	Secondary	0.21%
Manufacturing	Natural gas production	Methane	Secondary	0.21%
Manufacturing	LPG production	Ethane	Secondary	0.18%
Manufacturing	CRT tube mfg.	Xylene (mixed isomers)	Primary	0.17%
Manufacturing	LPG production	Pentane	Secondary	0.16%

Table 3-29. Top 99% of the CRT photochemical smog impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	Natural gas production	Benzene	Secondary	0.14%

*Column may not add to 99% due to rounding.

3.3.7.2 Major contributors to the LCD photochemical smog results

Table 3-30 lists the materials that contribute to the top 99% of the LCD life-cycle photochemical smog results. LCD results are dominated by unspeciated hydrocarbon emissions, methane emissions, and benzene emissions from natural gas production in the materials processing life-cycle stage, which together account for about 75% of the total. This natural gas is used as an ancillary material by one LCD monitor/module manufacturer. Other LCD monitor/module manufacturers reported using LNG as a fuel, but not as an ancillary number. A number of other materials and processes contribute more than 1% of the total LCD photochemical smog score, most notably unspeciated, nonmethane hydrocarbon emissions associated with steel production. As noted above under the CRT results, the latter hydrocarbon emissions could occur from any one of various processes (e.g., ore mining, steel production, electricity generation, etc.) wrapped into the steel production inventory.

Table 3-30. Top 99% of the LCD photochemical smog impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Materials processing	Natural gas production	Nonmethane hydrocarbons, unspeciated	Secondary	45%
Materials processing	Natural gas production	Methane	Secondary	17%
Materials processing	Natural gas production	Benzene	Secondary	12%
Materials processing	Steel production, cold-rolled, semi-finished	Nonmethane hydrocarbons, unspeciated	Secondary	11%
Manufacturing	LCD monitor/module mfg.	Isopropyl alcohol	Primary	2.5%
Manufacturing	LPG production	Hydrocarbons, unspeciated	Secondary	2.1%
Manufacturing	LPG production	Nonmethane hydrocarbons, unspeciated	Secondary	1.4%
Materials processing	Natural gas production	Hydrocarbons, unspeciated	Secondary	1.2%
Materials processing	Steel production, cold-rolled, semi-finished	Hydrocarbons, unspeciated	Secondary	1.2%
Use	U.S. electric grid	Methane	Model/secondary	1.2%
Manufacturing	Natural gas production	Nonmethane hydrocarbons, unspeciated	Secondary	1.0%
Materials processing	PMMA sheet production	Nonmethane hydrocarbons, unspeciated	Secondary	0.87%
Materials processing	Polycarbonate production	Nonmethane hydrocarbons, unspeciated	Secondary	0.73%
Manufacturing	Natural gas production	Methane	Secondary	0.39%

Table 3-30. Top 99% of the LCD photochemical smog impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Materials processing	Aluminum production	Nonmethane hydrocarbons, unspeciated	Secondary	0.39%
Materials processing	PET resin production	Nonmethane hydrocarbons, unspeciated	Secondary	0.36%

*Column may not add to 99% due to rounding.

3.3.7.3 Limitations and uncertainties

Photochemical smog indicators are calculated using the mass of a chemical released to air per functional unit and the chemical-specific partial equivalency factor. The equivalency factor is a measure of the chemical's photochemical oxidant creation potential (POCP) compared to the reference chemical ethylene. As noted in Section 3.1.2.6, photochemical smog impacts are based on partial equivalency because some chemicals cannot be converted into POCP equivalency factors (e.g., nitrogen oxide). The inability to develop equivalency factors for some chemicals is a limitation of the photochemical smog impact assessment methodology.

The CRT impact score for photochemical smog formation is being driven by the process for producing the large amount of LPG used in CRT glass manufacture. However, as discussed in Section 2.3.3.3 and previous subsections of this Section 3.3, the three sets of glass manufacturing energy data received by the CDP were highly variable, making the average glass energy inputs used in the baseline analysis uncertain. Therefore, the emissions of smog forming chemicals from LPG production, which are based on the glass LPG inputs, are also uncertain. CRT glass energy inputs were subjected to a sensitivity analysis. Sensitivity results are discussed in Section 3.4.

The LCD impact score for photochemical smog formation is being driven by the natural gas production process to produce the large amount of LNG used as an ancillary material during LCD monitor/module manufacturing. However, as discussed earlier, only one LCD monitor/module manufacturer reported this use of LNG, which indicates the average LNG inputs used in the LCD inventory may be unduly high. Therefore, the mass of smog forming chemical emissions from the natural gas production process, which are based on the amount of ancillary LNG inputs, may also by unduly high.

The majority of the CRT and LCD photochemical smog results are based on life-cycle inventories from secondary sources and are therefore subject to the limitations and uncertainties associated with secondary data, discussed previously. In particular, see Section 3.3.1.1 for a detailed discussion of limitations and uncertainties in the LPG and natural gas production data.

3.3.8 Acidification

Figure 3.11 presents the CRT and LCD LCIA results for the acidification impact category, based on the impact assessment methodology presented in Section 3.1.2.7. Tables M-19 and M-20 in Appendix M list complete results for the CRT and LCD, respectively. The life-cycle acidification impact indicator result is 5.25 kg of SO_2 equivalents per monitor for the CRT and 2.96 kg of SO_2 equivalents per monitor for the LCD. As might be expected, acidification impacts are greatest in the use stage for both monitor types, due to the emissions of SO_x and NO_x from U.S. power plants. Use stage impacts are more dominant for the CRT (65% of life-cycle acidification impacts) than the LCD (43%) due to the relatively large amount of power consumed during use by the less energy-efficient CRT.

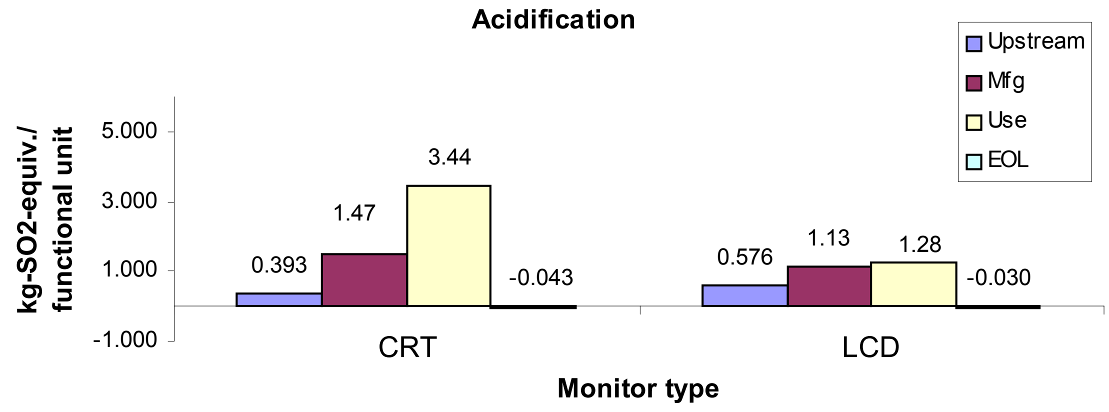

Figure 3-11. Acidification impacts by life-cycle stage

Emissions from manufacturing processes account for 28% of CRT acidification impacts and 38% of LCD acidification impacts. Material processing is responsible for about 7 and 19% of CRT and LCD impacts in this category, respectively. Both technologies receive a slight credit on acidification impacts during the EOL stage due to an energy credit from incineration processes with energy recovery, which offset some of the impacts from electricity production.

3.3.8.1 Major contributors to the CRT acidification results

Table 3-31 lists the materials that contribute to the top 99% of the CRT acidification impacts score and their LCI data type. SO_2 and NO_x emissions from the U.S. electric grid are the two largest contributors to the CRT acidification indicator, together accounting for 63% of the total. SO_x and NO_x emissions from the LPG production process are also significant, contributing about 23%. As noted previously, most of the LPG from this production process is used to manufacture CRT glass, but the mass of LPG inputs is uncertain and the basis of a sensitivity analysis later in this chapter (see Section 3.4).

Other materials that contribute more than one percent of the CRT acidification indicator are SO_2 emissions from invar production, hydrochloric acid emissions from electricity generation during the use stage, and sulfur dioxide emissions from electricity used in manufacturing. Note that most of the LCI data for materials in Table 3-31 are from secondary sources.

Table 3-31. Top 99% of the CRT acidification impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Sulfur dioxide	Model/secondary	47%
Use	U.S. electric grid	Nitrogen oxides	Model/secondary	16%
Manufacturing	LPG production	Sulfur oxides	Secondary	15%
Manufacturing	LPG production	Nitrogen oxides	Secondary	7.6%
Materials processing	Invar	Sulfur dioxide	Secondary	4.8%
Use	U.S. electric grid	Hydrochloric acid	Model/secondary	1.8%
Manufacturing	Japanese electric grid	Sulfur dioxide	Secondary	1.6%
Manufacturing	U.S. electric grid	Sulfur dioxide	Model/secondary	0.76%
Materials processing	Steel production, cold-rolled, semi-finished	Sulfur dioxide	Secondary	0.73%
Manufacturing	CRT glass/frit manufacturing	Nitrogen oxides	Primary	0.59%
Manufacturing	Japanese electric grid	Nitrogen oxides	Model/secondary	0.54%
Use	U.S. electric grid	Hydrofluoric acid	Model/secondary	0.41%
Materials processing	Aluminum production	Sulfur dioxide	Secondary	0.40%
Materials processing	Polycarbonate production	Nitrogen dioxide	Secondary	0.26%
Manufacturing	U.S. electric grid	Nitrogen oxides	Model/secondary	0.25%
Materials processing	Polycarbonate production	Sulfur dioxide	Secondary	0.23%
Manufacturing	LPG production	Nitrous oxide	Secondary	0.22%

*Column may not add to 99% due to rounding.

3.3.8.2 Major contributors to the LCD acidification impact results

Table 3-32 lists the materials responsible for the top 99% of the LCD acidification impact results and the LCI data type. Sulfur dioxide emissions from the U.S. electric grid during the use stage are the greatest contributor at 31%, followed by NO_x from natural gas production in the materials processing stage. The latter process produces natural gas used by one LCD monitor/module manufacturer as an ancillary material, indicating the LCD monitor/module manufacturing process group is ultimately responsible for this contribution to the impact score. However, as noted previously, only one LCD monitor/module manufacturer reported the ancillary use of LNG. Other LCD monitor/module manufacturers reported using LNG as a fuel, but not as an ancillary material. NO_x, ammonia, hydrofluoric acid, and hydrochloric acid emissions from LCD monitor/module manufacturing contribute another 22% of the LCD acidification impact score. LCD monitor/module manufacturing data were collected directly by the CDP from manufacturers in Asia.

NO_x emissions from the U.S. electric grid during the use stage, and SO_x and NO_x emissions from the Japanese electric grid during manufacturing are also among the top contributors to the LCD acidification results. LCI data for these process groups were developed by the CDP from secondary sources.

Table 3-32. Top 99% to the LCD acidification impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Sulfur dioxide	Model/secondary	31%
Materials processing	Natural gas prod.	Nitrogen oxides	Secondary	15%
Manufacturing	LCD monitor/module mfg.	Nitrogen oxides	Primary	13%
Use	U.S. electric grid	Nitrogen oxides	Model/secondary	10%
Manufacturing	Japanese electric grid	Sulfur dioxide	Model/secondary	9.8%
Manufacturing	LCD monitor/module mfg.	Ammonia	Primary	4.0%
Manufacturing	Japanese electric grid	Nitrogen oxides	Model/secondary	3.2%
Manufacturing	LCD monitor/module mfg.	Hydrofluoric acid	Primary	2.8%
Manufacturing	LCD monitor/module mfg.	Hydrochloric acid	Primary	1.8%
Manufacturing	LPG production	Sulfur oxides	Secondary	1.3%
Use	U.S. electric grid	Hydrochloric acid	Model/secondary	1.2%
Manufacturing	LCD backlight	Nitrogen oxides	Primary	0.70%
Materials processing	Natural gas production	Ammonia	Secondary	0.69%
Materials processing	Natural gas production	Sulfur oxides	Secondary	0.65%
Manufacturing	LPG production	Nitrogen oxides	Secondary	0.65%
Materials processing	Steel production, cold-rolled, semi-finished	Sulfur oxides	Secondary	0.64%
Materials processing	PMMA sheet production	Sulfur oxides	Secondary	0.44%
Manufacturing	Natural gas production	Nitrogen oxides	Secondary	0.35%
Use	U.S. electric gird	Hydrofluoric acid	Model/secondary	0.27%

*Column may not add to 99% due to rounding.

3.3.8.3 Limitations and uncertainties

Acidification impact characterization is a function of the mass of an acid-forming chemical emitted to air and the acidification potential (AP) equivalency factor for that chemical. The AP equivalency factor is the number of hydrogen ions that can theoretically be formed per mass unit of the pollutant being released compared to SO_2. This is a full equivalency approach to impact characterization where all substances are addressed in a unified, technical model, which lends more certainty to the characterization results than partial equivalency factors discussed with regard to photochemical smog (Section 3.3.7).

For the CRT, and less so for the LCD, impact results are being driven primarily by SO_2 and NO_x emissions from U.S. power plants during use of the monitor by the consumer. As discussed in Section 3.3.5 and noted above, the U.S. and Japanese electric grid inventories were developed by the CDP from secondary sources. U.S. electric grid emissions of the criteria pollutants, including SO_2 and NO_x, are based on data in the EPA publication, *National Air Quality and Emissions Trends Report, 1997* (EPA, 1998), which were the best data available when the electric grid inventory data was developed and are expected to be reasonably accurate. However, the Japanese electric grid inventory was derived from the U.S. inventory based on the mix of fuels used in Japan. Because Japanese power plants may employ different pollution control devices, use fuels of different quality, or other factors, their emissions could actually be higher or lower than those reported in the inventory.

LCI data for many of the other primary contributors to the CRT acidification impact category are from existing LCI databases. The limitations and uncertainties associated with these data have been discussed extensively in other subsections of this chapter and pertain here. On the other hand, LCI data for many of the other primary contributors to the LCD acidification indicator results were collected directly by the CDP from manufacturers in Asia. These data are considered to be of better quality since they were collected to meet the goals, objectives and temporal and spatial boundaries of the CDP.

3.3.9 Air Particulates

Figure 3-12 presents the CRT and LCD LCIA results for the air particulates impact category by life-cycle stage, based on the impact assessment methodology presented in Section 3.1.2.8. Tables M-21 and M-22 in Appendix M list complete air particulates results for the CRT and LCD, respectively.

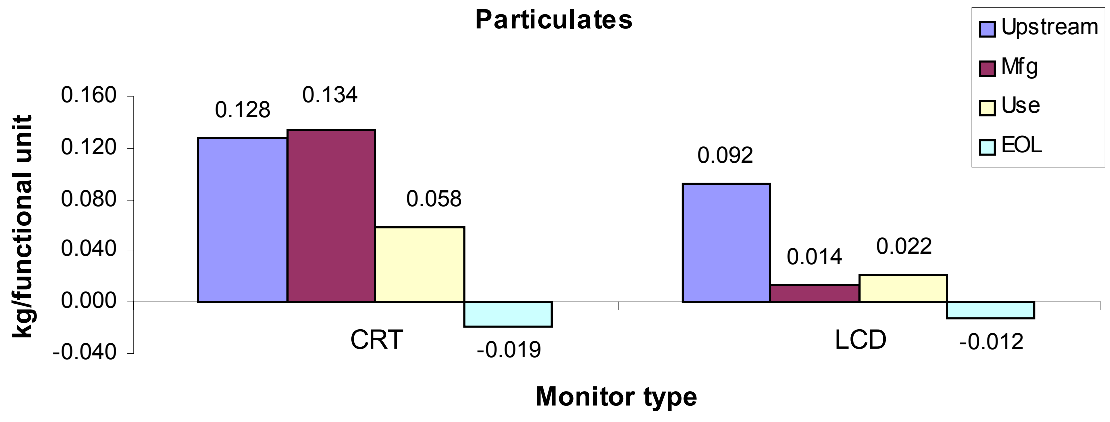

Figure 3-12. Particulates impacts by life-cycle stage

The life-cycle air particulates indicator is 0.30 kg of air particulates per monitor for the CRT and 0.115 kg of air particulates per monitor for the LCD. Recall from Section 3.1.2.8 that air particulates impact results are ideally based on release amounts of particulate matter with average aerodynamic diameter less than 10 micrometers (PM_{10}) to the air. This is the size of particulate matter that is most damaging to the respiratory system. However, as will be shown later in this section, a significant portion of the particulate emissions data for both monitor types do not specify a particulate size. This makes it more difficult to draw conclusions about the relative life-cycle air particulate impacts of the CRT and LCD.

The manufacturing and upstream materials processing stages have almost equal contribution to CRT air particulate impacts, at 45% of the total for the manufacturing stage and 43% of the total for the upstream stages. LCD impacts, on the other hand, are dominated by particulate emissions during the upstream, materials processing stages, which contribute 80% of the total score. Both technologies receive a substantial reduction in life-cycle air particulate impacts at EOL due to an energy credit from incineration with energy recovery. The energy credit, which is from incineration with energy recovery, is applied to electric power production where it offsets some particulate emissions that would otherwise occur from electrical power production.

3.3.9.1 Major contributors to the CRT air particulates impact results

Table 3-33 lists the materials that contribute to the top 99% of the CRT air particulates impact score and their LCI data type. PM emissions from LPG production are the single largest contributor to the overall score, at 43% of the total. This LPG is primarily an energy source in CRT glass manufacturing, indicating the glass/frit process group is the ultimate source of these air particulate emissions. As noted previously, CRT glass energy inputs are the subject of a sensitivity analysis, discussed in Section 3.4.

Other major contributors to the CRT air particulates impact results are PM emissions from the steel production process group, PM_{10} emissions from the U.S. electric grid during the use stage, and PM emissions from aluminum production processes. Note that the inventories for steel and aluminum production combine data from the raw materials extraction, materials manufacture, and electricity generation processes. The PM emissions reported for the material production process group could be from any one of these individual processes, but particulate matter emissions are most often associated with combustion processes.

Table 3-33. Top 99% of the CRT air particulates impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LPG production	PM	Secondary	43%
Materials processing	Steel production, cold-rolled, semi-finished	PM	Secondary	35%
Use	U.S. electric grid	PM-10	Model/secondary	19%
Materials processing	Aluminum production	PM	Secondary	3.0%

*Column adds to greater than 99% due to an offset of emissions from incineration with energy recovery at EOL.

As shown in Table 3-33**,** the impact scores associated with the LPG, steel, and aluminum production process groups—82% of CRT air particulates impacts—are based on emissions of PM instead of emissions of PM_{10}. This could be a matter of different terminology used in the secondary data sets for these process groups (that is, PM is used to represent PM_{10}), or it could represent a broader class of particulate emissions, of which PM_{10} emissions would be a subset. If the latter case is true, it is likely that CRT air particulate impacts are overstated.

3.3.9.2 Major contributors to the LCD air particulates impact results

Table 3-34 lists the materials that contribute to the top 99% of the LCD air particulates impact score and their LCI data type. PM emissions from steel production are the largest contributor to the overall score, followed by PM emissions from natural gas production. Natural gas from this process supplies the LNG used as an ancillary material by one LCD monitor/module manufacturer.

Other major contributors to the LCD air particulates impact results are PM_{10} emissions from the U.S. electric grid during the use stage and from the Japanese electric grid during manufacturing, and PM emissions from LPG production. LPG from the latter process supplies energy to the LCD glass manufacturing process.

Table 3-34. Top 99% of the LCD air particulates impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Materials processing	Steel production, cold-rolled, semi-finished	PM	Secondary	45%
Materials processing	Natural gas production	PM	Secondary	25%
Use	U.S. electric grid	PM-10	Model/secondary	19%
Manufacturing	Japanese electric grid	PM-10	Model/secondary	5.9%
Manufacturing	LPG production	PM	Secondary	5.4%

*Column adds to greater than 99% due to an offset of emissions from incineration with energy recovery at EOL.

As shown in Table 3-34, the impact scores associated with the steel, natural gas, and LPG production process groups—roughly 75% of LCD air particulates impacts—are based on emissions of PM instead of emissions of PM_{10}. As with the CRT, air particulate impacts should be based on PM_{10} emissions, indicating LCD air particulate impacts may be overstated.

3.3.9.3 Limitations and uncertainties

The CDP LCIA methodology for air particulates is based on emissions of PM_{10} to air, which is the size of particulate matter that is most damaging to the respiratory system. However, as noted in Tables 3-33 and 3-34, the majority of the CRT and LCD impacts were calculated from emissions of "PM" rather than PM_{10}. This could be a matter of different terminology used in the secondary data sets for these process groups, or it could represent a broader class of particulate emissions, of which PM_{10} emissions would be a subset. If the latter case is true, it is likely that both the CRT and LCD air particulate impacts are overstated.

The LCI data for all of the major contributors to both the CRT and LCD were either developed by the CDP from secondary sources (e.g., the U.S. and Japanese electric grids) or are from secondary LCI data sets (e.g., the fuel and upstream materials production processes). The limitations and uncertainties associated with these data have been discussed in other subsections of this chapter and pertain here. Note that U.S. electric grid emissions of the criteria pollutant PM_{10} are based on data in the EPA publication, *National Air Quality and Emissions Trends Report, 1997* (EPA, December, 1998, EPA/454/R-98-016), and are expected to be reasonably accurate.

Finally, the amount of LPG used to produce CRT glass, which is ultimately driving the CRT air particulates results, is also uncertain due to the large variability in CRT glass energy inputs received from glass manufacturers. See Section 3.4 for a sensitivity analysis of CRT glass energy inputs.

3.3.10 Water Eutrophication

Figure 3-13 presents the CRT and LCD LCIA results for the water eutrophication impact category by life-cycle stage, based on the impact assessment methodology presented in Section 3.1.2.9. Tables M-23 and M-24 in Appendix M are complete results for the CRT and LCD, respectively.

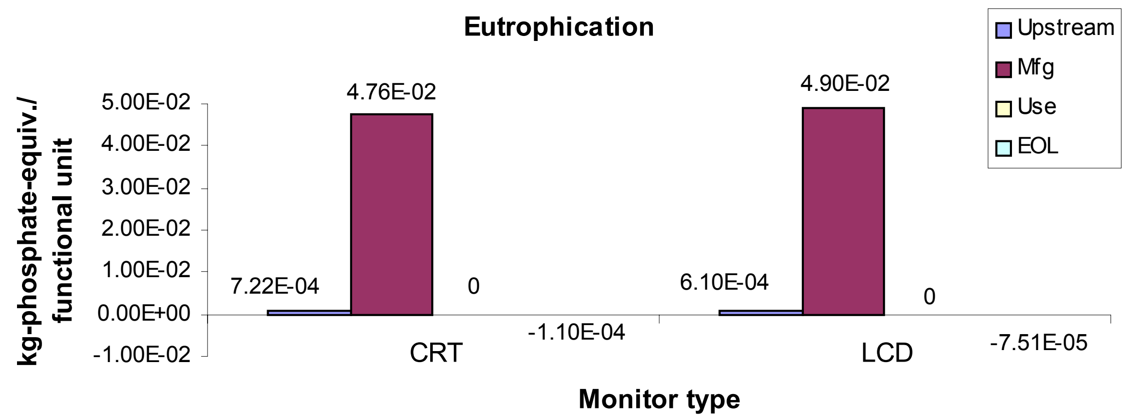

Figure 3-13. Eutrophication impacts by life-cycle stage

The life-cycle water eutrophication indicators are 0.048 kg of phosphate equivalents for the CRT and 0.050 kg of phosphate equivalents for the LCD. Results for both the CRT and LCD are completely dominated by emissions from the manufacturing stage, which accounts for 99% of the indicator for both technologies. Both technologies have negative scores at the end-of-life due to incineration with energy recovery. The energy recovery offsets some of the water emissions from the electricity generation inventory included in the incineration data set.

3.3.10.1 Major contributors to the CRT water eutrophication impact results

Table 3-35 lists the materials that contribute to the top 99% of the CRT water eutrophication results. Together, chemical oxygen demand (COD) and ammonia ions from the LPG production process group account for about 91% of the total score. Most of the LPG from this process is used as an energy source in CRT glass manufacturing (see Section 3.4 for the sensitivity analysis of CRT glass energy inputs). Emissions of nitrogen, COD and phosphorus from the CRT tube manufacturing process group contribute about seven percent of the CRT water eutrophication impacts. COD and other nitrogen emissions from steel production are the remaining top contributors to the CRT eutrophication score. LPG and steel production data are from secondary sources, while the CRT tube manufacturing outputs are primary data collected by the CDP.

Table 3-35. Top 99% of the CRT water eutrophication impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LPG production	COD	Secondary	72%
Manufacturing	LPG production	Ammonia ions	Secondary	19%
Manufacturing	CRT tube manufacturing	Nitrogen	Primary	6.3%
Materials processing	Steel production, cold-rolled, semi-finished	Other nitrogen	Secondary	0.37%
Materials processing	Steel production, cold-rolled, semi-finished	COD	Secondary	0.33%
Manufacturing	CRT tube manufacturing	COD	Primary	0.33%
Manufacturing	CRT tube manufacturing	Phosphorus (yellow or white)	Primary	0.32%

*Column may not add to 99% due to rounding.

3.3.10.2 Major contributors to the LCD water eutrophication impact results

Table 3-36 lists the materials that contribute to the top 99% of the LCD water eutrophication results. Like the CRT, the LCD water eutrophication indicator is driven by emissions from a single process group, in this case, LCD monitor/module manufacturing. Together, emissions of nitrogen and phosphorus from that process account for 94% of the total score. The LPG production process is the next largest contributor to the LCD water eutrophication score, where water releases of COD and ammonia ions account for more than 4% of the total.

Table 3-36. Top 99% to the LCD water eutrophication impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LCD monitor/module mfg.	Nitrogen	Primary	67%
Manufacturing	LCD monitor/module mfg.	Phosphorus (yellow or white)	Primary	27%
Manufacturing	LPG production	COD	Secondary	3.4%
Manufacturing	LPG production	Ammonia ions	Secondary	0.88%
Manufacturing	LCD panel components	Phosphorus (yellow or white)	Primary	0.48%
Materials processing	PMMA sheet production	Ammonia	Secondary	0.40%

*Column may not add to 99% due to rounding.

3.3.10.3 Limitations and uncertainties

Eutrophication (nutrient enrichment) impacts are calculated from the mass of a chemical released directly to surface water and the chemical's eutrophication potential (EP). The EP is a partial equivalency factor derived from the ratio of nitrogen and phosphorus in the average composition of algae compared to the reference compound phosphate (see Section 3.1.2.9). As a partial equivalency approach, only a subset of substances can be converted into equivalency factors, which is a limitation of this LCIA methodology. However, the methodology does take into account nitrogen and phosphorus, which are the two major limiting nutrients of importance to eutrophication.

CRT water eutrophication results are dominated by LCI data from secondary sources, and are therefore subject to the limitations and uncertainties associated with secondary data. Furthermore, these results are ultimately due to the large amount of LPG reported to be used as a fuel in LPG glass production. Because of the large degree of variability in glass energy data received from three CRT glass manufacturers, CRT glass energy inputs are also uncertain and the subject of a sensitivity analysis (see Section 3.4). LCD results, on the other hand, are driven almost entirely by primary LCI data from the manufacturing life-cycle stage, which were collected to meet the goals, objectives, and temporal and geographic boundaries of the CDP and are therefore considered to be of better quality.

3.3.11 Water Quality

3.3.11.1 Biological oxygen demand (BOD)

Figure 3-14 presents the CRT and LCD LCIA results for the BOD water quality impacts category by life-cycle stage, based on the impact assessment methodology presented in Section 3.1.2.10. Complete results are listed in Tables M-25 (CRT) and M-26 (LCD) in Appendix M.

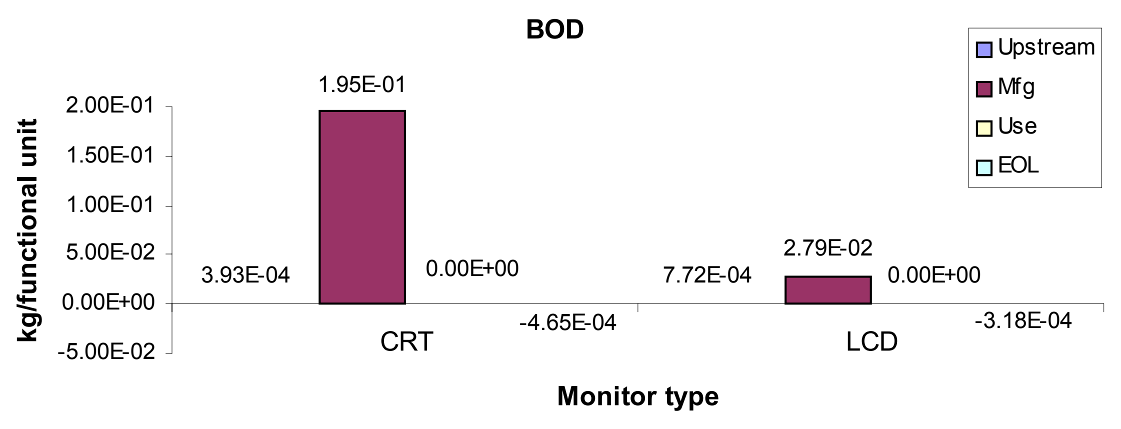

Figure 3-14. BOD impacts by life-cycle stage

During the life-cycle of a 17" CRT monitor, 0.195 kg of BOD are released to surface water. The life-cycle of a functionally equivalent 15" LCD results in 0.0283 kg of BOD surface water releases. As shown in Figure 3-14, BOD impacts for both monitor types are driven by surface water releases in the manufacturing stage, which contribute 100% of CRT impacts and 99% of LCD impacts. Note that small BOD impacts also occur in the upstream, materials processing life-cycle stage for both monitor types. These are almost entirely offset by negative BOD values at end of life due to the offset of electric grid emissions when the monitors are incinerated with energy recovery. Note also that there are no BOD emissions from the U.S. electric grid during the use stage. The incineration inventory is a secondary data set that contains a different electric grid inventory than the U.S. electric grid inventory developed by the CDP.

Table 3-37 lists the materials responsible for the top 99% of the CRT BOD impacts. CRT impacts in this category are driven by BOD releases from the LPG production process, most of which is used to make LPG employed as fuel in CRT glass manufacturing. BOD releases from CRT tube manufacturing also contribute a small percentage to the total score.

Table 3-37. Top 99% of the CRT BOD impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
Manufacturing	LPG production	BOD	Secondary	96%
Manufacturing	CRT tube manufacturing	BOD	Primary	3.3%

Table 3-38 lists the materials that contribute to the top 99% of the LCD BOD impacts. As shown in the table, LCD impacts are slightly more distributed among processes than CRT impacts, with BOD releases from four processes or process groups making up the list of top contributors. Note that BOD releases from LPG production (most of which is used to make LPG for LCD glass manufacturing) are much less for the LCD than the CRT, even though the LCD glass manufacturing inventory was derived from the CRT glass manufacturing inventory. This is because the CRT contains approximately ten times more glass than the LCD.

Table 3-38. Top 99% of the LCD BOD impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
Manufacturing	LCD monitor/module mfg.	BOD	Primary	61%
Manufacturing	LPG production	BOD	Secondary	32%
Manufacturing	LCD panel components	BOD	Primary	4.7%
Materials processing	Natural gas production	BOD	Secondary	0.99%

3.3.11.2 Total suspended solids (TSS)

Figure 3-15 presents the CRT and LCD LCIA results for the TSS water quality impacts category by life-cycle stage, based on the impact assessment methodology presented in Section 3.1.2.10. Tables M-27 and M-28 in Appendix M list complete results for the CRT and LCD, respectively.

The life-cycle TSS impact indicator is 0.874 kg of TSS for the CRT and 0.0615 kg of TSS for the LCD. TSS impacts for both monitor types are driven by the manufacturing stage, where 99 and 94% of impacts occur for the CRT and LCD, respectively. TSS impacts also occur in the upstream, materials processing life-cycle stage for both monitor types. Both technologies receive a credit on TSS impacts at EOL due to an offset of electric grid emissions when the monitors are incinerated with energy recovery.

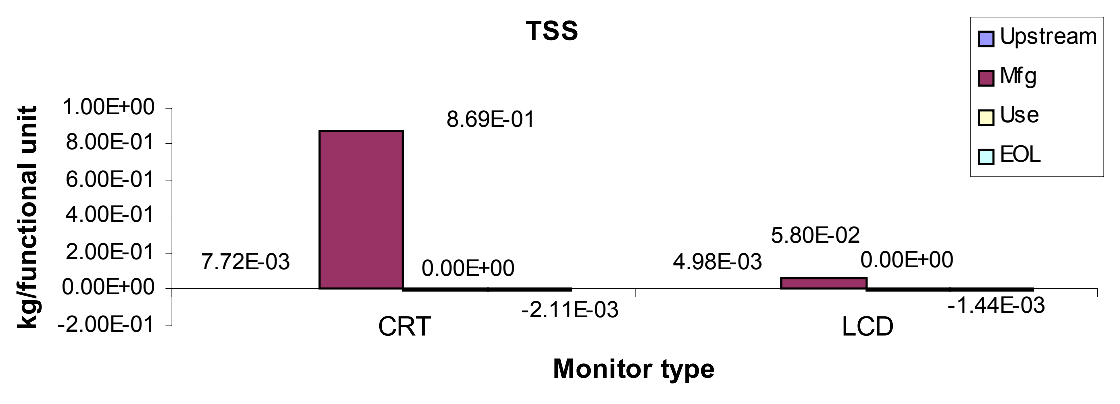

Figure 3-15. TSS impacts by life-cycle stage

Table 3-39 presents the major contributors to the CRT TSS indicator and lists the LCI data type. As with many other impact categories, the LPG production process is the single largest contributor to the CRT TSS indicator, accounting for 97% of the total score. Most of the LPG from this process is used as a fuel to produce CRT glass, but CRT energy inputs are uncertain and evaluated in a sensitivity analysis in Section 3.4. TSS surface water releases from the CRT glass/frit process group, CRT tube manufacturing, and fuel oil #6 production are also top contributors to the CRT TSS score. However, the contribution of these processes or process groups is small compared to that of the LPG production process.

Table 3-39. Top 99% of the CRT TSS impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
Manufacturing	LPG production	Suspended solids	Secondary	97%
Manufacturing	CRT glass/frit mfg.	Suspended solids	Primary	0.83%
Manufacturing	CRT tube manufacturing	Suspended solids	Primary	0.53%
Manufacturing	Fuel oil # 6 production	Suspended solids	Secondary	0.33%

Table 3-40 presents the top contributors to the LCD TSS impact score. Like the CRT results discussed above, TSS surface water releases from the LPG production process are responsible for the majority of LCD TSS impacts. LPG from this production process is used to produce LCD glass. Note that the actual mass of TSS releases from the LCD-related process is much smaller than those from the CRT-related process. This is because the LCD only uses about 10% as much glass as the CRT. TSS releases from the LCD monitor/module process group also account for a sizeable percentage of LCD TSS impacts.

Table 3-40. Top 99% of the LCD TSS impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LPG production	Suspended solids	Secondary	66%
Manufacturing	LCD monitor/module mfg.	Suspended solids	Primary	25%
Materials processing	PMMA sheet production	Suspended solids	Secondary	2.2%
Materials processing	Natural gas production	Suspended solids	Secondary	2.0%
Materials processing	Steel production, cold-rolled, semi-finished	Suspended solids	Secondary	1.6%
Materials processing	Aluminum production (all virgin)	Suspended solids	Secondary	1.1%
Manufacturing	LCD panel components	Suspended solids	Primary	1.0%

*Column may not add to 99% due to rounding.

3.3.11.3 Limitations and uncertainties

Both BOD and TSS indicators are calculated using a loading approach (i.e., the impact score is based on the inventory amounts) and are therefore highly sensitive to inventory data quality. CRT impact results are driven almost entirely by the LPG production inventory (a secondary data set) and are therefore subject to the limitations and uncertainties associated with secondary data. In particular, see Section 3.3.2.3 for a detailed discussion of LPG production data quality. In addition, note that LPG production impacts are almost all due to the large amount of LPG reported to be used as a fuel in CRT glass manufacturing. As note previously, CRT glass energy inputs are uncertain and are evaluated in a sensitivity analysis (see Section 3.4).

LCD impact results, on the other hand, are driven by LCI data from both primary and secondary sources and are therefore considered to be of somewhat better quality than the CRT results. However, a significant percentage of LCD water quality impacts also come from the large amount of LPG used as a fuel input to LCD glass manufacturing. These energy inputs are also uncertain and are evaluated in the sensitivity analysis in Section 3.4.

3.3.12 Radioactivity

Figure 3-16 presents the CRT and LCD LCIA results for the radioactivity impact category by life-cycle stage, based on the impact assessment methodology presented in Section 3.1.2.11. Complete CRT and LCD results are presented in Tables M-29 and M-30 in Appendix M, respectively.

The life-cycle radioactivity indicator is 38.5 million Bequerels (Bq) for the CRT and 12.2 million Bq for the LCD. Radioactivity impacts are driven by radioactive emissions from the upstream, materials processing stage for both monitor types, which contributes 99% of CRT life-cycle impacts and 98% of LCD life-cycle impacts. This result was unforeseen, since one might expect the majority of radioactive emissions to occur from the use stage, due to electricity generation at nuclear power plants. As it turns out, radioactivity impacts are being driven by data for nuclear fuel reprocessing that are included in the electric grid inventories for the steel, invar (an alloy of nickel and ferrite), and ferrite production process groups.

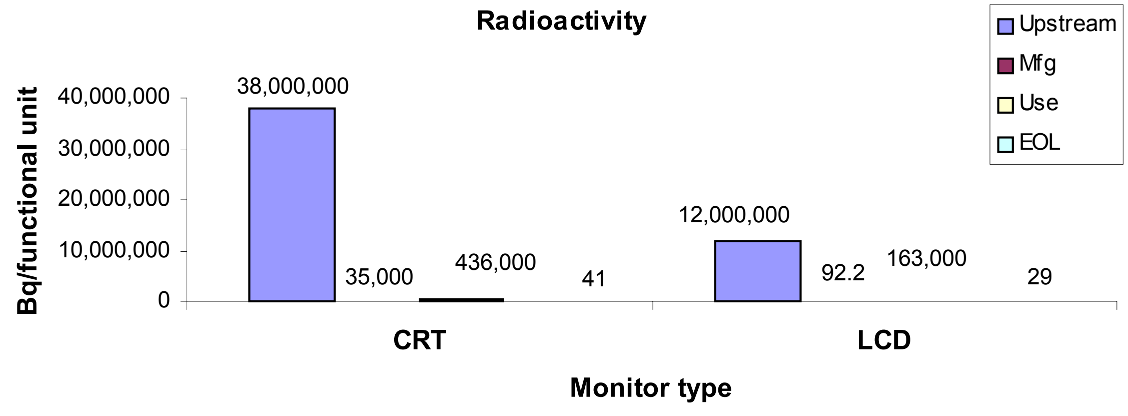

Figure 3-16. Radioactivity impacts by life-cycle stage

The LCIs for steel, invar, and ferrite were obtained from two databases developed by the former *Ecobilan Group,* an LCA consulting firm that was previously headquartered in France (see Section 2.2.1.1 for a discussion of how these databases were selected). Per *Ecobilan*, the ferrite inventory contains older data that may include radioactive emissions from electricity use. For the steel and nickel inventories, the source of both is site data in Europe, with the radioactive emissions coming from electricity in Europe, where nuclear fuel is reprocessed. In fact, the electricity data are from France for both materials, and France is one of the few countries (including Japan and the United Kingdom) that reprocesses nuclear fuel (Glazebrook, 2001). Therefore, the radioactivity impacts calculated from these inventories are more representative of impacts from countries that reprocess nuclear fuel than impacts from countries that do not.

To further illustrate this point, Tables 3-41 and 3-42 lists the materials and process groups that contribute to the top 99% of the CRT and LCD radioactivity indicator results, respectively. As shown in the tables, radioactivity impacts for both monitor types are driven by releases of plutonium-241 from steel (both monitor types), invar (CRT), and ferrite (CRT) production. Plutonium-241 is a byproduct of fuel reprocessing. Xenon -133 releases from the U.S. electric grid contribute slightly to the LCD radioactivity impacts and to a lesser degree to the CRT total impacts. Note that the actual amount of radioactivity from Xenon-133 is greater for the CRT than the LCD, but contributes a smaller percent of total impacts.

Table 3-41. Top 99% of the CRT radioactivity impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Materials processing	Steel production, cold-rolled, semi-finished	Plutonium-241 (isotope)	Secondary	62%
Materials processing	Invar	Plutonium-241 (isotope)	Secondary	18%
Materials processing	Ferrite	Plutonium-241 (isotope)	Secondary	17%
Use	U.S. electric grid	Xenon-133 (isotope)	Model/secondary	0.81%
Materials processing	Steel production, cold-rolled, semi-finished	Plutonium-240 (isotope)	Secondary	0.27%
Materials processing	Steel production, cold-rolled, semi-finished	Cesium-135 (isotope)	Secondary	0.24%

*Column may not add to 99% due to rounding.

Table 3-42. Top 99% of the LCD radioactivity impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Materials processing	Steel production, cold-rolled, semi-finished	Plutonium-241 (isotope)	Secondary	96%
Use	U.S. electric grid	Xenon-133 (isotope)	Model/secondary	0.95%
Manufacturing	Japanese electric grid	Xenon-133M (isotope)	Secondary	0.54%
Materials processing	Steel production, cold-rolled, semi-finished	Plutonium-240 (isotope)	Secondary	0.42%
Materials processing	Steel production, cold-rolled, semi-finished	Cesium-135 (isotope)	Secondary	0.38%

*Column may not add to 99% due to rounding.

Most of the radioactivity impacts are based on LCI data from secondary sources and are therefore subject to the limitations and uncertainties in secondary data, discussed previously. In addition, because radioactivity impacts are being driven by radioactive emissions from fuel reprocessing in France, they may not be representative of radioactivity impacts elsewhere. However, most of the CRT and LCD primary manufacturing data were collected from companies in Japan, where fuel reprocessing also occurs. For example, if Japanese CRT and LCD monitor and/or components manufacturers purchase steel from Japanese steel mills, the radioactivity emissions from electricity used to manufacture the steel could be similar. Japan ranked second in worldwide steel production in 2000 behind Mainland China, and third in 1999 behind Mainland China and the United States (IISI, 2001).

Note that the Japanese electric grid, which is linked to CRT and LCD production inventories, was developed from the U.S. electric grid inventory and therefore does not account for radioactive emissions from fuel reprocessing. This means that radioactive impacts from Japanese manufacturing processes that consume electricity are understated. For example, electricity used in the CRT glass/frit process group was the ninth largest contributor to the CRT energy use score, but the inventory for this process group does not account for fuel reprocessing emissions.

3.3.13 Potential Human Health Impacts

As discussed in Section 3.1.2.12, human health impacts included in the scope of this LCA are chronic (repeated dose) effects, including non-carcinogenic and carcinogenic effects to both workers and the public, and aesthetics. (Although not a health effect *per se*, aesthetics pertains to human welfare.)

Chronic health effect (cancer and noncancer) impacts are calculated using the scoring of inherent properties approach where an impact score is based on the inventory amount weighed by a hazard value (HV). The HV represents the chronic toxicity of a specific material (see Table K-8 in Appendix K for a list of toxicity values used to calculate hazard values). In this manner the inventory amount (the toxic chemical input amount for occupational health effects, and the output amount for public health effects) is used as a surrogate for exposure, while the hazard value represents the inherent toxicity of the chemical for chronic exposure.

The CDP human health effects LCIA methodology does not consider the fate and transport of a toxic chemical in the environment, nor does it evaluate the potential for actual exposures to occur. LCI data do not have the temporal and spatial specificity needed to estimate potential dose rates, for example, nor do they contain information on engineering controls used in an occupational setting to reduce exposure. [It should be noted that more sophisticated models for evaluating human health effects in an LCA framework are being developed that use a multimedia fate, multi-pathway human exposure, and toxicological potency approach (Bare, 1999). However, such models are less comprehensive in terms of the number of chemicals for which there are data.] The limitations and uncertainties in the health effects scores are discussed further below, following the presentation of results.

3.3.13.1 Chronic occupational health effects

Figure 3-17 presents the CRT and LCD LCIA results by life-cycle stage for the chronic occupational health effects impact category, based on the impact assessment methodology presented in Section 3.1.2.12. Complete CRT and LCD results are presented in Tables M-31 and M-32 in Appendix M.

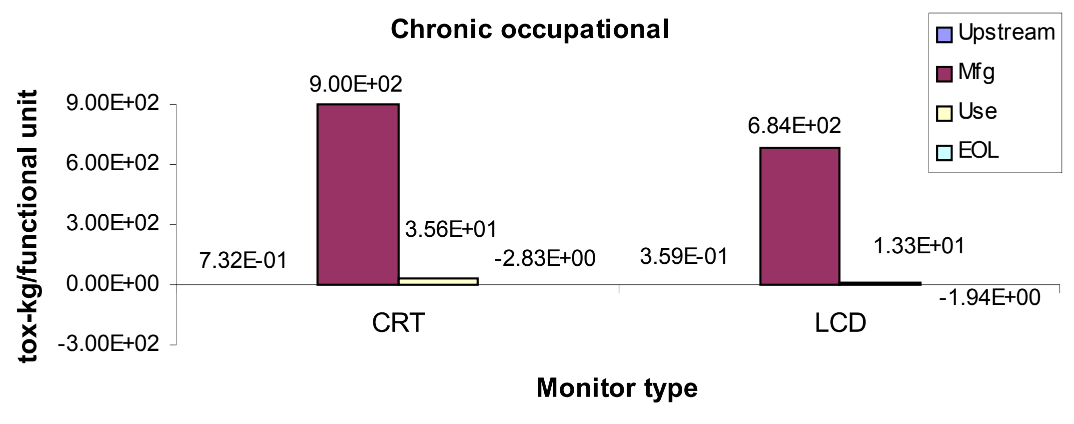

Figure 3-17. Chronic occupational impacts by life-cycle stage

The life-cycle chronic occupational health effects indicator is 934 tox-kg per functional unit for the CRT, and 696 tox-kg per functional unit for the LCD. As shown in the figure, the total score is dominated by toxic chemical inputs to the manufacturing stage, which account for 98% and 96% of CRT and LCD impacts in this category, respectively. This result was expected since inputs to the other life-cycle stages tend to be raw materials (e.g., ores, coal, etc., for the materials processing and use life-cycle stages) or finished products (e.g., the monitors themselves for the EOL stage) that are not classified as toxic materials (see Table K-9 in Appendix K for a l

list of materials excluded from the toxic classification). Both the CRT and LCD receive negative chronic occupational health effects scores at end of life due to the offset of electric grid emissions when the monitors are incinerated with energy recovery.

Table 3-43 lists the materials responsible for the top 99% of the CRT chronic occupational health effects score and the LCI data type. LCI data for most of the top contributors are primary data collected from manufacturers by the CDP. In general, these data are expected to be of better quality (for the purposes of the CDP) than data from secondary sources, since they were collected to meet the goals and scope of the CDP.

Table 3-43. Top 99% of the CRT chronic occupational health effects score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	CRT glass/frit mfg.	Liquified petroleum gas	Primary	75%
Manufacturing	PWB manufacturing	Sulfuric acid	Primary	13%
Manufacturing	CRT tube manufacturing	Sulfuric acid	Primary	4.1%
Use	U.S. electric grid	Natural gas	Model/secondary	3.0%
Manufacturing	CRT glass/frit mfg.	Barium carbonate	Primary	1.8%
Use	U.S. electric grid	Petroleum (in ground)	Model/secondary	0.81%
Manufacturing	CRT tube manufacturing	Fuel oil # 6	Primary	0.79%

*Column may not add to 99% due to rounding.

LPG inputs to the glass/frit process group, primarily from CRT glass manufacturing, contribute 75% of the CRT impacts in this category. The high impact score for LPG is mainly due to the large amount of LPG inputs to the glass/frit process group (351 kg/functional unit), which results in a high score when multiplied by the HV. No toxicity data were available for LPG. Therefore, it was assigned default HVs of one for both cancer and noncancer effects (total HV=2), representative of mean cancer and noncancer toxicity values. As noted previously, glass manufacturing energy data are uncertain and therefore evaluated in a sensitivity analysis (see Section 3.4).

Sulfuric acid used in PWB manufacturing is the next greatest contributor to the CRT chronic occupational health effects results (13%) followed by sulfuric acid used in CRT tube manufacturing (4.1%). The sulfuric acid HV is based on an inhalation NOAEL of 0.1 mg/m^3, which is significantly lower (and therefore more toxic) than the geometric mean inhalation NOAEL of 68.7 mg/m^3. Consequently, sulfuric acid impacts are driven more by its inherent toxicity for noncancer effects than the input amounts (0.18 kg per functional unit for PWB manufacturing and 0.056 kg per functional unit for CRT tube manufacturing). Sulfuric acid has no cancer slope factor and an IARC weight of evidence (WOE) classification of 3 (not classifiable for carcinogenicity), and therefore received an HV of zero for cancer effects.

Natural gas and petroleum used as fuels in the U.S. electric grid, barium carbonate used in the CRT glass/frit process group and fuel oil #6 used to manufacture the CRT tube round out the top contributors to the CRT chronic occupational health effects score. Barium carbonate has no cancer slope factor and an EPA cancer WOE of D (not classifiable), and therefore has an HV of zero for cancer effects. However, its oral NOAEL is 0.21 mg/kg-day compared to the geometric mean oral NOAEL of 11.9 mg/kg-day, which results in an HV of 57 for noncancer effects. Therefore, like sulfuric acid, the barium carbonate impacts are driven more by its inherent toxicity than the input amount (0.297 kg per functional unit). No specific toxicity data were available for natural gas, petroleum, or fuel oil #6; consequently they were assigned a default HV of one for both cancer and noncancer effects (total HV=2).

Table 3-44 lists the materials that contribute to the top 99% of the LCD chronic occupational health effects score. Like the CRT, LCI data for most of the top contributors are primary data collected from manufacturers by the CDP, and are therefore expected to be of generally better quality (for the purposes of the CDP) than data from secondary sources.

Table 3-44. Top 99% of the LCD chronic occupational health effects score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LCD monitor/module mfg.	Liquified natural gas	Primary	57%
Manufacturing	LCD monitor/module mfg.	Sulfuric acid	Primary	23%
Manufacturing	PWB manufacturing	Sulfuric acid	Primary	8.0%
Manufacturing	LCD glass manufacturing	Liquified petroleum gas	Primary	4.7%
Manufacturing	LCD monitor/module mfg.	Phosphine	Primary	1.8%
Manufacturing	LCD panel components	Sulfuric acid	Primary	1.6%
Use	U.S. electric grid	Natural gas	Model/secondary	1.5%
Manufacturing	LCD monitor/module mfg.	Dimethylsulfoxide	Primary	1.1%
Manufacturing	LCD monitor/module mfg.	Ethanolamine	Primary	0.62%

*Column may not add to 99% due to rounding.

As shown in the table, LCD impacts in this category are dominated by LNG used in LCD monitor/module manufacturing. The high impact score for LNG is primarily due to the large amount of ancillary LNG inputs (194 kg/functional unit) in the LCD monitor/module manufacturing inventory, which results in a high score when multiplied by the HV. No toxicity data were available for LNG. Therefore, it was assigned a default, mean HV of one for both cancer and noncancer effects (total HV=2). As noted previously, only one of seven LCD module/monitor manufacturers reported using LNG as an ancillary material. Therefore, the total score for LCD chronic occupational health effects may not be representative of the industry as a whole. If we remove this application of LNG from the LCD inventory, the LCD occupational health effects result is reduced by 58 percent, from 683 tox-kg per monitor to 288 tox-kg per monitor. Note, however that other LCD monitor/module manufacturers did report using LNG as a fuel.

Sulfuric acid used in three process groups (LCD module/monitor manufacturing, PWB manufacturing, and LCD panel components) accounts for another 33% of the LCD chronic occupational health effects score. As discussed above for the CRT, sulfuric acid has a relatively low toxicity value, and therefore a high HV, which results in a high impact score for a small input amount. The LCD module/monitor manufacturing process group has the highest impact score for sulfuric acid because it has the greatest input amount (0.229 kg per functional unit).

The remaining top contributors to the LCD chronic occupational health effects score are LPG used in LCD glass manufacturing; and phosphine, dimethylsulfoxide, and ethanolamine used in LCD monitor/module manufacturing; and natural gas used as a fuel by the U.S. electric grid. As discussed earlier, LCD glass energy inputs are uncertain and evaluated in a sensitivity analysis in Section 3.4. The LPG score is based on default HVs (representative of the geometric mean toxicity values) for both cancer and noncancer effects, since no toxicity data were available for LPG.

The phosphine score is driven by its low oral NOAEL value (0.026 mg/kg-day), which is significantly lower than the geometric mean value of 68.7 mg-kg-day. Thus, due to its inherently high toxicity, a relatively small input of phosphine (in this case, 0.027 kg per functional unit) results in a relatively high chronic occupational health effects score. No slope factors or cancer WOE classifications were found for phosphine, indicating a default HV of one was used, which is far outweighed by the non-cancer hazard value.

Dimethylsulfoxide is less toxic than phosphine (oral LOAEL =1.0 mg/kg-day), but has a greater input amount (0.066 kg per functional unit). However, phosphine's greater toxicity outweighs the greater input amount for dimethylsulfoxide, resulting in a higher impact score for phosphine.

No specific toxicity data were available for natural gas; consequently it was assigned a default HV of one for both cancer and noncancer effects (total HV=2).

3.3.13.2 Chronic public health effects

Figure 3-18 presents the CRT and LCD LCIA scores by life-cycle stage for the chronic public health effects category, based on the impact assessment methodology presented in Section 3.1.2.12. Complete results are presented in Tables M-33 and M-34 in Appendix M, respectively.

The life-cycle chronic public health effects score is 1,980 tox-kg per functional unit for the CRT and 902 tox-kg per functional unit for the LCD. As shown in the figure, the CRT score is dominated by toxic chemical outputs from electricity generation in the use stage, which

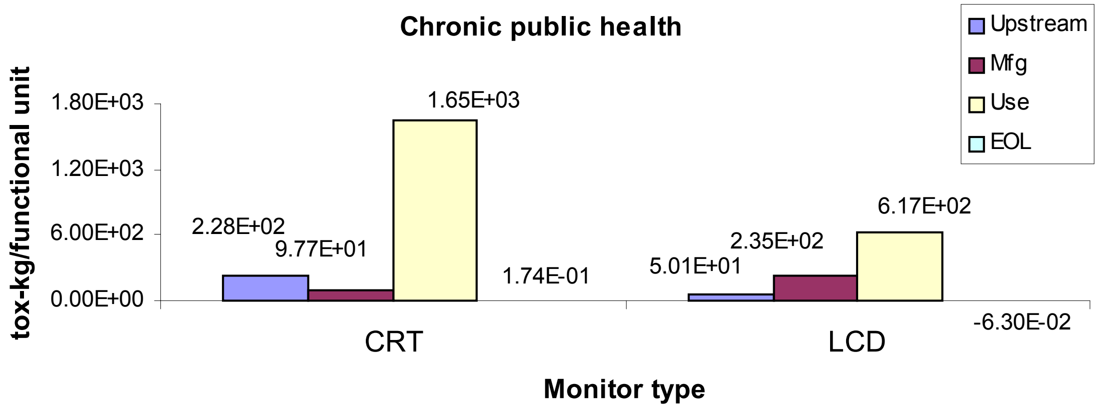

Figure 3-18. Chronic public health impacts by life-cycle stage

account for almost 84% of CRT impacts in this category. To a lesser degree, LCD chronic public health effect impacts are also driven by emissions from electricity generation in the use stage, which account for more than 68% of the total. Note that the ratio of CRT to LCD use stage public health impacts is the same as the ratio of CRT to LCD use stage electricity consumption (634 kWh/life for the CRT to 237 kWh/life for the LCD).

The materials processing stage contributes almost 12% of CRT chronic public health effect impacts and almost six percent of LCD impacts. The manufacturing life-cycle stage is responsible for five and 26% of CRT and LCD impacts in this category, respectively. Both monitors receive very small public chronic health effects scores at end of life. This is because most public health effect impacts from CRT and LCD recycling and disposal processes are offset by a credit on electric grid emissions when the monitors are incinerated with energy recovery.

Table 3-45 presents the materials that contribute to the top 99% of the CRT chronic public health effects score. As shown in the table, SO_2 emissions from a number of different process groups almost completely dominate CRT impacts in this category, accounting for more than 98% of the total. All of the SO_2 LCI data shown in the table are either from secondary data sets not developed specifically for the CDP, or from the electric grid inventories developed from secondary sources for this project. Sulfur dioxide has a relatively high HV based on an inhalation NOAEL of 0.104 mg/m^3, compared to the geometric mean inhalation NOAEL of 68.7 mg/m^3. In addition, from a mass loading perspective, SO_2 emissions were the second largest contributor to CRT life-cycle air pollutant emissions, exceeded only by emissions of carbon dioxide (CO_2). Carbon dioxide is not classified as toxic, and therefore does not contribute to the human health effects scores.

Table 3-45. Top 99% of the CRT chronic public health effects score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Sulfur dioxide	Model/secondary	83%
Materials processing	Invar	Sulfur dioxide	Secondary	8.3%
Manufacturing	Japanese electric grid	Sulfur dioxide	Model/secondary	2.9%
Manufacturing	U.S. electric grid	Sulfur dioxide	Model/secondary	1.3%
Materials processing	Steel production, cold-rolled, semi-finished	Sulfur dioxide	Secondary	1.3%
Materials processing	Aluminum production	Sulfur dioxide	Secondary	0.70%
Materials processing	Polycarbonate production	Sulfur dioxide	Secondary	0.40%
Manufacturing	LPG production	Carbon monoxide	Secondary	0.29%
Materials processing	Lead production	Sulfur dioxide	Secondary	0.23%

*Column may not add to 99% due to rounding.

Most of the sulfur dioxide emissions that contribute to the CRT chronic public health effects score are from the combustion of fossil fuels used to generate electricity. For example, the electricity required to power the monitor during the use stage accounts for the vast majority of SO_2 emissions and 83% of the CRT chronic public health effects score. Sulfur dioxide emissions from electricity consumed in the United States and Japan during the manufacturing life-cycle stage account for another 4.2% of the total score. Much of the SO_2 emissions reported in secondary data sets for the materials processing life-cycle stage may also be from electricity generation since many of these data also contain an electric grid inventory.

Table 3-46 lists the materials that contribute to the top 99% of the LCD chronic public health effects score and the LCI data type. LCD impacts in this category are also dominated by SO_2 emissions, which are responsible for roughly 93% of impacts. Like the CRT, most of these emissions occur from electricity generation, either during the use stage (68%) or manufacturing (21%). As noted previously, SO_2 has a relatively high HV due to its low toxicity value (inhalation NOAEL = 0.104 mg/m^3). Similar to the CRT, from a mass loading perspective, SO_2 emissions were the second largest contributor to LCD life-cycle air pollutant emissions, exceeded only by emissions of CO_2.

Table 3-46. Top 99% of the LCD chronic public health effects score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Sulfur dioxide	Model/secondary	68%
Manufacturing	Japanese electric grid	Sulfur dioxide	Model/secondary	21%
Manufacturing	LCD monitor/module mfg.	Phosphine	Primary	3.2%
Materials processing	Steel production, cold-rolled, semi-finished	Sulfur dioxide	Secondary	1.4%
Materials processing	PMMA sheet production	Sulfur dioxide	Secondary	0.96%
Materials processing	Natural gas production	Methane	Secondary	0.78%
Materials processing	Natural gas production	Benzene	Secondary	0.59%
Materials processing	Aluminum production	Sulfur dioxide	Secondary	0.57%
Materials processing	Natural gas production	Carbon monoxide	Secondary	0.53%
Materials processing	Polycarbonate production	Sulfur dioxide	Secondary	0.49%
Manufacturing	LCD monitor/module mfg.	Phosphorus (yellow or white)	Primary	0.38%
Manufacturing	U.S. electric grid	Sulfur dioxide	Model/secondary	0.35%

*Column may not add to 99% due to rounding.

Other top contributors to the LCD chronic public health effects score include phosphine and phosphorus from LCD monitor/module manufacturing, and methane, benzene, and carbon monoxide from natural gas production. As noted above in the section on chronic occupational health effects, the phosphine score is driven by its low oral NOAEL value (0.026 mg/kg-day), which is significantly lower than the geometric mean value of 68.7 mg-kg-day, resulting in a high HV. Thus, a relatively small output of phosphine (in this case, air emissions of 0.063 kg per functional unit) results in a relatively high chronic public health effects score.

The benzene and phosphorus chronic health effects scores are also driven more by their toxicity than the output amounts. Benzene is a known human carcinogen (EPA WOE Class A) that also causes noncancer health effects. The HV for benzene is based on its oral slope factor [0.055 (mg/kg-day)$^{-1}$] and its inhalation NOAEL for noncancer effects (1.15 mg/m^3), which together result in a high HV. (Benzene also has an *inhalation* slope factor and an *oral* NOAEL value, but these yield lower hazard values when compared to the geometric mean values.)

Phosphorus has an EPA WOE classification of D (not classifiable as to human carcinogenicity), but has a low oral NOAEL value (0.015 mg/kg-day), which also gives it a high HV.

No toxicity data were available for methane. Therefore, it received a default HV of one for both cancer and noncancer effects (HV=2 total). The HV for carbon monoxide is based on an inhalation LOAEL of 55 mg/m^3.

3.3.13.3 Chronic public health effect scores modified to exclude sulfur dioxide

Because the chronic public health effects scores for both the CRT and the LCD are dominated by SO_2 emissions, a secondary analysis was run to identify the top contributors to public health impacts when SO_2 emissions are excluded from the inventories. Results of this analysis may be more useful to manufacturers seeking to identify problematic toxic chemicals within their own manufacturing processes.

Figure 3-19 presents the CRT and LCD chronic public health effects scores by life-cycle stage when SO_2 emissions are excluded from the inventories. Under this scenario, the CRT score is reduced almost 99% from 1980 tox-kg to 26 tox-kg per functional unit, and the LCD score is reduced about 93% from 902 tox-kg to 61 tox-kg per functional unit. Note that these scores should not be used to evaluate which monitor type has higher overall impacts in this category, but they are useful for identifying life-cycle improvement opportunities that were previously obscured by SO_2 impacts.

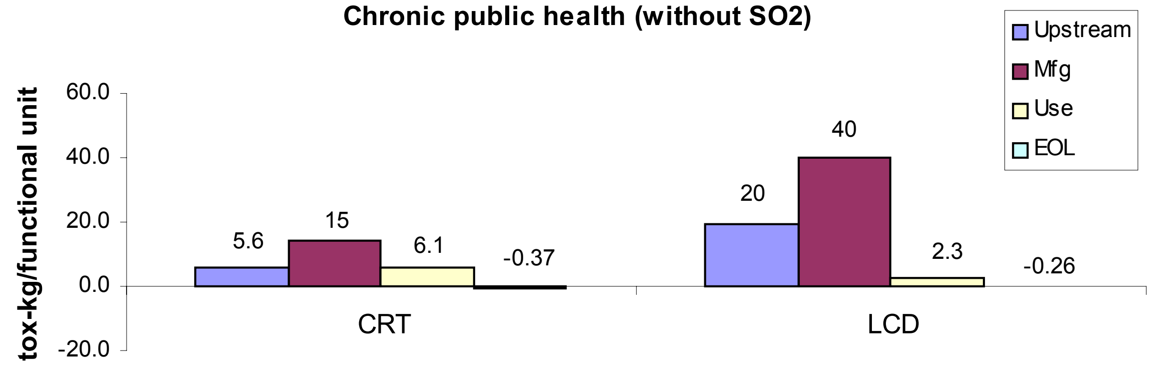

Figure 3-19. Chronic public health impacts (without SO2) by life-cycle stage

With SO_2 emissions removed from the inventories, chronic public health effect impacts are highest in the manufacturing life-cycle stage for both the CRT (56% of impacts) and the LCD (65% of impacts). The use stage is the next largest contributor for the CRT (22%), and the materials processing stage in the next largest contributor for the LCD (32%). As will be shown below, use stage impacts are significant for the CRT, even when SO_2 emissions are excluded, because of the CRT's relatively high electricity consumption during use by the consumer and the associated emissions of pollutants from U.S. power plants.

Table 3-47 presents the materials that contribute greater than one percent of CRT impacts when SO_2 emissions are excluded from the CRT inventory. Under this scenario, CRT chronic public health impacts are still being driven by emissions of criteria air pollutants,[2] including carbon monoxide, nitrogen oxides, and sulfur oxides (assuming that SO_2 emissions comprise a large part of the sulfur oxide emissions shown in the table). As shown in the table, emissions of these three pollutants or pollutant categories are responsible for some 48% of CRT chronic public health impacts when pure SO_2 emissions are excluded from the CRT inventory. Note that the majority of these emissions occur from the LPG production process, and most of this LPG is used as a fuel in CRT glass manufacturing. CRT glass manufacturing energy inputs are uncertain and evaluated in a sensitivity analysis (See Section 3.4). Other significant contributors include arsenic from lead production, methane from LPG production and the U.S. electric grid inventory, vanadium and benzene from LPG production, and titanium tetrachloride from aluminum production.

Table 3-47. Materials contributing greater than 1% of the CRT chronic public health effects score (without SO_2)

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
Manufacturing	LPG production	Carbon monoxide	Secondary	22.35%
Use	U.S. electric grid	Nitrogen oxides	Modeled/secondary	9.12%
Materials processing	Lead	Arsenic	Secondary	8.55%
Manufacturing	LPG production	Methane	Secondary	6.50%
Manufacturing	LPG production	Sulfur oxides	Secondary	6.21%
Use	U.S. electric grid	Methane	Modeled/secondary	4.99%
Manufacturing	LPG production	Nitrogen oxides	Secondary	4.44%
Use	U.S. electric grid	Carbon monoxide	Modeled/secondary	4.23%
Manufacturing	LPG production	Vanadium	Secondary	4.05%
Manufacturing	LPG production	Benzene	Secondary	3.32%
Materials processing	Aluminum production (virgin)	Titanium tetrachloride	Secondary	2.79%
Manufacturing	CRT glass/frit mfg.	Fluorides (F-)	Primary	2.27%
Use	U.S. electric grid	Arsenic	Modeled/secondary	2.16%
Use	U.S. electric grid	Hydrochloric acid	Modeled/secondary	1.91%
Materials processing	Steel Prod., cold-rolled, semi-finished	Carbon monoxide	Secondary	1.16%

Table 3-48 presents the materials that contribute greater than one percent of LCD impacts when SO_2 emissions are excluded from the LCD inventory. Under this scenario, phosphine emissions from LCD monitor/module manufacturing are the dominant factor in the LCD chronic public health effects score, contributing 47% of the total. Other significant contributors include methane, benzene, carbon monoxide, and nitrogen oxides from natural gas production, and phosphorus, fluorides, tetramethyl ammonium hydroxide, and nitrogen oxides from LCD monitor/module manufacturing. Recall that the LCD monitor/module manufacturing process

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[2] The criteria air pollutants are those for which U.S. National Ambient Air Quality Standards have been adopted. They are carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur dioxide.

consumes the majority of the natural gas made in the natural gas production process, where LNG is used as an ancillary material. However, only one of the seven LCD monitor/module manufacturers that provided inventory data to the CDP reported the ancillary use of LNG. Other LCD monitor/module manufactures did report the use of LNG as a fuel.

Table 3-48. Materials contributing greater than 1% of the LCD chronic public health effects score (without SO_2)

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
Manufacturing	LCD monitor/module mfg.	Phosphine	Primary	46.7%
Materials processing	Natural gas production	Methane	Secondary	11.4%
Materials processing	Natural gas production	Benzene	Secondary	8.61%
Materials processing	Natural gas production	Carbon monoxide	Secondary	7.81%
Manufacturing	LCD monitor/module mfg.	Phosphorus (yellow or white)	Primary	5.56%
Manufacturing	LCD monitor/module mfg.	Fluorides (F-)	Primary	4.15%
Materials processing	Natural gas production	Nitrogen oxides	Secondary	2.12%
Manufacturing	LCD monitor/module mfg.	Tetramethyl ammonium hydroxide	Primary	2.09%
Manufacturing	LCD monitor/module mfg.	Nitrogen oxides	Primary	1.78%
Use	U.S. electric grid	Nitrogen oxides	Modeled/secondary	1.43%

3.3.13.4 Limitations and uncertainties: chronic human health effects

Most of the limitations and uncertainties in the chronic human health effects results presented here can be grouped into three categories:

1. *Structural or modeling limitations and uncertainties* associated with the accuracy of the toxic chemical classification method and the chemical scoring approach used to characterize human health effects.
2. *Toxicity data limitations and uncertainties* associated with the availability and accuracy of toxicity data to represent potential human health effects.
3. *LCI data limitations and uncertainties* associated with the accuracy and representativeness of the inventory data.

Each of these are discussed below.

Structural or modeling limitations and uncertainty. The chemical scoring method used in the human health effects impact characterization is a screening tool to identify chemicals of potential concern, not to predict actual effects or characterize risk. A major limitation in the method is that it only measures relative toxicity, combined with inventory amount. It does not take chemical fate, transformation, or degradation into account. In addition, it uses a simple surrogate value (i.e., inventory amount) to evaluate the potential for exposure, when actual exposure potential involves many more factors, some of which are chemical-specific. Other sources of uncertainty include possible omissions by the CDP researchers in the impact classification process (e.g., potentially toxic chemicals not classified as such) or misrepresentation of chemicals in the impact characterization method itself (e.g., misrepresenting a chemical as a small contributor to total impacts, because of missing or inaccurate toxicity data). Some of these limitations and uncertainties may also be considered limits in the toxicity data which are discussed further below.

It should also be noted, however, that because LCA involves analyzing many processes over the entire life cycle of a product, a comprehensive, quantitative risk assessment of each chemical input or output can not be done. Rather, LCA develops relative impacts that often lack temporal or spatial specificity, but can be used to identify materials for more detailed evaluation. More detailed assessments of the toxicity and potential exposures to selected materials are performed in Chapter 4.

Toxicity data limitations and uncertainties. Major uncertainties in the impact assessment for potentially toxic chemicals result from missing toxicity data and from limitations of the available toxicity data. Uncertainties in the human health hazard data (as typically encountered in a hazard assessment) include the following:

- Using dose-response data from laboratory animals to represent potential effects in humans.
- Using data from homogeneous populations of laboratory animals or healthy human populations to represent the potential effects on the general human populations, with a wide range of sensitivities.
- Using dose-response data from high dose toxicity studies to represent potential effects that may occur at low levels.
- Using data from short-term studies to represent the potential effects of long-term exposures.
- Assuming a linear dose-response relationship.
- Possibly increased or decreased toxicity resulting from chemical interactions.

Regarding uncertainties resulting from missing toxicity data, there is uncertainty associated with using a default HV (i.e., assuming average toxicity for that measure when a chemical could be either more or less toxic than average). However, the use of neutral default values for missing data reduces the bias that typically favors chemicals with little available information. Use of a data-neutral default value to fill data gaps is consistent with principles for chemical ranking and scoring (Swanson and Socha, 1997). Of the 273 chemicals classified as potentially toxic in the CDP LCA, 156 (57%) had no toxicity data for carcinogenic effects and 128 (47%) had no data for noncarcinogenic effects. Ninety-seven chemicals (36%) had no human health toxicity data whatsoever.

LCI data limitations and uncertainty. Limitations and uncertainties in the LCI data have been discussed previously and are generally related to: (1) uncertainties in data from secondary sources that may not be representative of the geographic and temporal boundaries of this LCA, and (2) uncertainties in a few of the primary data points collected specifically for this project. With regard to the latter, glass manufacturing energy inputs are particularly uncertain despite numerous attempts to resolve the uncertainty, but are responsible for a significant portion of CRT human health impacts. Glass manufacturing energy inputs are evaluated in a sensitivity analysis in Section 3.4. The amount of LNG used as an ancillary material in LCD monitor/module manufacturing is also uncertain (also despite attempts to resolve questions regarding the data), but this material contributes a significant portion of LCD occupational health impacts. As noted previously, removing this application of LNG from the LCD monitor/module manufacturing inventory would reduce the LCD chronic occupational health effects score by 68%.

3.3.13.5 Aesthetic impacts (odor)

Figure 3-20 presents the CRT and LCD LCIA results for the aesthetic impacts (odor) category, based on the impact assessment methodology presented in Section 3.1.2.12. Complete results for the CRT and LCD are presented in Tables M-35 and M-36 in Appendix M, respectively. The life-cycle aesthetic (odor) impact result is 7.58 million m^3 malodorous air per functional unit for the CRT and 5.04 million m^3 malodorous air per functional unit for the LCD. As shown in the figure, this impact category indicator is dominated by air emissions in the manufacturing stage for both the CRT (96% of total) and the LCD (98% of total). Both monitor types receive relatively minor contributions in the use and materials processing life-cycle stages, and negative values at end of life. Negative values are due to the offset of electric power plant emissions from incineration with energy recovery.

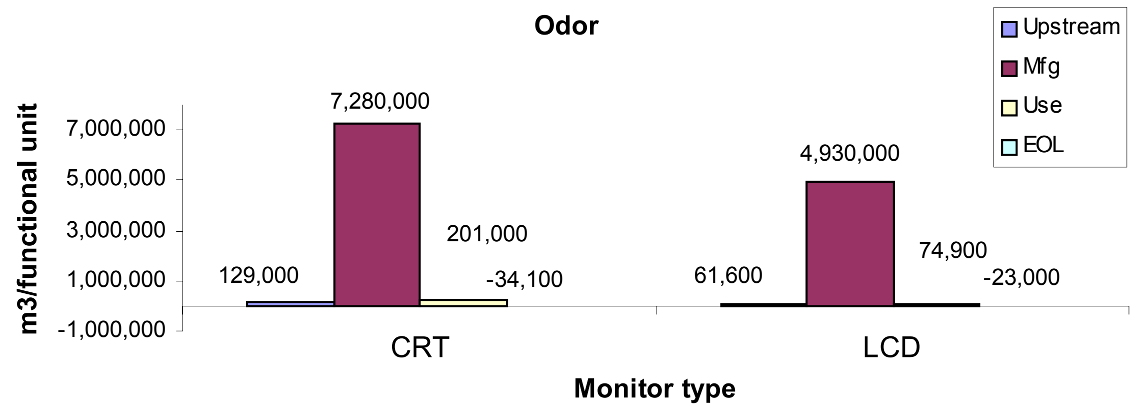

Figure 3-20. Odor impacts by life-cycle stage

Major Contributors to the CRT Aesthetics (Odor) Result

Table 3-49 lists the materials that contribute to the top 99% of the CRT aesthetic impacts result and the LCI data type. Air emissions of hydrogen sulfide from LPG production in the manufacturing life-cycle stage dominate the CRT odor impacts, contributing 94% of the total score. Hydrogen sulfide impacts are calculated based on an odor threshold value (OTV) of 0.00043 mg/m^3. [See Table K-7 in Appendix K for a list of OTVs used to calculate aesthetic (odor) impacts.] As noted previously, most of the LPG produced by this process is used as a fuel in CRT glass manufacturing, but glass manufacturing energy inputs are uncertain. The next largest contributor to the CRT is acetaldehyde emitted from the U.S. electric grid during the use stage. Acetaldehyde has a lower OTV (0.00027 mg/m^3) than LPG, and is also emitted in smaller quantities. Emissions of hydrogen sulfide from fuel oil #6 production, steel production, and ABS production are the remaining top contributors to the CRT aesthetic impacts score. LCI data for all of the top contributors are either from secondary data sets or developed by CDP researchers from secondary sources.

Table 3-49. Top 99% of the CRT aesthetic (odor) impacts score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LPG production	Hydrogen sulfide	Secondary	94%
Use	U.S. electric grid	Acetaldehyde	Model/secondary	2.5%
Manufacturing	Fuel oil #6 production	Hydrogen sulfide	Secondary	0.98%
Materials processing	Steel production, cold-rolled, semi-finished	Hydrogen sulfide	Secondary	0.42%
Materials processing	ABS production	Hydrogen sulfide	Secondary	0.31%

*Column may not add to 99% due to rounding.

Major Contributors to the LCD Aesthetics (Odor) Result

Table 3-50 presents the materials that contribute to the top 99% of the LCD aesthetics impact score and the LCI data type. LCD impacts are dominated by air emissions of phosphine from LCD monitor/module manufacturing, which contribute 89% of the total score. OTVs reported for phosphine range from 0.014 to 2.8 mg/m^3. The lower, more sensitive value (0.014 mg/m^3) was used to calculate impacts.

Table 3-50. Top 99% of the LCD aesthetic (odor) impacts score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	LCD monitor/module mfg.	Phosphine	Primary	89%
Manufacturing	LPG production	Hydrogen sulfide	Secondary	6.8%
Use	U.S. electric grid	Acetaldehyde	Model/secondary	1.4%
Manufacturing	LCD monitor/module mfg.	Ammonia	Primary	1.2%
Manufacturing	LCD monitor/module mfg.	Acetic acid	Primary	0.44%

*Column may not add to 99% due to rounding.

Other significant contributors include hydrogen sulfide from LPG production, acetaldehyde from the U.S. electric grid, and ammonia and acetic acid from LCD module/monitor manufacturing. Most of the LPG made in the LPG production process is used as a fuel in LCD glass manufacturing, indicating this process is ultimately responsible for LPG production impacts. However, LCD glass energy inputs are uncertain and evaluated in a sensitivity analysis (Section 3.4). LCD monitor/module manufacturing data were collected directly from manufacturers by the CDP, while the LPG production inventory was obtained from *Ecobilan.* The U.S. electric grid inventory was developed by CDP researchers from secondary sources.

Limitations and Uncertainties

Aesthetic (odor) impact scores are based on the identity and amount of odor-causing chemicals (Heijungs *et al.*, 1992; EPA, 1992), released to the air divided by their chemical-specific OTVs. An OTV is the lowest concentration of a substance in air that can be smelled based on a standardized test. Limitations and uncertainties in the aesthetics impact score stem from structural or model uncertainty (whether or not odor thresholds will actually be exceeded), OTV data uncertainty (how well published OTVs represent the odor threshold of different populations), and LCI data uncertainty.

The aesthetics impact score calculates the mass of malodorous air that could result if a chemical release occurs in a finite volume of air. It does not predict whether actual odor impacts will occur. This is because LCI data do not describe the time rate of release or whether dilution and mixing with ambient air will dilute the concentration of a pollutant to below its odor threshold. In addition, odor thresholds are highly variable because of the differing ability of individuals to detect odors. Therefore, the impact scores may not account for odors perceived by the most sensitive populations or may overstate impacts perceived by less sensitive populations. Finally, the aesthetic impact scores are subject to the limitations and uncertainties in the LCI data, since they are calculated from air emissions data in the inventories. The limitations and uncertainties in LCI data were discussed in Section 2.2.2.2, and have been discussed extensively with LCIA results for other impact categories, above.

3.3.14 Ecotoxicity

Ecotoxicity refers to effects of chemical outputs on non-human living organisms. As discussed in Section 3.1.2.13, ecotoxicity impact categories included in the scope of this LCA include impacts to aquatic and terrestrial organisms.

Ecotoxicity impacts are calculated using the scoring of inherent properties approach where an impact score is based on the inventory amount weighed by a hazard value (HV). The HV represents the toxicity of a specific material to aquatic or terrestrial organisms (see Table K-8 in Appendix K for a list of toxicity values used to calculate hazard values). Aquatic HVs are based on acute and chronic toxicity values for fish, while terrestrial HVs are based on chronic noncancer toxicity values for mammals, usually rodents. Similar to the chronic human health impacts discussed in Section 3.3.13, the inventory amount (the toxic chemical outputs to water for aquatic toxicity effects, and the outputs to air and water for terrestrial toxicity effects) is used as a surrogate for exposure, while the hazard value represents the inherent toxicity of the substance.

Also like the human health effects methodology, the CDP ecotoxicity LCIA methodology does not consider the fate and transport of a toxic chemical in the environment, nor does it evaluate the potential for actual exposures to occur. In addition, the methodology is limited in that it does not consider toxicity data from all types of aquatic or terrestrial species, but rather focuses on a few selected species for which more toxicity data are available. The limitations and uncertainties in the ecotoxicity scores are discussed further below, following the presentation of results.

3.3.14.1 Aquatic toxicity

Figure 3-21 presents the CRT and LCD LCIA results for the aquatic toxicity impact category, based on the impact assessment methodology presented in Section 3.1.2.13. Complete results for the CRT and LCD are presented in Tables M-37 and M-38 in Appendix M, respectively.

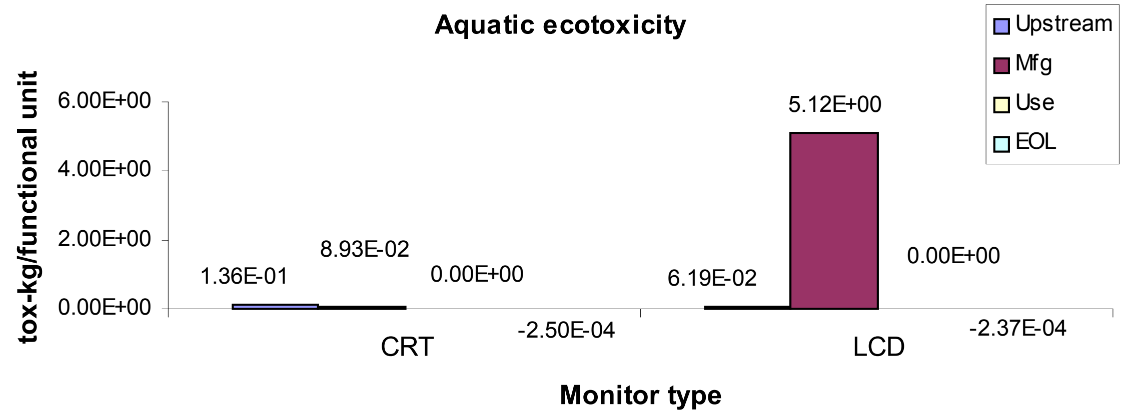

Figure 3-21. Aquatic ecotoxicity impacts by life-cycle stage

The life-cycle aquatic toxicity indicator is 0.22 tox-kg per functional unit for the CRT and 5.19 tox-kg per functional unit for the LCD. As shown in the figure, the CRT aquatic toxicity indicator is driven by water releases in the materials processing stage (64% of total), while the LCD aquatic toxicity indicator is completely dominated by water releases in the manufacturing stage (99% of total). Both monitor types receive zero scores in the use stage and small, negative values at end of life. Negative values are due to the offset of electric power plant emissions from incineration with energy recovery.

Table 3-51 lists the materials that contribute to the top 99% of the CRT aquatic toxicity impact score and the LCI data type. As shown in the table, CRT aquatic toxicity impacts are broadly distributed across a number of different process groups, with most of the top contributors responsible for less than five percent of the impacts. Most of the LCI data from which the scores were calculated are from secondary data sets, although a substantial fraction are from primary data collected to meet the goals and scope of the CDP LCA. Water releases of phosphorus from CRT tube manufacturing represents the single largest contributor to the CRT aquatic toxicity score, accounting for 26% of the total. Aquatic toxicity impacts for phosphorus are driven more by its inherent acute toxicity than the output amount. The phosphorus acute HV is calculated from a fish LC_{50} of 0.020 mg/L, which is significantly more toxic than the geometric mean value of 23.5 mg/L.

The only other specific outputs that contribute more than five percent of the CRT aquatic toxicity score are water discharges of aluminum ions (valence = +3) and copper ions (valence = +1 and +2) from aluminum production. The aluminum HV is calculated from an LC_{50} value of 36 mg/L and a NOAEL value of 3.6 mg/L, which are within an order of magnitude of the geometric mean values of 23.5 mg/L and 3.9 mg/L. Copper, on the other hand, is much more toxic to fish, with an LC_{50} value of 0.014mg/L and a NOAEL value of 0.004 mg/L. The aluminum aquatic toxicity score exceeds that of copper because it is discharged in much greater quantities.

Table 3-51. Top 99% of the CRT aquatic toxicity impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Manufacturing	CRT tube manufacturing	Phosphorus (yellow or white)	Primary	26%
Materials processing	Aluminum production	Aluminum (+3)	Secondary	12%
Materials processing	Aluminum production	Copper (+1 & +2)	Secondary	9.5%
Materials processing	Invar	Copper (+1 & +2)	Secondary	5.0%
Materials processing	Invar	Aluminum (+3)	Secondary	4.4%
Materials processing	Invar	Zinc (+2)	Secondary	4.0%
Materials processing	Lead	Aluminum (+3)	Secondary	3.6%
Manufacturing	CRT tube manufacturing	Fluoride	Primary	3.1%
Materials processing	Ferrite manufacturing	Zinc (+2)	Secondary	3.0%
Materials processing	Aluminum production	Zinc (+2)	Secondary	2.9%
Materials processing	ABS production	Ammonia	Secondary	2.7%
Materials processing	Lead	Copper (+1 & +2)	Secondary	2.7%
Manufacturing	CRT glass/frit mfg.	Fluorides (F-)	Primary	2.6%
Manufacturing	CRT tube manufacturing	Zinc (elemental)	Primary	2.3%
Manufacturing	CRT tube manufacturing	Copper	Primary	2.1%
Materials processing	Steel production, cold-rolled, semi-finished	Phosphorus (yellow or white)	Secondary	2.0%
Manufacturing	LPG production	Phenol	Secondary	1.9%
Materials processing	Steel production, cold-rolled, semi-finished	Ammonia	Secondary	1.2%
Manufacturing	LPG production	Aluminum (+3)	Secondary	1.1%
Materials processing	Lead	Zinc (+2)	Secondary	0.82%
Materials processing	Polycarbonate production	Copper (+1 & +2)	Secondary	0.54%
Materials processing	Steel production, cold-rolled, semi-finished	Copper (+1 & +2)	Secondary	0.45%
Materials processing	Ferrite manufacturing	Aluminum (+3)	Secondary	0.43%
Materials processing	Aluminum production	Barium sulfate	Secondary	0.40%
Materials processing	ABS production	Aluminum (+3)	Secondary	0.39%
Materials processing	Invar	Ammonia	Secondary	0.36%
Materials processing	Ferrite manufacturing	Copper (+1 & +2)	Secondary	0.31%
Materials processing	ABS production	Copper (+1 & +2)	Secondary	0.25%
Materials processing	Styrene-butadiene copolymer production	Copper (+1 & +2)	Secondary	0.24%
Materials processing	Aluminum production	Titanium tetrachloride	Secondary	0.20%
Materials processing	Polycarbonate production	Mercury compounds	Secondary	0.19%
Materials processing	Aluminum production	Strontium (Sr II)	Secondary	0.14%

Table 3-51. Top 99% of the CRT aquatic toxicity impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Materials processing	Steel production, cold-rolled, semi-finished	Aluminum (+3)	Secondary	0.12%
Materials processing	Ferrite manufacturing	Ammonia	Secondary	0.12%
Materials processing	Lead	Barium sulfate	Secondary	0.10%
Materials processing	Steel production, cold-rolled, semi-finished	Nitrogen dixode	Secondary	0.088%
Materials processing	ABS production	Mercury compounds	Secondary	0.088%
Materials processing	Steel production, cold-rolled, semi-finished	Zinc (+2)	Secondary	0.087%
Materials processing	Styrene-butadiene copolymer production	Mercury compounds	Secondary	0.086%
Materials processing	Steel production, cold-rolled, semi-finished	Fluorides (F-)	Secondary	0.086%
Materials processing	Aluminum production	Lead compounds	Secondary	0.076%
Materials processing	Polycarbonate production	Zinc (+2)	Secondary	0.076%
Materials processing	Invar	Strontium (Sr II)	Secondary	0.074%

*Column may not add to 99% due to rounding.

Table 3-52 lists the materials that contribute to the top 99% of the LCD aquatic toxicity impact score and the LCI data type. Unlike the CRT, LCD impacts in this category are not distributed across a number of different process groups, but dominated by phosphorus emissions from a single process group, LCD monitor/module manufacturing. Phosphorus releases from LCD monitor/module manufacturing are several orders of magnitude higher than phosphorus releases from CRT tube manufacturing (the greatest contributor to the CRT aquatic toxicity impact score). However, the LCD aquatic toxicity score for phosphorus is still driven by the inherent acute toxicity of phosphorus, rather than the release amount.

Other top contributors to LCD impacts in this category include ammonia releases from PMMA sheet production, and phosphorus emissions from LCD panel components manufacturing. No toxicity data were available for ammonia. Consequently, it was assigned a default HV of two, representative of mean acute and chronic fish toxicity values.

Table 3-52. Top 99% of the LCD aquatic toxicity impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
Manufacturing	LCD monitor/module mfg.	Phosphorus (yellow or white)	Primary	98%
Materials processing	PMMA sheet production	Ammonia	Secondary	0.63%
Manufacturing	LCD panel components	Phosphorus (yellow or white)	Primary	0.56%

3.3.14.2 Terrestrial ecotoxicity

Figure 3-22 presents the CRT and LCD LCIA results for the terrestrial toxicity impact category, based on the impact assessment methodology presented in Section 3.1.2.13. Complete results for the CRT and LCD are presented in Tables M-39 and M-40 in Appendix M, respectively.

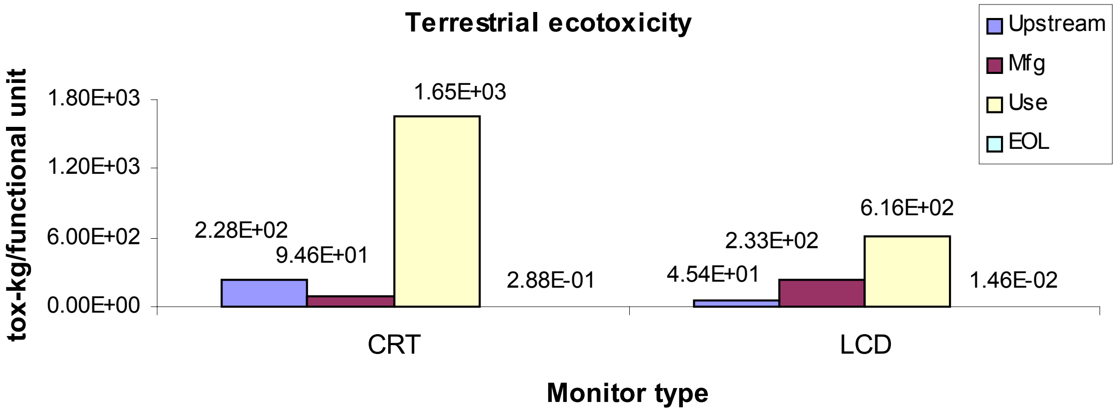

Figure 3-22. Terrestrial ecotoxicity impacts by life-cycle stage

The life-cycle terrestrial toxicity indicator is 1,970 tox-kg per functional unit for the CRT and 894 tox-kg per functional unit for the LCD. As shown in the figure, the CRT result is dominated by toxic chemical outputs from electricity generation in the use stage, which account for almost 84% of CRT impacts in this category. To a lesser degree, LCD terrestrial toxicity impacts are also driven by emissions from electricity generation in the use stage, which account for more than 69% of the total.

The materials processing stage contributes about 12% of CRT terrestrial toxicity impacts and about five percent of LCD impacts. The manufacturing life-cycle stage is responsible for five and 26% of CRT and LCD impacts in this category, respectively. Both monitors receive very small terrestrial toxicity scores at end of life. This is because most terrestrial toxicity impacts from CRT and LCD recycling and disposal processes are offset by a credit on electric grid emissions when the monitors are incinerated with energy recovery.

The terrestrial toxicity impact results are almost identical to the chronic public health effects results presented previously (see Section 3.3.13). Recall that human health and terrestrial toxicity impacts are calculated using the same noncancer toxicity values (and the same inventory data), with the main difference being that toxicity data on carcinogenic effects are excluded from the terrestrial toxicity impact calculations. However, human health and terrestrial toxicity impacts are almost identical because: (1) impacts in both categories are dominated by emissions of sulfur dioxide from electricity generation (see Tables 3-53 and 3-54 below for top contributors to the CRT and LCD terrestrial toxicity impacts), and (2) sulfur dioxide has a high hazard value for noncancer effects and a hazard value of zero for cancer effects.

Table 3-53 presents the materials that contribute to the top 99% of the CRT terrestrial toxicity impact score. As already noted, SO_2 emissions from a number of different process groups almost completely dominate CRT impacts in this category, accounting for slightly less than 99% of the total. Most of these emissions are from the combustion of fossil fuels to generate electricity. All of the SO_2 LCI data are either from secondary data sets not developed specifically for the CDP or from the electric grid inventories developed from secondary sources for this project. Sulfur dioxide has a relatively high HV, based on an inhalation NOAEL of 0.104 mg/m^3 and the geometric mean inhalation NOAEL of 68.7 mg/m^3. In addition, as noted in the section on human health effects (3.3.13), from a mass loading perspective (i.e., based on the inventory alone), SO_2 emissions were the second largest contributor to CRT life-cycle air pollutant emissions, exceeded only by emissions of carbon dioxide (CO_2). Carbon dioxide is not classified as toxic, and therefore did not contribute to the terrestrial toxicity impact category.

Table 3-53. Top 99% of the CRT terrestrial toxicity impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score*
Use	U.S. electric grid	Sulfur dioxide	Model/secondary	83%
Materials processing	Invar	Sulfur dioxide	Secondary	8.4%
Manufacturing	Japanese electric grid	Sulfur dioxide	Model/secondary	2.9%
Manufacturing	U.S. electric grid	Sulfur dioxide	Model/secondary	1.3%
Materials processing	Steel production, cold-rolled, semi-finished	Sulfur dioxide	Secondary	1.3%
Materials processing	Aluminum production	Sulfur dioxide	Secondary	0.70%
Materials processing	Polycarbonate production	Sulfur dioxide	Secondary	0.40%
Manufacturing	LPG production	Carbon monoxide	Secondary	0.27%

* Column may not add to 99% due to rounding.

Table 3-54 lists the materials that contribute to the top 99% of the LCD terrestrial toxicity impact score and the LCI data type. LCD impacts in this category are also dominated by SO_2 emissions, which are responsible for roughly 92% of impacts. Like the CRT, most of these emissions occur from electricity generation, either during the use stage (68%) or manufacturing (21%). As noted previously, SO_2 has a relatively high HV, due to its low toxicity value (inhalation NOAEL = 0.104 mg/m^3). Similar to the CRT, from a mass loading perspective (i.e., based on the inventory alone), SO_2 emissions were the second largest contributor to LCD life-cycle air pollutant emissions, exceeded only by emissions of CO_2.

Other top contributors to the LCD terrestrial toxicity score include phosphine and phosphorus from LCD monitor/module manufacturing, and carbon monoxide and methane from natural gas production. As noted above in the section on chronic occupational health effects, the phosphine, phosphorus, and benzene scores are driven more by their inherent toxicity than their output amounts.

Table 3-54. Top 99% of the LCD terrestrial toxicity impact score

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
Use	U.S. electric grid	Sulfur dioxide	Model/secondary	68%
Manufacturing	Japanese electric grid	Sulfur dioxide	Model/secondary	21%
Manufacturing	LCD monitor/module mfg.	Phosphine	Primary	3.2%
Materials processing	Steel production, cold-rolled, semi-finished	Sulfur dioxide	Secondary	1.4%
Materials processing	PMMA sheet production	Sulfur dioxide	Secondary	0.96%
Materials processing	Natural gas production	Benzene	Secondary	0.59%
Materials processing	Aluminum production	Sulfur dioxide	Secondary	0.57%
Materials processing	Natural gas production	Carbon monoxide	Secondary	0.50%
Materials processing	Polycarbonate production	Sulfur dioxide	Secondary	0.50%
Materials processing	Natural gas production	Methane	Secondary	0.39%
Manufacturing	LCD monitor/module mfg.	Phosphorus (yellow or white)	Primary	0.38%

3.3.14.3 Terrestrial toxicity impact scores modified to exclude sulfur dioxide

Because the terrestrial toxicity impact scores for both the CRT and the LCD are dominated by SO_2 emissions, a secondary analysis was run to identify the top contributors to these impacts when SO_2 emissions are excluded from the inventories. Results of this analysis may be more useful to manufacturers seeking to identify problematic toxic chemicals within their own manufacturing processes.

Figure 3-23 presents the CRT and LCD terrestrial toxicity impact scores by life-cycle stage when SO_2 emissions are excluded from the inventories. Under this scenario, the CRT score is reduced almost 99% from 1,970 tox-kg to 21 tox-kg per functional unit, and the LCD score is reduced about 94%, from 894 tox-kg to 54 tox-kg per functional unit. Note that these scores should not be used to evaluate which monitor type has higher overall impacts in this category, but they are useful for identifying life-cycle improvement opportunities that were previously obscured by SO_2 impacts.

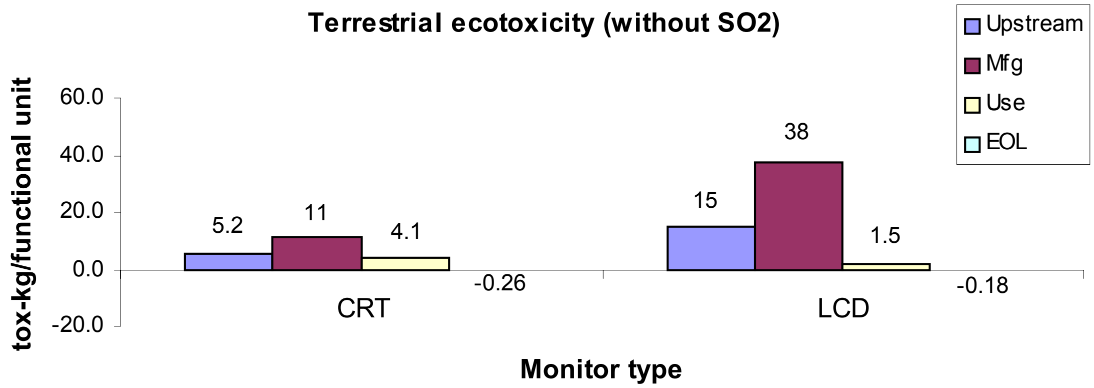

Figure 3-23. Terrestrial ecotoxicity impacts (without SO2) by life-cycle stage

With SO_2 emissions removed from the inventories, terrestrial toxicity impacts are highest in the manufacturing life-cycle stage for both the CRT (56% of impacts) and the LCD (70% of impacts). The materials processing stage is the next largest contributor for both monitor types, contributing 25% of CRT impacts and 27% of LCD impacts, followed by the use stage, which contributes 20% of CRT impacts and almost 3% of LCD impacts. Both monitors have slight negative values at end-of-life, due to the offset of electric grid emissions from incineration with energy recovery.

Table 3-55 presents the materials that contribute greater than one percent of CRT terrestrial toxicity impacts when SO_2 emissions are excluded from the CRT inventory. Like the modified public chronic human health effects results discussed in Section 3.3.13, under this scenario CRT chronic public health impacts are still being driven by emissions of criteria air pollutants, including carbon monoxide, nitrogen oxides, and sulfur oxides (assuming that SO_2 emissions comprise a large part of the sulfur oxide emissions shown in the table). As shown in the table, emissions of these three pollutants or pollutant categories are responsible for some 46% of CRT terrestrial toxicity impacts when pure SO_2 emissions are excluded from the CRT inventory. Note that the majority of these emissions occur from the LPG production process, and most of this LPG is used as a fuel in CRT glass manufacturing. CRT glass manufacturing energy inputs are uncertain and evaluated in a sensitivity analysis (see Section 3.4). Other significant contributors include arsenic from lead production, methane from LPG production and the U.S. electric grid inventory, vanadium and benzene from LPG production, and titanium tetrachloride from aluminum production.

Table 3-55. Materials contributing greater than 1% of the CRT terrestrial toxicity impact score (without SO_2)

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
Manufacturing	LPG production	Carbon monoxide	Secondary	26%
Materials processing	Lead	Arsenic	Secondary	11%
Use	U.S. electric grid	Nitrogen oxides	Model/secondary	5.7%
Manufacturing	LPG production	Vanadium	Secondary	5.1%
Use	U.S. electric grid	Carbon monoxide	Model/secondary	4.9%
Manufacturing	LPG Production	Benzene	Secondary	4.2%
Manufacturing	LPG production	Methane	Secondary	4.1%
Manufacturing	LPG production	Sulfur oxides	Secondary	3.9%
Materials processing	Aluminum production (all virgin)	Titanium tetrachloride	Secondary	3.5%
Use	U.S. electric grid	Methane	Model/secondary	3.1%
Manufacturing	CRT glass/frit mfg.	Fluorides (F-)	Primary	2.8%
Manufacturing	LPG production	Nitrogen oxides	Secondary	2.8%
Use	U.S. electric grid	Arsenic	Model/secondary	2.7%
Use	U.S. electric grid	Hydrochloric acid	Model/secondary	2.4%
Materials processing	Steel Prod., cold-rolled, semi-finished	Carbon monoxide	Secondary	1.4%
Materials processing	Invar	Titanium tetrachloride	Secondary	1.2%
Manufacturing	CRT tube manufacturing	Carbon monoxide	Primary	1.0%
Materials processing	Lead	Titanium tetrachloride	Secondary	1.0%
Manufacturing	LPG production	Arsenic	Secondary	1.0%

Table 3-56 presents the materials that contribute greater than one percent of LCD terrestrial toxicity impacts when SO_2 emissions are excluded from the LCD inventory. As with the LCD modified chronic human health results discussed in Section 3.3.13, when SO_2 emissions are excluded, phosphine emissions from LCD monitor/module manufacturing are the dominant factor in the LCD terrestrial toxicity score, contributing 53% of the total. Other significant contributors include benzene, carbon monoxide, methane, and nitrogen oxides from natural gas production, and phosphorus, fluorides, tetramethyl ammonium hydroxide, and nitrogen oxides from LCD monitor/module manufacturing. Recall that the LCD monitor/module manufacturing process consumes the majority of the natural gas made in the natural gas production process, where LNG is used as an ancillary material. However, only one of the seven LCD monitor/module manufacturers that provided inventory data to the CDP reported the ancillary use of LNG. Other manufacturers reported using LNG as a fuel.

Table 3-56. Materials contributing greater than 1% of the LCD terrestrial toxicity impact score (without SO_2)

Life-cycle stage	Process group	Material	LCI data type	Contribution to impact score
Manufacturing	LCD module/monitor mfg.	Phosphine	Primary	53%
Materials processing	Natural gas production	Benzene	Secondary	9.8%
Materials processing	Natural gas production	Carbon monoxide	Secondary	8.2%
Materials processing	Natural gas production	Methane	Secondary	6.5%
Manufacturing	LCD module/monitor mfg.	Phosphorus (yellow or white)	Primary	6.3%
Manufacturing	LCD module/monitor mfg.	Fluorides (F-)	Primary	4.7%
Materials processing	Natural gas production	Nitrogen oxides	Secondary	1.2%
Manufacturing	LCD module/monitor mfg.	Tetramethyl ammonium hydroxide	Primary	1.2%
Manufacturing	LCD module/monitor mfg.	Nitrogen oxides	Primary	1.0%

3.3.14.4 Limitations and uncertainties

Most of the limitations and uncertainties in the ecotoxicity results are similar to the limitations and uncertainties in the human health effects scores. The reader is referred to Section 3.3.13 for a full discussion of these limitation and uncertainties. In summary, they can be grouped into three categories:

1. *Structural or modeling limitations and uncertainties* associated with the accuracy of the toxic chemical classification method and the chemical scoring approach used to characterize human health effects.
2. *Toxicity data limitations and uncertainties* associated with the availability and accuracy of toxicity data to represent ecotoxicity.
3. *LCI data limitations and uncertainties* associated with the accuracy and representativeness of the inventory data.

With regard to toxicity data, other limitations and uncertainties in the ecotoxicity results are related to the use of surrogates to assess toxicity to all species within an impact category. For example, the aquatic toxicity category uses fish (usually the fathead minnow) as a surrogate to assess toxicity to all aquatic organisms, but it has been well-established in the ecotoxicology literature that fish are not the most sensitive test species to all or most industrial chemicals. In fact, invertebrates (daphnids) or algae (Selenastrum) often are more sensitive to particular chemicals than fish (Smrchek, 1999). Similarly, the terrestrial toxicity category uses mammals, primarily rodents, as a surrogate to assess toxicity to all terrestrial organisms. Terrestrial plants and soil organisms (insects, earthworms, etc.) are not considered, but both of these may be more sensitive than mammals.

Because there are difficulties in comparing test endpoints for different types of organisms, and because there is a very limited toxicity database for some of the other organisms, the LCIA methodology employed in this study uses fish as a surrogate for aquatic toxicity and mammals as a surrogate for terrestrial ecotoxicity. This helps to reduce data gaps and the difficulties in comparing test endpoints for different types of organisms. Furthermore, we believe this approach to be acceptable for a study, such as the CDP LCA, that gives relative ranking of impacts from different chemicals or process groups instead of absolute values. However, it should be noted that this approach can result in an underestimation of the absolute ecotoxicity and hazards of chemicals.

With regard to LCI data limitations not discussed previously, it should be noted that the CRT and LCD LCAs do not address spills or other accidental releases that could have significant adverse effects on aquatic or terrestrial organisms. This is a common limitation of LCA, which is often too labor-intensive to address different operational scenarios across the product life cycle.

3.3.15 Summary of Top Contributors by Impact Category

Tables 3-57 and 3-58 summarize the top contributors to CRT and LCD life-cycle impacts by impact category. As shown in Table 3-57, CRT impacts are largely driven by two factors: (1) the large amount of LPG fuel used in CRT glass/frit manufacturing, and (2) the relatively large amount of electricity consumed during the use stage. The LPG production process yields the CRT's top contributor in eight of 20 impact categories. Most of this LPG is used as a fuel source in CRT glass manufacturing in the glass/frit process group, which, in turn, produces the top contributor to two of 20 impact categories. Thus, LPG used in the glass/frit process group (primarily CRT glass manufacturing) is ultimately the key driver for CRT impacts in ten categories. Similarly, outputs from electricity generation during the use stage result in the top contributor to seven CRT impact categories. Note that in 14 of the 20 impact categories, the top contributor to CRT impacts is responsible for more than 50% of impacts.

Both the glass manufacturing energy and the use stage lifespan (which determines the amount of electricity generated during the use stage) are evaluated in a sensitivity analysis in Section 3.4. In the modified glass energy sensitivity analysis, LPG inputs are greatly reduced and impacts are therefore reduced, but in the modified lifespan (manufactured life) sensitivity analysis, the number of hours a monitor is in use is increased. Thus, CRT impacts are increased.

LCD impacts are not as dominated by a few data points, but a few processes (LCD monitor/module manufacturing and electricity generation in the use stage) are responsible for a large percent of the impacts. As shown in Table 3-58, both of these processes result in the top contributors to six LCD impact categories each. In addition, the process to produce LNG used as an ancillary material in LCD monitor/module manufacturing is the top contributor to an additional impact category (photochemical smog). Note that in 11 of the 20 impact categories, the top contributor to LCD impacts is responsible for more than 50% of impacts.

Like the CRT, both the glass energy inputs and use stage lifespan of the LCD are evaluated in a sensitivity analysis in Section 3.4. LCD monitor/module manufacturing energy and LCD EOL dispositions are also evaluated. LCD monitor/module manufacturing energy was selected for a sensitivity analysis because of the high degree of variability seen in data provided by manufacturers. The impacts presented in the baseline scenario are calculated with energy outliers removed from the average, but the outliers are included in the sensitivity analysis. This results in higher electricity consumption but lower fuel consumption, which, in turn, causes reduced impacts in some categories and increased impacts in others. Note that the LNG used as an ancillary material in LCD monitor/module manufacturing is not affected by the sensitivity analysis since it only focuses on materials used as an energy source.

Table 3-57. Summary of top contributors to CRT impacts by impact category

Impact category	Top contributors			
	Life-cycle stage	Process group	Material	Contribution to impact score
Renewable resource use	Manufacturing	LPG production	water	79%
Nonrenewable resource use	Manufacturing	LPG production	Petroleum (in ground)	56%
Energy use	Manufacturing	CRT glass/frit mfg.	Liquefied petroleum gas	72%
Solid waste landfill use	Use	U.S. electric grid	Coal waste	38%
Hazardous waste landfill use	End-of-life	CRT landfilling	EOL CRT monitor, landfilled	91%
Radioactive waste landfill use	Use	U.S. electric grid	Low-level radioactive waste	61%
Global warming	Use	U.S. electric grid	Carbon dioxide	64%
Ozone depletion	Use	U.S. electric grid	Bromomethane	49%
Photochemical smog	Manufacturing	LPG production	Hydrocarbons, unspeciated	36%
Acidification	Use	U.S. electric grid	Sulfur dioxide	47%
Air particulates	Manufacturing	LPG production	PM	43%
Water eutrophication	Manufacturing	LPG production	COD	72%
Water quality, BOD	Manufacturing	LPG production	BOD	96%
Water quality, TSS	Manufacturing	LPG production	Suspended solids	97%
Radioactivity	Materials Processing	Steel production, cold-rolled, semi-finished	Plutonium-241 (isotope)	62%
Chronic health effects, occupational	Manufacturing	CRT glass/frit manufacturing	Liquefied petroleum gas	78%
Chronic health effects, public	Use	U.S. electric grid	Sulfur dioxide	83%
Aesthetics (odor)	Manufacturing	LPG production	Hydrogen sulfide	94%
Aquatic toxicity	Manufacturing	CRT tube manufacturing	Phosphorus (yellow or white)	26%
Terrestrial toxicity	Use	U.S. electric grid	Sulfur dioxide	83%

Table 3-58. Summary of top contributors to LCD impacts by impact category

Impact category	Top contributors			
	Life-cycle stage	Process group	Material	Contribution to impact score
Renewable resource use	Manufacturing	LCD monitor/module mfg.	Water	38%
Nonrenewable resource use	Materials processing	Natural gas production	Natural gas (in ground)	65%
Energy use	Use	LCD monitor use	Electricity	30%
Solid waste landfill use	Use	U.S. electric grid	Coal waste	44%
Hazardous waste landfill use	End-of-life	LCD landfilling	EOL LCD monitor, landfilled	97%
Radioactive waste landfill use	Use	U.S. electric grid	Low-level radioactive waste	44%
Global warming	Manufacturing	LCD monitor/module mfg.	Sulfur hexafluoride	29%
Ozone depletion	Manufacturing	LCD panel components manufacturing	HCFC-225cb	34%
Photochemical smog	Materials processing	Natural gas production	Nonmethane hydrocarbons, unspeciated	45%
Acidification	Use	U.S. electric grid	Sulfur dioxide	31%
Air particulates	Materials processing	Steel production, cold-rolled, semi-finished	PM	45%
Water eutrophication	Manufacturing	LCD monitor/module mfg.	Nitrogen	67%
Water quality, BOD	Manufacturing	LCD monitor/module mfg.	BOD	61%
Water quality, TSS	Manufacturing	LPG production	Suspended solids	66%
Radioactivity	Materials processing	Steel production, cold-rolled, semi-finished	Plutonium-241 (isotope)	96%
Chronic health effects, occupational	Manufacturing	LCD monitor/module mfg.	Liquefied natural gas	58%
Chronic health effects, public	Use	U.S. electric grid	Sulfur dioxide	68%
Aesthetics (odor)	Manufacturing	LPG production	Hydrogen sulfide	94%
Aquatic toxicity	Manufacturing	LCD monitor/module mfg.	Phosphorus (yellow or white)	98%
Terrestrial toxicity	Use	U.S. electric grid	Sulfur dioxide	68%

3.4 SENSITIVITY ANALYSES

Due to assumptions and uncertainties in this LCA, as in any LCA, several sensitivity analyses of the baseline results were conducted. Section 2.7.3 described how areas for sensitivity analyses (scenarios) were selected, and the modifications made to the baseline inventory. Sections 3.4.1 through 3.4.4 recap these modifications and present sensitivity analysis results. Section 3.4.5 summarizes the effects of different scenarios on CRT and LCD impacts.

3.4.1 Manufactured Life Scenario

Due to the uncertainty and assumptions associated with the baseline use stage lifespan (effective life) scenario, a “manufactured life” scenario was also considered. Recall that the manufactured life is defined as the length of time a monitor is designed to operate effectively, while the effective life is defined as the actual amount of time a monitor is used, by one or multiple users, before it reaches its final disposition. The manufactured life is the number of hours a monitor would function as manufactured, and is independent of user choices or actions. Section 2.4.1.3 presented a detailed discussion of how the manufactured life was determined, and is summarized below.

The manufactured life of both monitor types was estimated using the mean-time-before-failure (MTBF) specifications of the monitor and its components. From review of MTBF information obtained on CRT-based monitors (see Appendix H, Attachment A, Table A2), it appears that the CRT tube itself is the component that 99% of the time determines whether the entire monitor has reached its end-of-life. Thus, an average of the two ranges obtained on the estimated lifetime of CRT tubes (10,000 and 15,000 hours) was used as the CRT manufactured lifetime (12,500 hours).

For active matrix LCDs, the components that have the greatest potential to fail first are the display panel itself (including the liquid crystals and thin-film transistors), backlights, driver integrated circuit (IC) tabs, and other smaller components. The backlights and driver IC tabs can be field-replaced, thus their failure does not necessarily represent the end of the monitor’s life. However, failure of the liquid crystals or transistors, which would require replacement of the display panel itself, would most likely mean that the monitor cannot be cost-effectively repaired. Thus, in this study, the amount of time an LCD monitor would operate during its manufactured life is assumed to be the average of the non field-replaceable values, or 45,000 hours. In order for a monitor to operate for 45,000 hours, any major field-replaceable parts that have MTBFs less than 45,000 hours are accounted for in the inventory. For example, assuming the backlights last on average 32,500 hours (the average of the values obtained for backlights), approximately 1.4 backlights on average would be needed for every panel during its 45,000 hour lifetime.

To calculate the manufactured life electricity consumption (kWh/life), the energy use rate (kW) was multiplied by the lifespan (hours/life) for each monitor in each power mode (see Table 2-20 in Section 2.4.1.3). The LCD manufactured life (45,000 hours) is 3.6 times greater than the CRT manufactured life (12,500 hours). In an LCA, comparisons are made based on functional equivalency. Therefore, if one monitor will operate for a longer period of time than another, impacts should be based on an equivalent use. Thus, based on equivalent use periods, 3.6 CRTs would need to be manufactured for every LCD. This was incorporated into the profile analysis for the manufactured life LCA. To apply the manufactured life scenario to the CRT and LCD

life-cycle profiles, the following modifications were made to the baseline (effective life) scenario:

- change the CRT electricity input in the use stage from 635 kWh (2,286 MJ) to 788 kWh (2,837 MJ); [3]
- change the LCD electricity input in the use stage from 237 kWh (853 MJ) to 1,035 kWh (3,726 MJ);
- increase the manufacturing of CRTs by a factor of 3.6 to account for the functional equivalency of CRTs and LCDs. This was done by increasing the functional unit by a factor of 3.6, which equates to manufacturing, using, and recycling or disposing of 3.6 times more CRTs than in the baseline case; and
- increase the manufacturing of the LCD backlight lamp by a factor of 1.4 to account for the functional equivalency of LCDs and CRTs. This was done by increasing the backlight lamp mass (0.0023 kg) by a factor of 1.4, which in turn results in an increase in inputs and outputs associated with manufacturing the backlilght.

Table 3-59 presents the CRT and LCD life-cycle results by impact category for the baseline and manufactured life scenarios. It also presents the percent change from the baseline to the manufactured life scenario for both monitor types. Note that the manufactured life results are most useful for evaluating the CRT and LCD together, not for comparing the CRT or LCD baseline (effective life) results to its manufactured life results. This is because the CRT and LCD manufactured life results are functionally equivalent, but the CRT to CRT and LCD to LCD effective life and manufactured life scenarios are not. The baseline for both monitor types represents impacts from manufacture and final disposition of one monitor. The CRT manufactured life scenario represents impacts from 3.6 CRT monitors and the LCD manufactured life scenario represents impacts from one LCD monitor and 1.4 backlights. However, the percent change figures are presented to better understand how the manufactured life scenario affects overall results.

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[3] This represents the electricity use for a 12,500 hour life span. This figure is then multiplied by a factor of 3.6 in the functional equivalency calculations (see third bullet, below).

Table 3-59. Baseline and sensitivity analysis results—manufactured life

		CRT			LCD		
Impact category	**Units/ Monitor**	**Baseline**	**Manu-factured**	**% change**	**Baseline**	**Manu-factured**	**% change**
Renewable resource use	kg	1.31e+04	4.83e+04	268%	2.80e+03	4.30e+03	53.5%
Nonrenewable resource use	kg	6.68e+02	2.58e+03	286%	3.64e+02	6.12e+02	68.0%
Energy use	MJ	2.08e+04	7.70e+04	270%	2.84e+03	5.71e+03	101%
Solid waste landfill use	m3	1.67e-01	6.86e-01	312%	5.43e-02	1.79e-01	230%
Hazardous waste landfill use	m3	1.68e-02	6.05e-02	260%	3.60e-03	3.60e-03	0.00%
Radioactive waste landfill use	m3	2.00e-04	8.00e-04	328%	1.00e-04	3.00e-04	194%
Global warming	kg-CO2 eq.s	6.95e+02	2.90e+03	317%	5.93e+02	1.17e+03	97.3%
Ozone depletion	kg-CFC-11 eq.s	2.05e-05	8.27e-05	304%	1.37e-05	2.66e-05	94.1%
Photochemical smog	kg-ethene eq.s	1.71e-01	6.20e-01	262%	1.41e-01	1.47e-01	4.22%
Acidification	kg-SO2 eq.s	5.25e+00	2.19e+01	317%	2.96e+00	7.29e+00	146%
Air particulates	kg	3.01e-01	1.13e+00	277%	1.15e-01	1.87e-01	63.4%
Water eutrophication	kg-phosphate eq.s	4.82e-02	**1.74e-01**[a]	260%	4.96e-02	4.96e-02	0.02%
BOD	kg	1.95e-01	7.02e-01	260%	2.83e-02	2.83e-02	0.02%
TSS	kg	8.75e-01	3.15e+00	260%	6.15e-02	6.15e-02	0.02%
Radioactivity	Bq	3.85e+07	1.14e+08	197%	1.22e+07	1.28e+07	4.49%
Chronic health effects, occupational	tox-kg	9.34e+02	3.39e+03	263%	6.96e+02	7.41e+02	6.47%
Chronic health effects, public	tox-kg	1.98e+03	8.56e+03	333%	9.02e+02	2.98e+03	230%
Aesthetics (odor)	m3	7.58e+06	2.74e+07	262%	5.04e+06	5.30e+06	5.00%
Aquatic toxicity	tox-kg	2.25e-01	8.10e-01	260%	5.19e+00	5.19e+00	0.02%
Terrestrial toxicity	tox-kg	1.97e+03	8.54e+03	333%	8.94e+02	2.97e+03	232%

[a] Bold indicates impact category indicator that reversed direction from the baseline scenario such that the CRT indicator is now greater than the LCD.

As shown in Table 3-59, under the manufactured life scenario CRT impacts exceed those of the LCD in every impact category except aquatic toxicity. CRT impacts were expected to be greater than those of the LCD in most impact categories for the following reasons:

- Under the baseline scenario CRT impacts exceeded those of the LCD in every category but water eutrophication and aquatic toxicity.
- The manufactured life scenario assumes more CRTs are manufactured than LCDs during the manufactured life lifespan, which results in greater impacts.
- The manufactured life use stage is longer than the baseline, effective life use stage, and the CRT consumes more electricity during use than the LCD.

By looking at the percent change in impact scores from the baseline to manufactured life for a monitor type we can better understand which aspect of the life-cycle is driving impacts. For example, CRT impacts increased by roughly 260% in several impact categories, which is the increase from manufacturing or disposing of an additional 2.6 monitors. Energy impacts increased by more than 260% due to the additional increase in electricity consumption during use. The CRT chronic public human health effects category increased by some 330%. This is explained by the increase in SO_2 emissions in the use stage and the high HV for SO_2, which has a proportionately greater effect on overall impacts than increased outputs of other pollutants with lower HVs in other life-cycle stages.

LCD impacts increased only slightly from the baseline to the manufactured life scenario in some impact categories, but increased up to 230% in others. Most of the LCD impact categories with less than one percent increase are for impacts related to water discharges (e.g., water eutrophication, aquatic toxicity, etc.). This is because the most significant change to the LCD inventory from the baseline to the manufactured life scenario was in the use stage, and few water discharges are reported in the U.S. electric grid inventory. On the other hand, the chronic public health effects and terrestrial toxicity impact categories show the greatest increase. These results are driven by air emissions of SO_2 from U.S. power production, which increased significantly with the longer lifespan.

To further illustrate how the longer lifespan (and additional manufacturing requirements, mainly for the CRT) in the manufactured life scenario is affecting impacts, Figures 3-24 and 3-25 compare the energy impacts and public chronic health effects, respectively, of both monitor types under the baseline and manufactured life scenarios. As shown in Figure 3-24, CRT energy impacts are still dominated by the manufacturing stage in the manufactured life scenario. This is mainly due to the large amount of LPG used to manufacture 3.6 sets of CRT glass. On the other hand, LCD energy impacts during the use stage exceeded those in manufacturing by a factor of about 2.6 in the baseline scenario, but are ten times greater in the manufactured life scenario. This is due to the longer lifespan for a single LCD in the manufactured life scenario.

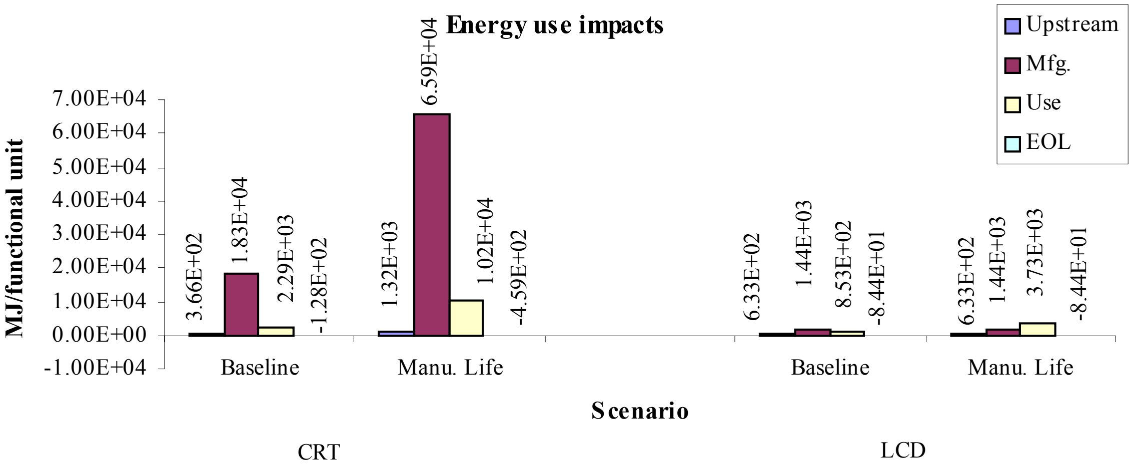

Figure 3-24. Energy use: baseline and manufactured life sensitivity results

Figure 3-25 shows that CRT chronic public health impacts are similarly distributed in the baseline and manufactured life scenarios. However, a greater percentage of LCD chronic health impacts are in the use stage under the manufactured life scenario than the baseline due to the longer use stage.

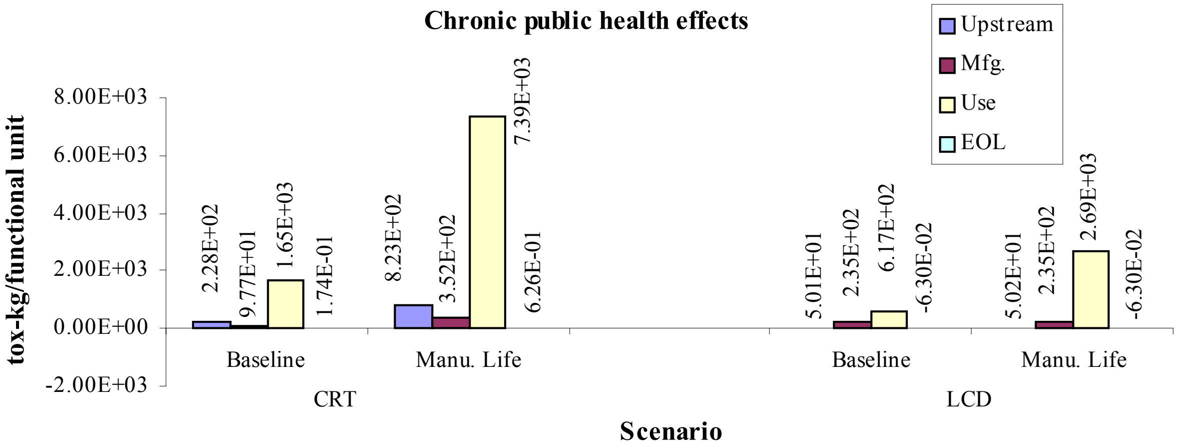

Figure 3-25. Chronic public health effects: baseline and manufactured life sensitivity results

3.4.2 Modified Glass Energy Scenario

One area of relatively large uncertainty and variability in the primary data supplied for the project was the glass manufacturing data. Both the CRT and LCD glass data were based on data supplied by CRT lead oxide (PbO) glass manufacturers, since no LCD glass manufacturers were willing to provide data to the project. To represent an LCD glass inventory, lead (Pb) materials in the CRT glass inventory were removed. Based on conversations with industry members, it was assumed that the same amount of energy per kilogram of glass produced is used to generate LCD and CRT glass. In addition, large variability among the three data sets collected resulted in a large degree of uncertainty in the glass inventory. Finally, a number of the CRT impact category results are being driven by the glass energy data or by the production process for producing the large amount of LPG used as a fuel in glass manufacturing. Consequently, the glass manufacturing inventories for both LCD and CRT glass were modified and life-cycle impacts were recalculated.

To conduct the sensitivity analysis, the energy input data for glass manufacturing were modified by removing, from the average, data that appeared unusually large, and that might be inconsistent with general industry statistics. However, industry statistics are greatly lacking when specifically considering specialty glasses such as CRT and LCD glass. Modifying the energy inputs greatly reduced the fuel energy amounts reported for the glass production process.

The baseline scenario, based on averaged primary data from manufacturers, assumed that the total energy to produce a kilogram of CRT or LCD glass was 1,560 MJ (433 kWh) of energy, with only 0.3% of that as electrical energy. The sensitivity analysis scenario assumes 16.3 MJ (4.5 kWh) per kilogram of glass produced, with approximately 30% as electrical energy. The majority of the fuel energy in the baseline scenario was from LPG. The actual input amounts are not presented here to protect the confidentiality of data provided by glass manufacturers.

Under the sensitivity (modified glass energy) scenario, only the manufacturing stage is affected, since the production of the fuels used during manufacturing is included in the manufacturing life-cycle stage. All impact categories, not only energy, are also affected because the inputs and outputs from fuel production and electricity generation processes affect each of the impact categories evaluated in this study.

Table 3-60 shows the baseline impact results and the revised impact results based on the modified glass energy inputs. The overall life-cycle impact results are highly sensitive to the energy consumption values from glass manufacturing. Under the modified glass energy scenario, the nonrenewable resource use, global warming, photochemical smog, BOD, TSS, chronic occupational health effects, and odor impact categories reversed direction such that the LCD had greater impacts within each impact category than the CRT in the overall life cycle. Note that the percent change in CRT results in most impact categories is much greater than that of the corresponding LCD results. This is because the CRT uses approximately ten times more glass than the LCD and therefore, the CRT results are much more sensitive to the glass manufacturing data than are the LCD results.

Table 3-60. Baseline and sensitivity analysis results—modified glass energy

		CRT			LCD		
Impact category	**Units/Monitor**	**Baseline**	**Glass energy**	**% change**	**Baseline**	**Glass energy[a]**	**% change**
Renewable resource use	kg	1.31e+04	2.67e+03	-79.6%	2.80e+03	2.43e+03	-13.4%
Nonrenewable resource use	kg	6.68e+02	2.35e+02	-64.8%	3.64e+02	**3.49e+02**	-4.14%
Energy use	MJ	2.08e+04	3.02e+03	-85.5%	2.84e+03	2.04e+03	-28.0%
Solid waste landfill use	m3	1.67e-01	1.23e-01	-26.0%	5.43e-02	5.27e-02	-2.82%
Hazardous waste landfill use	m3	1.68e-02	1.54e-02	-8.13%	3.60e-03	3.60e-03	-1.35%
Radioactive waste landfill use	m3	2.00e-04	2.00e-04	0.12%	1.00e-04	1.00e-04	0.01%
Global warming	kg-CO2 eq.s	6.95e+02	5.23e+02	-24.8%	5.93e+02	**5.87e+02**	-1.01%
Ozone depletion[b]	kg-CFC-11 eq.s	2.05e-05	1.97e-05	-3.75%	1.37e-05	1.37e-05	-0.18%
Photochemical smog	kg-ethene eq.s	1.71e-01	5.59e-02	-67.3%	1.41e-01	**1.37e-01**	-2.84%
Acidification	kg-SO2 eq.s	5.25e+00	4.02e+00	-23.4%	2.96e+00	2.92e+00	-1.45%
Air particulates	kg	3.01e-01	1.72e-01	-42.9%	1.15e-01	1.10e-01	-3.97%
Water eutrophication	kg-phosphate eq.s	4.82e-02	4.10e-03	-91.5%	4.96e-02	4.80e-02	-3.17%
BOD	kg	1.95e-01	7.00e-03	-96.4%	2.83e-02	**2.16e-02**	-23.8%
TSS	kg	8.75e-01	2.06e-02	-97.6%	6.15e-02	**3.09e-02**	-49.7%
Radioactivity	Bq	3.85e+07	3.16e+07	-17.9%	1.22e+07	1.22e+07	0.00%
Chronic health effects, public	tox-kg	1.98e+03	1.97e+03	-0.56%	9.02e+02	9.01e+02	-0.02%
Chronic health effects, occupational	tox-kg	9.34e+02	2.30e+02	-75.4%	6.96e+02	**6.63e+02**	-4.74%
Aesthetics (odor)	m3	7.58e+06	1.09e+04	-99.9%	5.04e+06	**4.79e+06**	-4.99%
Aquatic toxicity	tox-kg	2.25e-01	2.18e-01	-3.07%	5.19e+00	5.19e+00	0.01%
Terrestrial toxicity	tox-kg	1.97e+03	1.97e+03	-0.42%	8.94e+02	8.94e+02	-0.01%

[a] Bold indicates impact category indicator that reversed direction from the baseline scenario such that the LCD indicator is now greater than the CRT.

[b] LCD impacts in this category are greater than CRT impacts when phased out substances are removed from the inventories (see Section 3.3.6).

The energy impacts for the baseline and modified glass energy scenarios are presented in Figure 3-26. In the baseline scenario, over 18,000 MJ of energy were consumed per CRT monitor during manufacturing. Almost 83% of this was from the glass/frit process group, mainly from glass manufacturing energy alone. When the glass energy inputs are reduced under the modified scenario, total energy use in the CRT manufacturing stage decreases some 97% to just under 500 MJ, and the use stage dominates the overall life-cycle energy impacts at approximately 2,300 MJ per functional unit (i.e., per monitor). The 97% decrease in manufacturing stage energy use is due to the reduced glass manufacturing fuel inputs and the consequent reduction in energy inputs to the fuel production process.

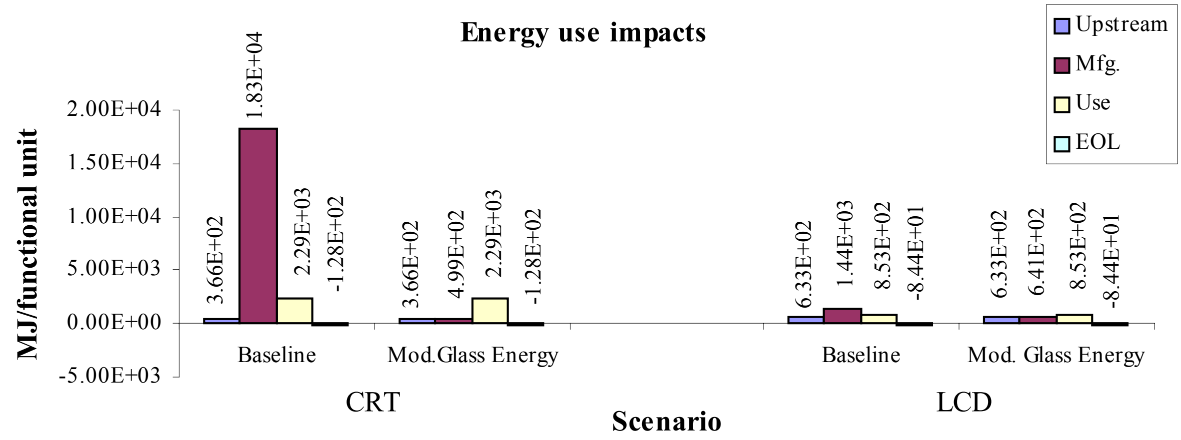

Figure 3-26. Energy impacts: baseline and modified glass energy sensitivity results

The modified glass energy scenario has a lesser, but still significant, effect on the distribution of LCD energy impacts across life-cycle stages. Under the sensitivity scenario, the LCD manufacturing stage energy consumption is reduced 55% from 1,440 MJ per monitor to about 640 MJ per monitor, and the use stage becomes the biggest energy consumer at about 850 MJ per monitor.

Global warming is one of the impact categories in which the CRT has the greater impacts than the LCD under the baseline scenario, but the LCD has the greater impacts under the sensitivity analysis. Figure 3-27 shows the global warming impacts for both monitor types under the baseline and modified glass energy scenarios. Under the latter scenario, CRT global warming impacts in the manufacturing stage are reduced some 85%, but LCD impacts are only reduced 2.5%. Again, this illustrates the greater sensitivity of CRT impact results to glass energy inputs. Also, as discussed in Section 3.3.5, a large part of LCD global warming impacts are driven by sulfur hexafluoride emissions from LCD monitor/module manufacturing, which are unaffected by the revised glass energy scenario.

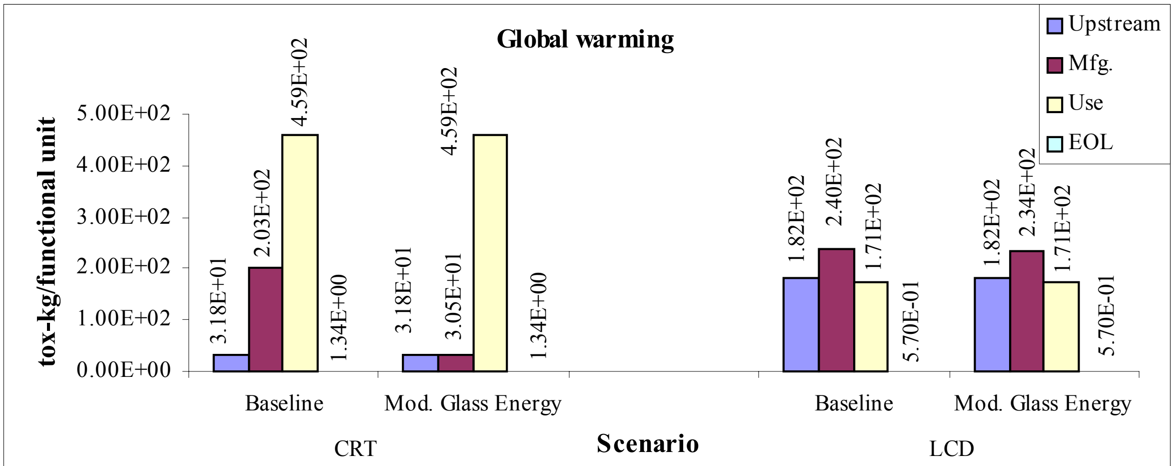

Figure 3-27. Global warming: baseline and modified glass energy sensitivity results

3.4.3 Modified LCD Module Energy Scenario

LCD monitor/module manufacturing energy was another area of relatively large uncertainty and variability in the inventory data. As discussed in Section 2.7.3.3, total energy inputs reported in six data sets received from LCD monitor/module manufacturers in Japan and Korea ranged from 330 MJ to 7,310 MJ, with a mean and standard deviation of 2,269 MJ and 2,906 MJ, respectively. The manufacturing energy data reported in two of the data sets were found to be outliers and removed from the averages used in the baseline inventory. However, for this sensitivity analysis, the outliers were added back in to the averages. Thus, to apply the modified LCD manufacturing energy scenario to the LCD profile, the following modifications were made to electricity and fuels:

- changed the electric energy inputs to the LCD monitor/module manufacturing process group from 82.1 kWh (253 MJ) per monitor to 70.1 kWh (217 MJ) per monitor,
- changed the fuel oil # 4 inputs from 0.25 kg to 0.30 kg per monitor,
- changed the kerosene inputs from 0.35 kg to 0.23 kg per monitor,
- changed the LPG inputs from 0.68 kg to 0.45 kg per monitor,
- changed the LNG inputs from 3.8 kg to 45 kg per monitor, and
- changed the natural gas inputs from 0.99 to 0.70 kg per monitor.

Note that one LCD monitor/module manufacturer also reported using a large amount of LNG as an ancillary material. However, this input amount is not affected by the sensitivity analysis, which only deals with inputs used as an energy source.

Table 3-61 presents the baseline impact results and the revised LCD impact results based on the modified LCD module energy scenario. It also shows the baseline CRT results. Under the modified LCD energy scenario, LCD impacts in ten categories actually decrease slightly, due to the slight decrease in average electrical energy consumed during LCD monitor/module manufacturing. However, impacts in six categories increase slightly, and impacts in four categories (nonrenewable resource use, energy use, photochemical smog and chronic occupational health effects) increase by more than 10%. As expected, life-cycle energy impacts are the most affected by this sensitivity analysis, due to the increased fuel consumption during manufacturing. However, under this scenario, none of the impact category results reversed direction from the baseline such that the LCD now has greater impacts than the CRT or vice versa, where the baseline LCD impacts were greater than the CRT.

Table 3-61. Baseline and sensitivity analysis results—LCD modified module energy

Impact category	Units/Monitor	CRT	LCD		
		Baseline	Baseline	Mod. energy	% change
Renewable resource use	kg	1.31e+04	2.80e+03	2.78e+03	-0.69%
Nonrenewable resource use	kg	6.68e+02	3.64e+02	4.06e+02	11.4%
Energy use	MJ	2.08e+04	2.84e+03	4.68e+03	64.9%
Solid waste landfill use	m3	1.67e-01	5.43e-02	5.47e-02	0.74%
Hazardous waste landfill use	m3	1.68e-02	3.60e-03	3.60e-03	-0.01%
Radioactive waste landfill use	m3	2.00e-04	1.00e-04	1.00e-04	-3.88%
Global warming	kg-CO2 eq.s	6.95e+02	5.93e+02	6.17e+02	4.05%
Ozone depletion[a]	kg-CFC-11 eq.s	2.05e-05	1.37e-05	1.37e-05	-0.26%
Photochemical smog	kg-ethene eq.s	1.71e-01	1.41e-01	1.61e-01	13.7%
Acidification	kg-SO2 eq.s	5.25e+00	2.96e+00	3.00e+00	1.48%
Air particulates	kg	3.01e-01	1.15e-01	1.19e-01	3.85%
Water eutrophication	kg-phosphate eq.s	4.82e-02	4.96e-02	4.96e-02	0.00%
BOD	kg	1.95e-01	2.83e-02	2.83e-02	-0.12%
TSS	kg	8.75e-01	6.15e-02	6.13e-02	-0.30%
Radioactivity	Bq	3.85e+07	1.22e+07	1.22e+07	-0.09%
Chronic health effects, occupational	tox-kg	9.34e+02	6.96e+02	7.66e+02	10.1%
Chronic health effects, public	tox-kg	1.98e+03	9.02e+02	8.82e+02	-2.14%
Aesthetics (odor)	m3	7.58e+06	5.04e+06	5.04e+06	0.01%
Aquatic toxicity	tox-kg	2.25e-01	5.19e+00	5.19e+00	0.02%
Terrestrial toxicity	tox-kg	1.97e+03	8.94e+02	8.74e+02	-2.25%

[a] LCD impacts in this category are greater than CRT impacts when phased out substances are removed from the inventories (see Section 3.3.6).

Figure 3-28 presents the LCD baseline and sensitivity analysis results for the energy use impact category, the category with the greatest percent change from the baseline to the modified LCD module energy scenario. Under this scenario, LCD energy use impacts in the manufacturing stage increased almost 230% from 1,440 MJ per functional unit to 3,280 MJ per functional unit. However, total life-cycle energy use impacts increased only 65%. This sensitivity analysis did not affect consumption rates outside of the manufacturing stage.

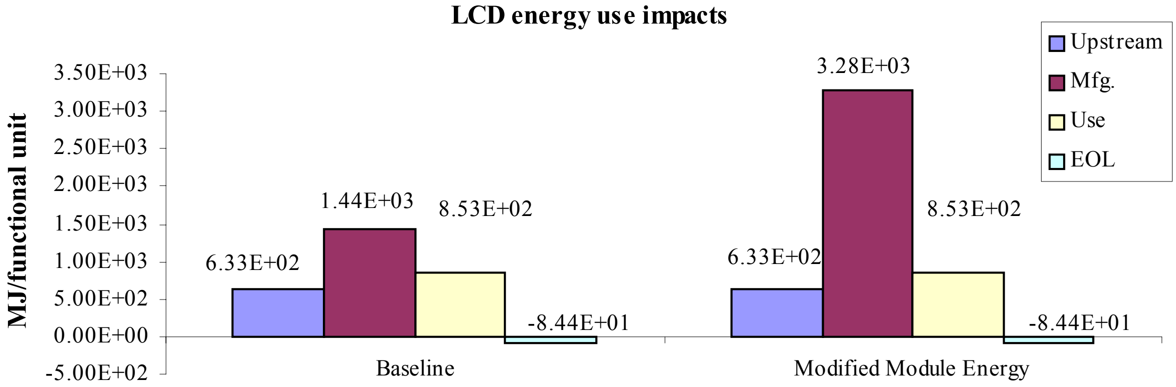

Figure 3-28. Energy use: LCD baseline and modified module energy sensitivity results

Figure 3-29 shows the effects of the sensitivity analysis on LCD chronic occupational health effects, another impact category with a relatively large percentage change. As shown in the figure, the manufacturing stage impact score in this category increased about ten percent, from 684 tox-kg per monitor to 755 tox-kg per monitor, due to the increase in fuel inputs. The chronic occupational health effect impacts were less sensitive than energy impacts because health effects results are calculated using a scoring approach that considers the inherent toxicity of a chemical instead of a simple loading approach (as is used for energy impacts). No toxicity data were available for LNG, the input with the greatest change in quantity. Therefore, the LNG HV is representative of a mean toxicity value.

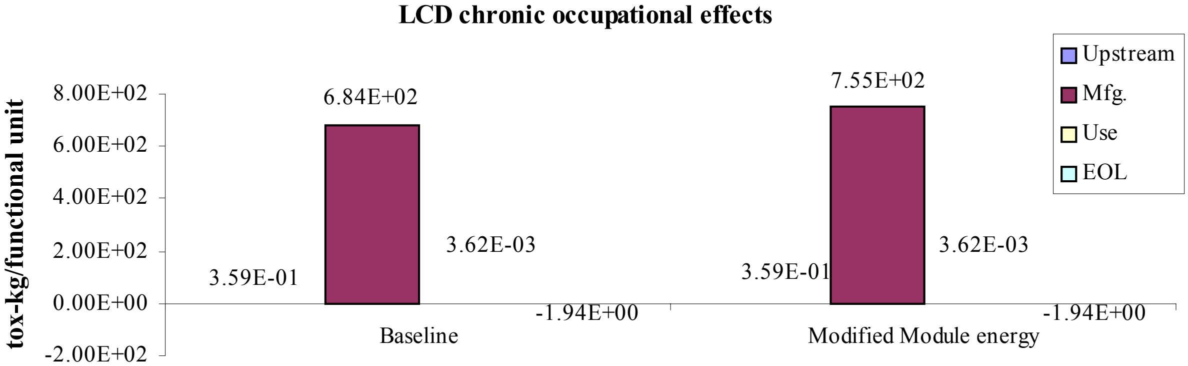

Figure 3-29. Chronic occupational effects: LCD baseline and modified module energy sensitivity results

3.4.4 Modified LCD EOL Dispositions Scenario

Finally, because very few desktop LCDs have reached their end of life, and usually only if they have been damaged in some way, very little is known about the EOL disposition of LCDs. In the baseline scenario it was assumed that a certain percent of EOL LCDs are incinerated, recycled, remanufactured, landfilled as solid waste, and landfilled as hazardous waste. (See Section 2.7.3 and Appendix I for an explanation of how EOL disposition percentages were determined.) To address uncertainties in the allocation of disposition percentages, this sensitivity analysis qualitatively evaluates a different set of final disposition numbers, as follows:

- change percent recycled from 15% to 0%,
- change percent remanufactured from 15% to 40%,
- change percent landfilled (solid waste) from 50% to 40%.
- do not change fraction incinerated (15%) or fraction sent to a hazardous waste landfill (5%).

Thus, under the modified EOL disposition scenario, recycling and solid waste landfilling impacts would decrease, remanufacturing impacts would increase, and incineration and hazardous waste landfilling impacts would not change. However, in attempts made to obtain remanufacturing data, it was found that remanufacturing processes spanned a wide range of activities, from as little as replacing button tops to as extensive as testing and replacing PWBs or transformers. Given the broad range of possibilities, and because few desktop LCDs have reached their end of life, no single set of operations could be identified to adequately represent remanufacturing activities that could be incorporated in our model. Remanufacturing data were, therefore, excluded from the assessment.

As shown in the baseline LCIA results (Section 3.3), LCD EOL dispositions have little effect on overall life-cycle impacts under the baseline scenario. In fact, the only impact categories in which an EOL process was a top contributor to overall impacts were the hazardous waste landfill use impact category, where the portion of a monitor landfilled contributed 97% of impacts, and the solid waste landfill use category, where the portion of a monitor landfilled contributed 3.5% of impacts. As noted above, hazardous waste landfill use impacts would not change under the modified LCD EOL dispositions scenario, but solid waste landfill impacts would be expected to decrease slightly. In a preliminary quantitative analysis of this scenario, LCD life-cycle solid waste landfill impacts were found to decrease less than one percent, and life-cycle impacts in other impact categories decreased less than 0.1%. Thus, the modified LCD EOL dispositions scenario would have only a minor effect on LCD life-cycle impacts and would not change comparative CRT and LCD results.

3.4.5 Summary of CRT and LCD Sensitivity Analysis Results

The results of the sensitivity analyses are useful to manufacturers who want to understand how uncertainty in the inventory affects impacts. This information can be used to identify areas for additional study or potential improvement opportunities. As discussed in Sections 3.4.1 through 3.4.2, it appears that CRT life-cycle impacts are highly sensitive to the glass energy data, and less sensitive to the lifespan assumptions (lifespan assumptions greatly affect the magnitude of CRT life-cycle impacts, but they do not greatly affect the distribution of impacts among life-cycle stage). LCD impacts are less sensitive to the glass energy data and in fact are not greatly affected by any of the sensitivity analysis scenarios, except the longer lifespan under the manufactured life scenario.

Sensitivity results are also useful to interested members of the public who may be evaluating the relative impacts of different monitor types and are interested in whether the CRT or LCD has greater life-cycle impacts in any given impact category. Table 3-62 presents the monitor type with greatest impacts by impact category and by scenario. This information helps us determine whether major assumptions (e.g., the monitor lifespan and LCD EOL distribution assumptions) or uncertain data (e.g., glass energy data and LCD monitor manufacturing energy) are driving results. As shown in the table, the modified glass energy scenario is the only scenario that significantly changes the results from the baseline CRT and LCD comparative results. Under this scenario, life-cycle impact results in seven categories reverse direction from the baseline assessment, such that the LCD has greater impacts than the CRT. Therefore, under this scenario, a total of nine out of 20 categories are greater for the LCD than the CRT, compared to two out of 20 categories under the baseline scenario. The only other scenario that affects these results is the manufactured life scenario, when impacts in the water eutrophication category are greater for the CRT than the LCD.

Table 3-62. Summary of CRT and LCD LCIA results

Impact category	Monitor type with greatest impacts by scenario				
	Baseline	Manu-factured life	Modified glass energy	Modified LCD module energy	Modifed LCD EOL distribution[a]
Renewable resource use	CRT	CRT	CRT	CRT	CRT
Nonrenewable resource use	CRT	CRT	LCD	CRT	CRT
Energy use	CRT	CRT	CRT	CRT	CRT
SW landfill use	CRT	CRT	CRT	CRT	CRT
HW landfill use	CRT	CRT	CRT	CRT	CRT
RW landfill use	CRT	CRT	CRT	CRT	CRT
Global warming	CRT	CRT	LCD	CRT	CRT
Ozone depletion [b]		[b] [b]	[b] [b]		
Photochemical smog	CRT	CRT	LCD	CRT	CRT
Acidification	CRT	CRT	CRT	CRT	CRT
Air particulates	CRT	CRT	CRT	CRT	CRT
Water eutrophication	LCD	CRT	LCD	LCD	LCD
Water quality, BOD	CRT	CRT	LCD	CRT	CRT
Water quality, TSS	CRT	CRT	LCD	CRT	CRT
Radioactivity	CRT	CRT	CRT	CRT	CRT
Chronic health effects, occupational	CRT	CRT	LCD	CRT	CRT
Chronic health effects, public	CRT	CRT	CRT	CRT	CRT
Aesthetics (odor)	CRT	CRT	LCD	CRT	CRT

Table 3-62. Summary of CRT and LCD LCIA results

Impact category	**Monitor type with greatest impacts by scenario**				
	Baseline	**Manu-factured life**	**Modified glass energy**	**Modified LCD module energy**	**Modifed LCD EOL distribution**[a]
Aquatic toxicity	LCD	LCD	LCD	LCD	LCD
Terrestrial toxicity	CRT	CRT	CRT	CRT	CRT

[a] Based on a qualitative evaluation, not quantitative results.

[b] CRT impacts are greater than LCD impacts in this category when all data are included in the inventories, including data for substances that have been phased out. However, LCD impacts are greater than CRT impacts when phased out substances are removed from the inventories (see Section 3.3.6).

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Chapter 4

QUALITATIVE RISK SCREENING OF SELECTED MATERIALS

The scope of the DfE CDP, as presented in Chapter 1, was to first conduct an environmental life-cycle assessment (LCA) to evaluate a generic 17" CRT and 15" LCD desktop computer display, followed by a streamlined Cleaner Technologies Substitutes Assessment (CTSA), which would target specific materials or processes that warrant further evaluation. Traditionally, the DfE Program has conducted CTSAs that perform detailed risk characterizations of alternative chemical processes. The streamlined CTSA for the CDP takes a more detailed look than the LCA at the toxic effects of chemicals used in a process, without conducting a complete risk characterization typical of past CTSAs.

In order to provide meaningful and timely results, the CDP Core group agreed to select a few materials that are of interest to EPA and industry and conduct analyses concurrently with the LCA, instead of conducting a CTSA on selected materials or processes after the LCA results were presented. The LCA identifies material inputs and outputs and then characterizes them in a life-cycle impact assessment (LCIA). In the human and environmental health effects impact categories, these input and output amounts are used as surrogates for exposure. For the selected materials, the additional CTSA-related analyses are intended to better understand the potential exposures to selected materials, during any processes that use thee materials, in order to try to better understand potential chemical risks.

The materials that were selected for further analysis were lead, mercury, and liquid crystals. The justification for choosing these materials, and a brief description of the scope are provided below:

- **Lead**: Lead is a top priority toxic material at the U.S. EPA. Lead is found in glass components of CRTs, as well as in electronics components (printed wiring boards and their components) of both CRTs and LCDs. The electronics industry is also concerned with lead and continues to take steps to reduce the use of lead in electronics products. Lead has been extensively studied for its toxic effects and has been addressed elsewhere with regard to CRTs and electronics (ATSDR, 1999). Therefore, within the scope of the CDP, lead is recognized as a material of concern, but extensive evaluation beyond the LCA is not conducted. Some discussion of the potential for exposure is included in this chapter, but it references existing studies for further information.
- **Mercury**: Another top priority toxic material at the U.S. EPA is mercury. The fluorescent tubes that provide the source of light in the LCD contain mercury. Although very small amounts of mercury are found in the LCD backlights, EPA's concern with mercury and the potential for exposure during manufacturing and end-of-life processes are reasons why a more detailed analysis of mercury is warranted in the CDP. In addition, mercury is emitted from some fuel combustion processes, such as coal-fired electricity generation processes, and there is interest in the relative magnitude of mercury emissions from these sources as compared to the magnitude of mercury emissions from its intentional use in LCD backlights. Another reason for including mercury is to begin to do an improvement assessment, because there appear to be potential alternatives to backlights with mercury.

- **Liquid crystals**: The toxicity of the liquid crystals in LCDs has been alluded to in the literature and there is a need to better understand the toxicity of these materials as well as provide the appropriate context of potential exposure and any associated risk. For example, during normal use of a display, no exposure would be expected. Liquid crystals are generally organic materials in broad categories such as polycyclic aromatic hydrocarbons (e.g., phenylcyclohexanes, biphenyls) (EIAJ, 1996). By including liquid crystals in a more detailed analysis, this chapter attempts to better characterize any potential hazard and/or potential exposure of liquid crystals from the manufacturing, use, and disposal of LCD monitors.

Choosing these three materials as a priority does not presume that these are the only materials of importance and worthy of additional analyses. The results of the LCI and LCIA in Chapters 2 and 3 provide more information on where to focus additional analysis efforts or improvements. Chapter 5 also identifies some potential improvement opportunities.

Sections 4.1 through 4.3 present the qualitative risk screening of lead, mercury, and liquid crystals, respectively. Subsections in each section briefly describe the following:

- *The use of the materials in computer displays:* These subsections describe how the materials are used in computer displays and give information on the mass used in particular applications.
- *Life-cycle inputs and outputs of the materials from computer displays:* The life-cycle assessment approach not only focuses on the material contained within the product, but also emphasizes the environmental impacts of material inputs and outputs from every life-cycle stage. These subsections summarize the life-cycle inputs and outputs of the materials found in the CDP life-cycle inventories (LCIs).
- *Life-cycle impacts associated with the material inputs and outputs:* As discussed in Chapter 3, life-cycle impact assessment (LCIA) is a screening-level evaluation of potential impacts to any system (e.g., the environment) as a result of some action (e.g., a chemical release). In the LCIA, life-cycle inventory data were classified into various impact categories (e.g., greenhouse gases or ozone depletion) based on the characteristics of the inventory item. Characterization methods were then used to quantify the magnitude of the contribution the emission or consumption of the inventory item could have in producing the associated impact. The result is expressed as an impact score which has been calculated using specific impact assessment tools. These subsections summarize the CDP LCIA results for lead, mercury, and liquid crystal inputs and outputs.
- *Potential exposures to the material including occupational, public, and ecological exposures:* Toxic materials may pose a threat to human health anytime there is the potential for human exposure throughout the life cycle of a computer display. Exposure occurs anytime a chemical or physical agent comes into contact with an organism, be it human or ecological. The magnitude of exposure depends on the concentration of the chemical at the contact point, and the duration and frequency of the exposure. The concentration of the chemical at the contact point is influenced by several factors, including the type, quantity, and disposition (e.g., airborne, surface water) of the initial release, and the subsequent environmental fate of the chemical (the ultimate disposition of the chemical as it is transported through the environment). Note that exposure is often defined in terms of exposure pathways. An exposure pathway describes the route a

contaminant travels from its source to an individual. A complete exposure pathway consists of the source and mechanism of release, transport medium, point of potential human contact, and the exposure route (e.g., inhalation, ingestion, dermal contact). These subsections focus on identifying potential exposures for three groups: workers in facilities using the chemicals (occupational exposures), the general public, who may be exposed to releases of the chemicals into the ambient environment, and ecological populations. While a quantitative exposure assessment is beyond the scope of this study, a qualitative discussion of potential pathways of exposure is presented for each of the groups listed above.

- *Potential human health effects:* Human health effects can include acute effects from short-term exposure, as well as chronic effects from repeated, long-term exposure. To be consistent with the scope of the LCIA, these subsections focus on chronic effects, including noncancer and cancer effects, unless no chronic toxicity data are available.
- *U.S. environmental regulations for the material:* These subsections briefly summarize U.S. environmental regulations that may affect facilities that manufacture materials for the computer display or are otherwise affected by the life cycle of computer displays (e.g., disposal facilities). They do not summarize environmental regulations from other countries where displays or display components are manufactured, which may differ significantly from U.S. regulations.
- *Alternatives to reduce the use of the material in computer displays:* These subsections identify alternatives that can substitute for a material, or, in some cases, source reduction methods to reduce the use of a material. The discussion of alternatives presented here is not a rigorous evaluation of their performance, cost, and environmental attributes, but rather a summary of the current knowledge base that may be useful for manufacturers seeking to identify improvement opportunities.

In Section 4.4, summary information and conclusions are presented.

4.1 LEAD

Lead and/or lead compounds are present in both CRTs and LCDs. Because lead and lead-containing compounds have long been known to pose a threat to both human health and the environment, this section presents a more detailed look at the use of lead in computer displays and its effects on human health and the environment.

4.1.1 Lead in Computer Displays

Lead is a significant material in current CRTs, accounting for up to 8% of the overall composition of the CRT by weight (Menad, 1999), with a 17" monitor containing as much as 1.12 kg of lead (Monchamp *et. al.*, 2001). Lead is used in several parts of the CRT monitor, including the funnel and neck glass, the sealing frit, as solder on printed wiring boards (PWBs) within the monitor, and sometimes in the front panel glass of the CRT. Lead is not as prevalent in LCDs, only being found on PWBs.

Lead, in the form of lead oxide, lines the inner surface of both the neck and funnel glass of the CRT, or may in some cases be contained within the glass itself. The lead oxide layer acts as a shield, protecting users from x-ray emissions given off by the electron gun. The lead oxide layer can comprise as much as 28% by weight of the funnel (Lee *et al.*, 2000) and 32% of the neck (Menad, 1999).

The sealing frit, which is used to make a vacuum-tight connection between the funnel and the front panel, is comprised of as much as 80% lead oxide (Busio and Steigelmann, 2000). The lead oxide is mixed with boric oxide and zinc oxide, along with several other compounds, into a paste. The glass frit paste is applied as a bead around the top of edge of the funnel and allowed to dry. The front panel is then attached to the funnel and fired using a belt furnace for 30 to 60 minutes at typical temperatures of 450°C (Busio and Steigelmann, 2000). The lead, boric, and zinc oxides devitrify to form large crystals which give strength to the frit seal (Techneglas, 2001). Recent research has been directed at either reducing the lead content of the frit or reducing the energy required to fuse the frit.

Printed wiring boards found in both LCDs and CRTs primarily use a lead-based solder as a surface finish and to attach electrical components to the circuit board. Solder is typically comprised of 37-40% lead. Depending on the type of component, parts can be applied using a solder paste which is subsequently melted, or by passing the boards over a wave of molten solder. Data collected for the life-cycle inventory indicates that a 17" monitor has approximately 51 grams of solder, or just under 19.8 grams of lead, while a 15" LCD panel contains nearly 22.4 grams of solder, or just about 8.5 grams of lead. Several lead-free solder alternatives are currently being tested and are in limited use. Solder is the only significant source of lead in LCDs.

The CRT panel glass itself may also contain a small percentage of lead oxide, typically ranging up to 4% by weight (Lee *et al.*, 2000). The lead acts as a stabilizer for the glass during its formation, and also serves to keep the glass from browning. Lead-free CRT panel glasses are currently being produced successfully.

A list of the lead-containing parts that make up a computer display, along with the quantity of lead and percentage of lead in each part, is presented in Table 4-1.

Table 4-1. Computer display parts that contain lead

Part	Display type	Quantity (Kg) [a]	% Lead content of part (by weight)
Funnel	CRT	0.91	22-28% [b, c]
Front panel	CRT	0.18	0-4 [b, c]
Neck	CRT	0.012	26-32 [b, c]
Frit	CRT	0.026	70-80 [b, c, d]
PWBs (total)	CRT	0.051	N/A
PWBs (total)	LCD	0.043	N/A

[a] Quantity of lead in a 17" monitor (Monchamp *et. al.*, 2001).
[b] Menad, 1999.
[c] Lee *et. al.*, 2000.
[d] Busio and Steigelmann, 2000.
N/A= Not applicable

4.1.2 Life-Cycle Inventory Inputs and Outputs of Lead for Computer Displays

Data on lead and lead-containing materials were collected and compiled as part of the life-cycle inventory. Material inputs containing lead included primary materials (e.g., lead-based solder) which end up as part of the product, as well as from ancillary materials (e.g., lead consumed during the production of steel used to make CRT parts) which are consumed as part of the manufacturing process or other supporting processes, such as energy production. The data were aggregated by material from individual processes and are presented by life-cycle stage for both CRTs and LCDs in Tables 4-2 and 4-3 below. More detailed material input data, which include the processes for each input and the quantity of lead released, are included in Appendix N.

Table 4-2. CRT lead-containing inputs by life-cycle stage

Life-cycle stage	Input	Quantity	Units	Type
Materials processing	Lead (Pb, ore)	6.50E-05	kg	Ancillary material
Materials processing	Lead (Pb, ore)	4.96E-01	kg	Primary material
Manufacturing	Frit	6.67E-02	kg	Primary material
Manufacturing	Lead	4.94E-01	kg	Primary material
Manufacturing	Printed wiring board (PWB)	8.47E-01	kg	Primary material
Manufacturing	Solder (63% tin; 37% lead)	5.08E-02	kg	Primary material
Manufacturing	Solder, unspecified - (CRT Assembly)	2.67E-02	kg	Primary material

Table 4-3. LCD lead-containing inputs by life-cycle stage

Life-cycle stage	Input	Quantity	Units	Type
Materials processing	Lead (Pb, ore)	2.47E-05	kg	Ancillary material
Manufacturing	Printed wiring board (PWB)	3.74E-01	kg	Primary material
Manufacturing	Solder (60% tin, 40% lead)	3.81E-02	kg	Primary material
Manufacturing	Solder (63% tin; 37% lead)	2.24E-02	kg	Primary material
Manufacturing	Solder, unspecified	7.35E-05	kg	Ancillary material

Material inputs can be raw materials such as lead ore, or output materials from a previous process or life-cycle stage. For example, small quantities of lead extracted from lead ore are sometimes used as additives in the production of several materials including ferrite, steel, and invar. Once extracted, lead is an input material to the manufacturing processes of several CRT components including CRT glass manufacturing and the manufacturing of the sealing frit paste, which then is an input for the CRT tube manufacturing process. Similarly, lead is used to produce solder which is then used to produce PWBs used in LCDs and CRTs.

Releases of lead and lead-based materials into the environment occur throughout the entire life cycle of the computer display. Environmental releases include airborne, waterborne, solid waste, and radioactive emissions of lead isotopes associated with nuclear fuel reprocessing. Similar to the inputs, emissions data were aggregated by the material released from individual processes and then reported by life-cycle stage. The lead or lead-based material released, the quantity of the release, the type of release (e.g., waterborne), and the ultimate disposition of the release all contribute to the environmental impacts.

The life-cycle outputs containing lead for both CRTs and LCDs are shown in Tables 4-4 and 4-5, respectively. More detailed data on lead and lead-based outputs for each process are presented in Appendix N.

Table 4-4. Life-cycle lead outputs to the environment from CRTs

Life-cycle stage	Output	Quantity	Units	Type	Disposition
Materials processing	Lead	1.66E-03	kg	Airborne	Air
Materials processing	Lead	2.29E-08	kg	Solid waste	Landfill
Materials processing	Lead compounds	1.59E-05	kg	Waterborne	Surface water
Materials processing	Lead-210 (isotope)	1.02E+00	Bq	Radioactivity	Air
Manufacturing	Broken CRT glass	1.88E-03	kg	Hazardous waste	Landfill
Manufacturing	Broken CRT glass	1.08E+00	kg	Solid waste	R/R
Manufacturing	Cinders from CRT glass mfg (70% PbO)	8.26E-03	kg	Hazardous waste	Landfill
Manufacturing	CRT glass faceplate EP dust (Pb) (D008 waste)	1.03E-03	kg	Hazardous waste	Landfill
Manufacturing	CRT glass funnel EP dust (Pb) (D008 waste)	5.01E-03	kg	Hazardous waste	R/R
Manufacturing	Frit	2.99E-03	kg	Hazardous waste	Landfill
Manufacturing	Hazardous sludge (Pb) (D008)	1.52E-03	kg	Hazardous waste	Landfill
Manufacturing	Lead	1.03E-06	kg	Waterborne	Treatment
Manufacturing	Lead	1.30E-05	kg	Airborne	Air
Manufacturing	Lead	4.64E-05	kg	Waterborne	Surface water
Manufacturing	Lead (Pb, ore)	4.41E-07	kg	Airborne	Air
Manufacturing	Lead compounds	1.62E-05	kg	Waterborne	Treatment
Manufacturing	Lead compounds	1.17E-09	kg	Waterborne	Surface water
Manufacturing	Lead contaminated grit (D008 waste)	3.46E-05	kg	Hazardous waste	Landfill
Manufacturing	Lead debris (D008 waste)	2.14E-04	kg	Hazardous waste	Landfill
Manufacturing	Lead sulfate cake	2.67E-05	kg	Hazardous waste	Landfill
Manufacturing	Printed wiring board (PWB)	3.70E-02	kg	Solid waste	R/R
Manufacturing	PWB-Solder dross	6.70E-02	kg	Hazardous waste	R/R
Manufacturing	Sludge from CRT glass mfg (1% PbO)	8.77E-04	kg	Hazardous waste	Landfill
Manufacturing	Waste batch (Ba, Pb) (D008 waste)	1.41E-03	kg	Hazardous waste	Landfill
Manufacturing	Waste finishing sludge (Pb) (D008 waste)	2.56E-04	kg	Hazardous waste	Landfill
Use	Lead	1.27E-05	kg	Airborne	Air
End-of-life	Lead	1.42E-05	kg	Airborne	Air
End-of-life	Lead compounds	1.60E-09	kg	Waterborne	Surface water
End-of-life	Printed wiring board (PWB)	1.46E-01	kg	Hazardous waste	R/R

R/R = recycling/reuse

Table 4-5. Life-cycle lead outputs to the environment from LCDs

Life-cycle stage	Outputs	Quantity	Units	Type	Disposition
Materials processing	Lead	3.13E-06	kg	Airborne	Air
Materials processing	Lead	5.42E-09	kg	Solid waste	Landfill
Materials processing	Lead compounds	3.68E-06	kg	Waterborne	Surface water
Materials processing	Lead-210 (isotope)	3.21E-01	Bq	Radioactivity	Air
Manufacturing	Lead	8.84E-06	kg	Airborne	Air
Manufacturing	Lead	8.33E-07	kg	Waterborne	Treatment
Manufacturing	Lead (Pb, ore)	1.48E-06	kg	Airborne	Air
Manufacturing	Lead compounds	5.67E-11	kg	Waterborne	Surface water
Manufacturing	Lead compounds	7.14E-06	kg	Waterborne	Treatment
Manufacturing	Printed wiring board (PWB)	7.50E-03	kg	Solid waste	Landfill
Manufacturing	PWB-Lead contaminated waste oil	5.14E-03	kg	Hazardous waste	Treatment
Manufacturing	PWB-Solder dross	2.96E-02	kg	Hazardous waste	Recycling/ reuse
Manufacturing	Waste batch (Ba, Pb) (D008 waste)	6.55E-05	kg	Hazardous waste	Landfill
Manufacturing	Waste CCFL, with lead	8.17E-08	kg	Hazardous waste	Treatment
Use	Lead	4.76E-06	kg	Airborne	Air
End-of-life	Lead	4.76E-06	kg	Airborne	Air
End-of-life	Lead compounds	4.98E-10	kg	Waterborne	Surface water

4.1.3 Computer Display Life-Cycle Impacts for Lead

The life-cycle impacts of lead, lead compounds, and materials containing lead (e.g., lead-based solder on printed wiring boards) calculated for CRTs and LCDs during the LCIA are summarized in Tables 4-6 and 4-7 respectively. Impact scores in the table are expressed in units specific to each impact category (see Chapter 3.1 for a discussion of impact category units and weighting). The total impact score for each category resulting from lead and lead-based materials is presented at the bottom of each table.

Table 4-6. Summary of Lead Impact Scores for CRTs

Life-cycle stage	Material	Impact Scores by Category							
		Non-renewable resource (kg)	Hazardous waste landfill use (m^3)	Solid waste landfill use (m^3)	Radio-activity (Bq)	Chronic health effects-public (tox-kg)	Chronic health effects-occupational (tox-kg)	Aquatic toxicity (tox-kg)	Terrestrial toxicity (tox-kg)
Materials processing	Lead	0	0	0	0	3.31e-03	0	0	1.66e-03
	Lead (Pb, ore)	4.96e-01	0	0	0	0	0	0	0
	Lead compounds	0	0	0	0	3.17E-05	0	3.10e-04	1.59E-05
	Lead-210 (isotope)	0	0	0	1.02E+00	0	0	0	0
Manufacturing	Broken CRT glass	0	6.22E-07	0	0	0	0	0	0
	Cinders from CRT glass mfg (70% PbO)	0	6.88E-06	0	0	0	0	0	0
	CRT glass faceplate EP dust (Pb) (D008 waste)	0	2.15E-06	0	0	0	0	0	0
	Frit	0	3.04E-06	0	0	0	0	0	0
	Hazardous sludge (Pb) (D008)	0	1.38E-06	0	0	0	0	0	0
	Lead	4.94e-01	0	0	0	1.19e-04	9.88e-01	9.3E-05	5.94E-05
	Lead compounds	0	0	0	0	2.35E-09	0	2.3E-08	1.17E-09
	Lead contaminated grit (D008 waste)	0	2.99E-09	0	0	0	0	0	0
	Lead debris (D008 waste)	0	1.85E-08	0	0	0	0	0	0
	Lead sulfate cake	0	3.03E-08	0	0	0	0	0	0
	Sludge from CRT glass mfg (1% PbO)	0	6.45E-07	0	0	0	0	0	0
	Waste Batch (Ba, Pb) (D008 waste)	0	1.22E-07	0	0	0	0	0	0
	Waste finishing sludge (Pb) (D008 waste)	0	2.32E-07	0	0	0	0	0	0
Use	Lead	0	0	0	0	2.55E-05	0	0	1.27E-05
End-of-life	Lead	0	0	0	0	2.85E-05	0	0	1.42E-05
	Lead compounds	0	0	0	0	3.19E-09	0	3.1E-08	1.6E-09
Total Impact Scores By Category		**9.89e-01**	**1.52E-05**	**0**	**1.02E+00**	**3.52e-03**	**9.88e-01**	**4.00e-04**	**1.80e-03**

Table 4-7. Summary of lead impact scores for LCDs

Life-cycle stage	Material	Impact scores by category							
		Non-renewable resource (kg)	Hazardous waste landfill use (m^3)	Solid waste landfill use (m^3)	Radio-activity (Bq)	Chronic health effects-public (tox-kg)	Chronic health effects-occupational (tox-kg)	Aquatic toxicity (tox-kg)	Terrestrial toxicity (tox-kg)
Materials processing	Lead	0	0	0	0	6.26E-06	0	0	3.13E-06
	Lead (Pb, ore)	2.47E-05	0	0	0	0	0	0	0
	Lead compounds	0	0	0	0	7.36E-06	0	7.25E-05	3.68E-06
	Lead-210 (isotope)	0	0	0	3.21E-01	0	0	0	0
Manufacturing	Lead	0	0	0	0	1.77E-05	0	1.64E-05	8.84E-06
	Lead compounds	0	0	0	0	1.13E-10	0	1.12E-09	5.67E-11
	Printed wiring board (PWB)	0	0	9.38E-06	0	0	0	0	0
	Waste Batch (Ba, Pb) (D008 waste)	0	5.67E-09	0	0	0	0	0	0
Use	Lead	0	0	0	0	9.52E-06	0	0	4.76E-06
End-of Life	Lead	0	0	0	0	9.52E-06	0	0	4.76E-06
	Lead compounds	0	0	0	0	9.95E-10	0	9.80E-09	4.98E-10
Total Impact Scores By Category		**2.47E-05**	**5.67E-09**	**9.38E-06**	**3.21e-01**	**5.03E-05**	**0**	**8.9E-05**	**2.52E-05**

Impact scores for some lead-based inputs and outputs shown in Tables 4-2 though 4-5 were not calculated if the type and disposition of the input or release was not expected to contribute to any of the impact categories. For example, a waterborne release of lead with a disposition going to treatment assumed that lead was not yet released to the environment where impacts could occur, and therefore no impacts were calculated. However, since inventory data for subsequent disposal processes could not be obtained, it was assumed the lead (or other inventory item) had been removed to a level such that the subsequent release of treated wastewater would not contribute significantly to the impact. Similarly, impact scores were not calculated for releases going to recycling/reuse or for product outputs.

Lead-based impacts from the CRT ranged from moderately to significantly greater than those from the LCD in every category, with the exception of solid waste landfill use. The most significant difference was in non-renewable resource consumption, where the CRT (989 grams) consumed over 40 thousand times the mass of non-renewable resources over the course of its life cycle than those consumed by the LCD (0.025 grams). Hazardous waste landfill use is another significant difference, with lead-based life-cycle outputs from CRTs using over 2,600 times the space of the lead-based outputs from LCDs. However, the absolute volume of waste from the CRT is still a relatively small volume (1.50 cm^3). Other categories where CRTs had notably greater impacts as a result of lead include the chronic public health effects and terrestrial toxicity impact categories.

Based on the CDP LCIA methodology, chronic occupational health effect impacts were only calculated for lead inputs (excluding lead ore) to processes in the computer display life cycle. Only the manufacturing life-cycle stage had lead inputs from which impacts were calculated as shown in Table 4-6. The overall impact scores (0.988 tox-kg for CRT, none for LCD) likely underestimate the chronic occupational impacts for lead because they do not consider chronic occupational impacts from other processes such as the mining, smelting, and refining of the lead, which are known to pose potential occupational exposures (see Section 4.1.4). For a more detailed discussion of how chronic occupational health effect impacts were calculated, refer to Section 3.1.2.12.

The contribution of lead-based impacts for each computer display technology to the overall impacts for each individual impact category is shown in Table 4-8. Values in the table are expressed in the percent contribution the material made to the overall impact score for all materials (e.g., mercury, fuel oil, glass) for each category. The percent contributions give an indication of the importance of lead-based impacts relative to the life-cycle impacts from other materials or outputs from the computer display.

Table 4-8. Summary of percent contributions from lead-based materials to individual impact categories

Impact category	CRT	LCD
Non-renewable resource	1.48E-01 %	6.78E-06 %
Hazardous waste landfill use	8.99E-02 %	1.57E-04 %
Solid waste landfill use	NA	1.73E-02 %
Radioactivity	2.70E-08 %	2.63E-06 %
Chronic health effects- public	1.80E-04 %	5.58E-06 %
Chronic health effects- occupational	1.10E-01 %	N/A
Aquatic toxicity	1.96E-01 %	1.71E-03 %
Terrestrial toxicity	8.90E-05 %	2.82E-06 %

N/A= Not applicable

It can be seen from Table 4-8 that the contributions of lead-based impacts are not significant relative to the total impacts from other materials (e.g., glass, copper wire, electronic components) in each category. Impacts from lead-based CRT outputs in the categories of nonrenewable resources, aquatic toxicity, and chronic public health effects are all range from 0.1-0.2% of the overall impact scores in each category.

4.1.4 Exposure Summary

Lead may pose a threat to human health anytime there is the potential for human exposure to the lead throughout the life cycle of a computer display. Exposure occurs anytime a chemical or physical agent, in this case lead or lead compounds, comes into contact with an organism, be it human or ecological. This section qualitatively identifies potential exposures for three groups: occupational workers in facilities using lead (occupational exposures), the general population living nearby these facilities which may be exposed to lead releases into the ambient environment, and ecological populations in the area surrounding a facility.

4.1.4.1 Occupational exposures

Workers are typically exposed to far greater concentrations of chemicals for longer periods of time than other populations. Worker exposures to lead can be especially serious given the overall toxicity of lead and lead compounds. As a result, both employers and government agencies have adopted recommendations or requirements for employers who wish to limit worker exposures.

Occupational exposures can occur anytime a worker comes into contact with lead, whether it be through dermal (skin) contact with a part containing lead (e.g., lead oxide coating on glass funnel), through the inhalation of lead particulates dispersed into the air, or through the inadvertent ingestion of lead. Many of the primary and support processes required to manufacture computer displays have lead in the workplace, and correspondingly, the potential for worker exposure. The processes associated with lead inputs and outputs throughout the computer displays' life cycles are presented in Tables N-1 through N-4 in Appendix N. It is important to note that while this list gives an indication of where likely lead exposures may occur, it is not exhaustive. Many processes and subprocesses may be contained within a process listed, each of which may pose its own potential for occupational lead exposures.

Exposures to lead are more likely to occur during the extraction, manufacturing, and disposal life-cycle stages of a computer display. During the use of the computer display, potential exposures to lead are unlikely as the components containing the lead are contained within the outside shell of the computer display, limiting the opportunity for contact with consumers. Table 4-9 presents some typical pathways leading to the occupational exposure of workers to lead over the life cycle of a computer display.

Table 4-9. Potential occupational exposure pathways for lead over the life cycle of a computer display

Exposure route	Transport media	Example mechanisms of exposure
Inhalation	Air	Lead fumes resulting from the vaporization of lead during smelting
	Air	Lead oxide dust released to the air during lead frit manufacturing
	Air	Lead aerosols created during the aeration of tin/lead solder plating baths during PWB production
Dermal	Direct contact	Handling of leaded CRT glass funnels prior to assembly
Ingestion	Direct contact	Consumption of food eaten with lead-contaminated hands (or drinking, smoking, etc)
	Air	Ingestion of lead contaminated soil particles which become airborne during lead mining

Workers may be exposed to airborne lead concentrations through the release of lead dust, fumes, or aerosols into the workplace. The lead is transported by the air, where it is inhaled into the lungs and then absorbed into the bloodstream. The greatest potential for high-level occupational exposure is during lead smelting and refining, where lead is vaporized during high temperature heating resulting in the release of lead fumes and small respirable particles of lead (EPA, 1986). Lead concentrations in air at three primary lead smelters were found to range from 80-2,900 μg/m^3, peaking at a level 58 times the OSHA recommended guidance level of 50 μg/m^3 (HSDB, 2001). Another study found that during the smelting and refining of lead, mean concentrations of lead in air reached as high as 4,470 μg/m^3, nearly 90 times the OSHA guidance level (Fu and Bofetta, 1995). Exposures to lead dust may also occur during lead mining, frit manufacturing, CRT glass manufacturing, or processes in which metallic lead is heated in the presence of air. Exposures to lead fumes are only possible during high temperature operations (above 500°C), such as welding or spray coating of metals with molten lead (Sittig, 1985).

Dermal exposures can take place anytime lead or materials containing lead are physically handled by workers. Opportunities for dermal exposures to lead are numerous in processes throughout the computer display life-cycle, as many processes involve lead or parts containing lead, especially in CRT manufacturing. Lead can be transferred to the skin of workers through contact with lead-containing materials and parts. Dermal exposures may also occur during cleaning and maintenance of equipment used to smelt, refine, or apply lead in a molten state (e.g., solder wave machinery for PWBs) or in areas with large airborne lead concentrations that may settle out onto work surfaces directly contacted by workers.

The contribution of dermal exposures to the overall lead body burden is uncertain. It is believed that most forms of lead are unable to readily penetrate the skin, allowing only a small amount of lead to enter the bloodstream. (ATSDR, 1999). Alkyl lead compounds, which are the known exception, are primarily used as additives in gasoline and are not used directly in computer display manufacturing (Bress and Bidanset, 1991; ATSDR, 1999). Therefore, dermal exposures to inorganic lead compounds are not expected to be as significant as the inhalation or ingestion routes of exposure (EPA, 1986).

Along with inhalation, ingestion of lead-bearing dust and fumes is a major route of exposure in lead smelting and refining industries (EPA, 1986). Airborne dust particles of lead can eventually settle onto skin, equipment, clothing, and work surfaces, where they may be subsequently transferred to the mouth and become ingested. Airborne particles may also be inhaled and swallowed, directly when greater than 5 micrometers in size (ATSDR, 1999). Once ingested, the amount of lead that reaches the bloodstream through the stomach depends on a number of factors, such as the age of the subject, length of time since last meal, and how well the lead was able to dissolve in the stomach. Studies have found that roughly 6% of the lead ingested will absorb into the blood stream of an adult who has recently eaten (within the last day), while upwards of 60-80% was absorbed in adults who had not recently eaten (ATSDR, 1999).

Lead exposures of workers are frequently measured by biological testing (e.g., blood lead levels, urinary lead levels) rather than monitoring the workplace for lead concentrations, making occupational data on lead exposures often not readily available (EPA, 1986). For a discussion of blood lead levels, corresponding effects, and recommended exposure guidelines, refer to Section 4.1.5 of this chapter.

Blood-lead levels have been reported in studies of workers for several industries relevant to computer display manufacturing. For example, workers occupationally exposed to lead during glass production were tested to determine their blood lead levels. Workers were divided into groups based on work activities and blood samples were collected at the end of each shift. Concentrations of lead in the blood ranged from 70 to 680 µg/l, with median values ranging from 170 to 340 µg/m^3, depending on the worker group. Data on types and rates of exposure were not identified (Ludersdorf *et al.,* 1987). Another study found that workers producing ceramic coated capacitors and resistors using leaded glass were exposed to occupational lead levels ranging from 61 to 1,700 µg/m^3. Blood lead levels ranged from 16 to 135 µg/dL in these same workers, greatly exceeding the OSHA recommended level of 50 µg/m^3 (Kaye *et al.*, 1987).

The presence of lead in the workplace does not mean that occupational exposures are unavoidable. Worker exposures to lead can be reduced or even eliminated through the use of personal protective equipment, sound operating practices, or through advanced machinery that protects workers from exposure (e.g., an enclosed and vented wave solder machine). To determine actual worker exposures to lead, a complete exposure assessment specific to each manufacturing process would be required.

4.1.4.2 General population

The general population living nearby a manufacturing facility using lead may potentially be exposed to lead emissions from the facility into the surrounding ambient environment. The likelihood and quantity of the potential exposure is dependent on the type and quantity of release, the receiving media, the local environmental conditions, and the fate and transport characteristics of the release. General population exposure to lead is most likely to occur through ingestion of lead contaminated food, water, and soil, as well as through inhalation of lead particulates in the ambient air (EPA, 1986).

Lead released into the ambient air will typically be in the form of lead particulate matter, which is eventually removed from ambient air through washout by precipitation (rain or snow) or through gravitational settling. Estimates indicate that the majority of lead released into the environment is dispersed into the atmosphere (EPA, 1980). With a relatively small mass mean diameter of 0.55 µm (HSDB, 2001), lead-containing particles can stay aloft for up to 64 hours and travel 1600 km, though they are more likely to be deposited within 10 km of the emission source (HSDB, 2001). General populations living near a source of lead emissions may encounter the lead while it is still airborne, leading to potential inhalation exposure. The direct inhalation of lead accounts for only a small part of the overall lead exposure to nearby populations, although the reentrainment of lead-contaminated soil is a common route of exposure (ATSDR, 1999).

Ingestion of lead is the most significant route of exposure for general populations (ATSDR, 1999). Particulates removed from the air are deposited into the soil, surface water, and onto local vegetation, where they may be ingested by nearby residents. Grains, vegetables, and fruits grown in close proximity to a source of lead emissions may contain lead which has been absorbed from contaminated soil through the root system. Lead also has the ability to bioaccumulate in the soft tissues of fish and wildlife, which are then consumed by sportsmen and their families.

Incidental ingestion of soil, which may occur while eating or smoking with soil-coated hands or when soil becomes reentrained and swallowed directly, often results in the largest lead exposures to residents living near emission sources. Lead-contaminated soil can also enter the home by being tracked into the house or carried home from the workplace on clothing, where it can come into contact with eating surfaces or food and become ingested. A study measuring lead in the home found mean lead levels as high as 22,191 µg/g in homes located within 1.6 km of a lead smelting facility, and mean levels of 2,687 µg/g in homes of workers at the smelting facility, irrespective of distance from the plant (ATSDR, 1999). One study found that once lead is swallowed, up to 50% of the lead is released from the contaminated soil into the stomach after only 10 minutes (HSDB, 2001).

Lead may also be released directly to surface water or indirectly to groundwater through the leaching of lead from landfills. Life-cycle inventory releases to surface water include 464 grams of lead and 159 grams of lead compounds per CRT. Surface water may also become contaminated through soil deposition or through surface water run-off from contaminated soil. Groundwater lead contamination from the leaching of lead-contaminated debris from solid- or hazardous waste disposal sites is unlikely to be significant due to the relative insolubility of lead (HSDB, 2001). Lead released to both surface waters and groundwater will typically remain insoluble, forming precipitates and settling into the sediment of the lake or stream. However, very little lead is typically found in U.S. waters which are used to supply the public with drinking water, due to strict governmental regulations (0.005 ppm lead) (ATSDR, 1999).

4.1.4.3 Ecological populations

Inorganic lead typically does not pose a significant health threat to fish and wildlife populations, except at extremely high concentrations. Once introduced into surface waters, the levels of soluble lead depend on the pH of the water and the dissolved salt content. At neutral pH, inorganic lead typically does not remain soluble in water at high concentrations, forming a precipitate that ultimately deposits in the sediment. However, as the alkalinity and pH decrease, the relative soluble concentrations of lead may become higher.

Toxic substances such as lead are capable of concentrating in the tissues of fish and wildlife. The bioconcentration of lead in fish is low-to-moderate in most species, with a bioconcentration factor (BCF) of 42 an 45 being reported for two fresh water fish species[1]. However, BCFs for certain other species, such as blue mussles (4,985), eastern oysters (1,000+) and 4 types of fresh water invertebrate species (range of 499 to 1,700), were much higher (EPA, 1999).

4.1.5 Human Health Effects

Lead has been classified by EPA as a persistent biaccumulative toxic (PBT) chemical (EPA, 2001b). PBT pollutants are highly toxic, long-lasting substances that can build up in the food chain to levels that are harmful to human and ecosystem health. Lead's ability to persist in the environment without breaking down, along with its tendency to bioaccumulate, poses adverse health effects to birds and mammals at the top of the food chain, along with anyone who consumes them for food. Lead and lead-based compounds have been associated with a range of adverse human health effects, including effects on the nervous system, reproductive and developmental problems, and cancer.

4.1.5.1 Chronic effects (noncancer)

Lead is toxic to human health regardless of the form (Gosselin, 1984). It is one of the most hazardous of the toxic compounds because the dose of lead is cumulative over a lifetime, and the health effects are many and severe. Lead has been known to cause hematological, gastrointestinal, and neurological dysfunction in adults and children. Chronic exposures have also caused hypertension and reproductive impairment in both men and women, as well as slowed development in children (Sittig, 1985).

Adverse effects, other than cancer or mutations, are generally assumed to have a dose or exposure threshold. A reference dose (RfD) is an estimate of the daily exposure through ingestion to the human population that is likely to be without an appreciable risk of noncancer detrimental effects during a lifetime. Likewise, a reference concentration (RfC) represents an estimate of the daily inhalation exposure to the human population that is likely to be without an appreciable risk of noncancer detrimental effects during a lifetime.

Because of the relative toxicity of lead and the cumulative nature of lead doses, a safe level of human exposure has yet to be identified by researchers, preventing EPA from

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[1] Bioconcentration is defined by EPA as the non-dietary accumulation of chemicals in aquatic organisms (U.S. EPA, 1999).

establishing a RfD or RfC for inorganic lead (ATSDR, 1999). Instead, lead exposure is determined by using exposure biokinetic models that relate exposure levels to an estimated blood lead level, which is then compared to actual blood lead levels where adverse effects are known to occur[2]. For example, increased blood pressure has been observed in adults with a blood-lead level as low as 7 µg/dL (ACGIH, 1991). Lead concentrations in excess of 60 µg/100g blood have been associated with neuropathy, gastrointestinal disturbances, and anemia, while workers with blood-lead levels between 50-70 µg/100 g to have shown decreased neural response (ACGIH, 1991).

As a guideline, a blood-lead level of concern for adult workers of 30 µg/dL has been established by both the Occupational Safety and Health Administration (OSHA) and ACGIH. A guideline of 10 µg/m^3 (for a child) has been set by the Center for Disease Control (CDC) for general population exposures to lead in the ambient environment. A summary of human health effect guidelines for lead is presented in Table 4-10.

Table 4-10. Human health effect regulations and guidelines for lead

Type	Agency/Category	Regulatory level
Workplace exposures to lead		
Worker blood-lead target/action levels	OSHA, Adults who "wish to bear children"	30 µg/dL
	OSHA, Blood-lead level of concern	40 µg/dL
	OSHA, Medical removal	50 µg/dL
	ACGIH, Biological Exposure Index (BEI) Blood-lead level of concern (ACGIH, 1998)	30 µg/dL
	NIOSH, level to be maintained through air concentrations	60 µg/100 g
Pregnant worker: fetal blood-lead target/action levels	OSHA	30 µg/100 g
	CDC	10 µg/dL[a]
Workplace air exposure limit	OSHA Permissible exposure limit (PEL)	50 µg/m^3
	NIOSH Recommended exposure limit (REL) (NIOSH, 1997)	100 µg/m^3
	ACGIH TLV TWA (ACGIH, 1998)	50 µg/m^3
Ambient environment exposures to lead		
Blood-lead target/action levels for child	CDC	10 µg/m^3 [a]
	OSHA	30 µg/100 g
	World Health Organization blood-lead level of concern	20 µg/dL

[a] CDC considers children to have an elevated level of lead if the amount of lead in the blood is at least 10 µg/dL. Medical evaluation and environmental remediation should be done for all children with blood-lead levels greater than 20 µg/dL. Medical treatment may be necessary for children with a blood-lead concentration above 45 µg/dL (RTI, 1999).

Notes: ACGIH: American Conference of Governmental Industrial Hygienists; NIOSH: National Institute for Occupational Safety and Health; TWA: Time weighted average; TLV: Threshold limit value

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[2] In order to estimate blood-lead levels, worker exposure levels based on releases reported in the inventory would be required. However, without information pertaining to the exposure conditions (which is unavailable to this study) and fate and transport of the releases, worker exposure cannot be calculated.

4.1.5.2 Carcinogenicity

The potential for a chemical to cause cancer is evaluated by weight-of-evidence classifications, specific to the rating organization, which are typically determined by laboratory or epidemiological studies. Lead and inorganic lead-based compounds have been classified by the International Agency for Research on Cancer (IARC) as possible human carcinogens (Group 2B), based on sufficient evidence of carcinogenicity in animals (IARC, 1987). Lead has also been classified as an A3 carcinogen (confirmed animal carcinogen with unknown relevance to humans) by the American Conference of Governmental Industrial Hygienists (ACGIH, 1998). The U.S. EPA has given lead a weight-of-evidence classification of B2, indicating lead is a probable human carcinogen and a confirmed animal carcinogen (IRIS, 1999). There is currently no established cancer slope factor for lead, which could be used to estimate cancer risk from an exposure amount.

4.1.6 Environmental Regulations for Lead

Apart from the regulations and recommendations regarding worker safety presented in the previous section, lead is regulated in a number of ways. This section presents a brief summary of the U.S. regulations for lead and lead compounds expected to impact facilities that manufacture materials for the computer display. It should be noted that many of the parts and materials which go into the manufacture of computer displays are manufactured in countries outside the U.S., with their own lead regulations which may differ significantly from those discussed below.

Air emissions of lead are regulated under the Clean Air Act (CAA) of 1970 and the amendments to the CAA of 1977 and 1990. Under the CAA, lead is regulated as a hazardous air pollutant (HAP), which is by definition a chemical that is generally known or suspected to cause serious health problems. Stationary source categories involved in the life cycle of a computer display that must meet new source performance standards include primary and secondary lead smelters, glass manufacturing plants, and metallic mineral processing plants (EPA, 1977; EPA, 1980a; ATSDR, 1999). A National Ambient Air Quality Standard (NAAQS) was also established for lead, requiring that the concentration of lead in air that the public breathes be no higher than 1.5 $\mu g/m^3$ averaged over 3 months [40 CFR 50.12].

Lead releases to surface water are regulated under the Clean Water and Effluent Guidelines and Standards promulgated under the Clean Water Act of 1977. Lead is identified as a priority pollutant [40 CFR 401.15], requiring the limitation of lead concentrations in pollutant discharges from point sources. The regulations also set standards of performance for new point sources, as well as pretreatment standards for both new and established sources. Regulated point source categories include lead smelters, steam electric power generation, glass manufacturers, and aluminum production and others, all of which contribute to the life-cycle impacts of a computer display. New point sources of lead contamination must also apply for National Pollution Discharge Elimination System (NPDES) permits which will establish effluent limits for sources of lead discharge.

To protect the population from a contaminated water supply, toxic substances in drinking water are regulated under the Safe Drinking Water Act of 1986. A federal drinking water standard of 15 ug/L has been established for lead.

EPA also regulates lead content in hazardous and solid wastes under the Resource Conservation and Recovery Act (RCRA). A solid waste containing lead or lead compounds may be considered a D008 characteristic hazardous waste if, when subjected to a Toxicity Characteristic Leachate Procedure (TCLP) test, the extract exceeds 5.0 mg/L [40 CFR 261.24] for lead. Other lead-contaminated wastes may be considered hazardous if specifically listed in 40 CFR 261.30-33, unless specifically excluded. Listed wastes from specific sources which contribute to the manufacture of computer displays include emission control dust from steel production and from lead smelting (K061 and K069 respectively), waste leaching solution of control dust from secondary lead smelting (K100), and spent baths and residues from electroplating operations containing cyanide (F006), which are sometimes used in PWB manufacturing. Specific sources of hazardous wastes, whether characteristic or listed wastes, are subject to handling, storage, and disposal restrictions detailed in the code of federal regulations.

Manufacturers who emit lead are required to report the quantity of the emissions under the Community Right-to-Know Act. EPA has recently reduced the reportable quantity threshold for lead from 10,000 lbs per year to 100 lbs per year of lead.

4.1.7 Alternatives to Lead Use in Computer Displays

Because of increasing pressure through regulation and market forces, attempts to reduce or eliminate lead in electronics have become popular. Several countries are considering or have already passed restrictions on the use and disposal of lead, prompting many companies to establish aggressive timelines for reducing or eliminating lead in their products. Several opportunities to eliminate or reduce the amount of lead used in a computer display are being aggressively researched. Two options being researched extensively are the development of a reduced lead frit, and lead-free solders for PWB manufacturing and assembly.

Although not large in mass in a monitor, frit glass is 70 to 80% lead by weight. Lead is one component of a mixture that crystalizes under intense heat, providing strength to the vacuum-tight frit seal. An alternative lead-free frit glass has been developed that is based on tin and zinc oxides, along with phosphate (Busio and Steigelmann, 2000). The lead-free glass is inherently mechanically weak, requiring large amounts of ceramic fillers (Al2O3) to be added to improve the mechanical strength of the seal. It also requires the addition of vitreous silica particles to match the thermal expansion requirements of the CRT glass. The resulting mixture requires a firing cycle approaching 450ºC, which is typical of frit glasses. A drawback is that the frit glasses stay vitreous during the typical 30-60 minute furnace dwell time. However, initial evidence suggests that the fired frit seal remains rigid during the pumping step, which occurs at 350ºC. Although comprehensive test results are not yet available, the high-temperature stability and rigidity of the lead-free frit glass is currently being tested under vacuum (Busio and Steigelmann, 2000).

Lead-free solders have been the subject of industry research for some time. Driven by renewed regulatory attention and by recent corporate commitments to reduce or eliminate lead from their product lines, alternatives to lead-based solder are garnering increased attention. Alternative lead-free solders include tin in combination with one or more of the following metals: silver, copper, bismuth, germanium, and antimony. Several companies, including Sony, Toshiba, Hitachi, and Ford Motor Company, have either already begun to implement electronics production using a lead-free solder alternative, or have announced plans to do so. Though still a relatively new and untested technology, initial testing has shown that alternatives are capable of producing quality component connections, though they have a narrower operating window and require higher temperatures to apply (Keenan and Kellett, 2001).

4.2 MERCURY

Mercury is not only used in the manufacturing of LCDs, but also is emitted from a number of processes over the life cycle of both LCDs and CRTs. Because of mercury's toxicity to both humans and the environment, this section presents a more detailed look at the uses and impacts of mercury, and its potential for causing harm as a result of the manufacture, use, and disposal of computer displays.

4.2.1 Mercury in Computer Displays

Mercury is an important material in the construction of cold cathode fluorescent lamps (CCFLs) that are used to backlight the LCD. A typical LCD utilizes a minimum of two CCFLs, and can use as many as eight in larger displays. The CCFL consists of a glass tube filled with a small amount of rare gas (typically argon) and a few drops of mercury. Metal electrodes built into the ends of the tube conduct electric current to the inside gas, vaporizing a portion of the mercury which then becomes excited, emitting light in the ultraviolet spectrum. Fluorescent phosphors, which coat the inside of the glass tube, convert the ultraviolet emissions from the mercury gas into visible white light. The phosphors are responsible for nearly all of the visible light from the lamp, with the visible mercury spectrum contributing only a little to the lamps output (Srivastava and Sommerer, 1998). No mercury is contained directly within the CRT.

Although a great deal of mercury is obtained by CCFLs, there also is a small source of mercury generated by the infrequent breakage of mercury lamps in the photolithographic exposure systems used to make both the CRT and LCD. Mercury filters are used in some water cooled exposure table equipment to catch the mercury from lamp explosions or trap it in water cooling baths. In air cooled lamp usage, the proximity of aluminum metal gives sites for amalgam formation and a number of clean-up procedures are used. Unbroken lamps are returned to the lamp manufacturer for recycling or disposal (Donofrio and Eckel, 1999).

Mercury may also be emitted from several processes required to manufacture, operate, and dispose of both CRTs and LCDs. For example, electricity generated from the combustion of coal results in the emission of mercury contained within the fuel. Other processes potentially responsible for mercury emissions include mercury ore processing, non-ferrous metal production, and the recycling of LCDs at the end of their useful life. The amount of mercury released through these incidental mercury emissions is comparable to the amount of mercury used as a direct material in the manufacture of LCD backlights.

4.2.2 Life-Cycle Inputs and Emissions of Mercury for Computer Displays

Data on mercury and mercury-containing materials were collected and compiled as part of the life-cycle inventory. Material inputs containing mercury include primary materials (e.g., CCFLs) which end up as part of the product, as well as ancillary materials (e.g., fossil fuels containing mercury) which are consumed as part of the manufacturing process or other supporting processes (e.g., energy production). The data were aggregated by material from individual processes and are presented by life-cycle stage for LCDs in Table 4-11**.** More detailed material input data, which include the processes that use each input and the quantity of mercury releases, are included in Appendix N.

Table 4-11. Life-cycle stage mercury inputs for LCDs

Life-cycle stage	Inputs	Quantity	Units	Type
Manufacturing	Mercury	3.99e-06	kg	Primary material
Manufacturing	Backlight lamp (CCFL)	1.94E-03[a]	kg	Product

[a] Quantity of release shown represents entire mass of input material. Mercury may only comprise a fraction of the total mass of material shown.

Mercury is not listed as an input in the life-cycle inventory for CRTs. However, mercury is contained in raw material inputs (e.g., mercury contaminants in fossil fuels burned to produce energy) into processes such as non-ferrous metal production and energy production for both LCDs and CRTs. Though mercury inputs exist, they occur in upstream manufacturing processes where input data did not contain detailed composition data for fuel inputs.

Releases of mercury and mercury-containing materials into the environment occur throughout the entire life cycle of the computer display. Environmental releases include airborne, waterborne, solid waste, and hazardous waste emissions. Similar to the inputs, emissions data were aggregated by the material released from individual processes and then reported by life-cycle stage. The mercury and mercury-containing material released, the quantity of the release, the type of release (e.g., waterborne), and the ultimate disposition of the release all affect the nature and type of environmental impacts.

The total life-cycle outputs/emissions containing mercury for both CRTs and LCDs are organized by output type and shown in Tables 4-12 and 4-13, respectively. More detailed data on mercury and mercury-containing outputs for each process are presented in Appendix N.

Table 4-12. Life-cycle stage mercury outputs from CRTs

Life-cycle stage	Outputs	Quantity	Units	Type	Disposition
Materials processing	Mercury	3.00E-06	kg	Airborne	Air
Materials processing	Mercury	1.42E-10[a]	kg	Solid waste	Landfill
Materials processing	Mercury compounds	9.68E-07	kg	Waterborne	Surface Water
Manufacturing	Mercury	1.12E-06	kg	Airborne	Air
Manufacturing	Mercury compounds	1.35E-12	kg	Waterborne	Surface Water
Use	Mercury	7.51E-06	kg	Airborne	Air
End-of-life	Mercury	-1.15E-07	kg	Airborne	Air
End-of-life	Mercury compounds	4.33E-11	kg	Waterborne	Surface Water

[a] Quantity of release shown represents entire mass of waste disposed. Mercury may only comprise a fraction of the total mass of waste shown.

Table 4-13. Life-cycle stage mercury outputs from LCDs

Life-cycle stage	Outputs	Quantity	Units	Type	Disposition
Materials processing	Mercury	9.44E-07	kg	Airborne	Air
Materials processing	Mercury compounds	5.82E-07	kg	Waterborne	Surface Water
Manufacturing	Broken CCFL	2.69E-07[a]	kg	Solid waste	Landfill
Manufacturing	Mercury	2.64E-06	kg	Waterborne	Treatment
Manufacturing	Mercury compounds	6.52E-14	kg	Waterborne	Surface Water
Manufacturing	Waste CCFL, with mercury	8.17E-10[a]	kg	Hazardous waste	Treatment
Manufacturing	Waste glass, with mercury	1.05E-10[a]	kg	Hazardous waste	Landfill
Manufacturing	Wastewater stream, from CCFL mfg.	167	kg	Waterborne	Treatment
Use	Mercury	2.80E-06	kg	Airborne	Air
End-of-life	Mercury	-8.64E-08	kg	Airborne	Air
End-of-life	Mercury compounds	1.62E-11	kg	Waterborne	Surface Water

[a] Quantity of release shown for solid waste and hazardous waste represents entire mass of waste disposed. Mercury may only comprise a fraction of the total mass of waste shown.

Mercury is released into the environment in many forms, but is most typically an airborne release. The largest air emissions of mercury result from the generation of electricity from fossil fuel burning. For LCDs, there is nearly the same amount of mercury emitted to the air from energy production (3.22 mg) as the mass of mercury used in the fabrication of an LCD (3.99 mg). In fact, the amount of mercury emitted to the air from electricity generation for CRTs (7.75 mg) is greater than the entire amount of mercury from both the fabrication and energy production for an LCD. Other airborne releases include the processing of ores such as lead, and the production of several raw materials such as aluminum, polycarbonate, and steel.

4.2.3 Computer Display Life-Cycle Impacts for Mercury

The life-cycle impacts of mercury, mercury-based compounds, and materials containing mercury (e.g., waste glass from broken CCFLs) calculated for CRTs and LCDs during the LCIA are summarized in Tables 4-14 and 4-15, respectively. Impact scores in the table are expressed in units specific to each impact category (see Chapter 3.1 for a discussion of impact category units and weighting). The total impact score for each category resulting from mercury and mercury-based materials is presented at the bottom of each table.

Table 4-14. Summary of mercury-based impact scores by impact category for CRTs

Life-cycle stage	Material	Impact scores by category					
		Hazardous waste landfill use (m³)	Solid waste landfill use (m³)	Chronic health effects-public (tox-kg)	Chronic health effects-occupational (tox-kg)	Aquatic toxicity (tox-kg)	Terrestrial toxicity (tox-kg)
Materials processing	Mercury	0	0	3.00E-06	0	0	3.00E-06
Materials processing	Mercury compounds	0	0	5.11E-04	0	9.02E-04	5.10E-04
Manufacturing	Mercury	0	0	1.12E-06	0	0	1.12E-06
Manufacturing	Mercury compounds	0	0	7.13E-10	0	1.26E-09	7.11E-10
Use	Mercury	0	0	7.51E-06	0	0	7.51E-06
End-of-life	Mercury	0	0	-1.15E-07	0	0	-1.15E-07
End-of-life	Mercury compounds	0	0	2.29E-08	0	4.04E-08	2.28E-08
Total Impact Scores by Category		**0**	**0**	**5.22E-04**	**0**	**9.02E-04**	**5.21E-04**

Table 4-15. Summary of mercury-based impact scores by impact category for LCDs

Life-cycle stage	Material	Impact scores by category					
		Hazardous waste landfill use [a] (m^3)	**Solid waste landfill use [a] (m^3)**	**Chronic health effects-public (tox-kg)**	**Chronic health effects-occupational (tox-kg)**	**Aquatic toxicity (tox-kg)**	**Terrestrial toxicity (tox-kg)**
Materials processing	Mercury	0	0	9.44E-07	0	1.82E-07	9.44E-07
Materials processing	Mercury compounds	0	0	3.07E-04	0	5.42E-04	3.07E-04
Manufacturing	Broken CCFL	0	1.98E-11	0	0	0	0
Manufacturing	Mercury	0	0	5.54E-07	3.99E-06	1.9387E-07	5.54E-07
Manufacturing	Mercury compounds	0	0	3.44E-11	0	6.08E-11	3.44E-11
Manufacturing	Waste glass, with mercury	7.73E-15	0	0	0	0	0
Use	Mercury	0	0	2.80E-06	0	0	2.80E-06
End of Life	Mercury	0	0	-8.64E-08	0	0	-8.64E-08
End of Life	Mercury compounds	0	0	8.53E-09	0	1.51E-08	8.52E-09
Total Impact Scores by Category		**7.73E-15**	**1.98E-11**	**3.11E-04**	**3.99E-06**	**5.43E-04**	**3.11E-04**

[a] Percentages of impacts shown for solid and hazardous wastes are based on the entire mass of material disposed, not necessarily on the amount of mercury. As such, the percentage over-estimates the impact of mercury to either the solid or hazardous waste landfill use.

Impact scores for some mercury-based inputs and outputs shown in Tables 4-11 through 4-13 were not calculated if the type and disposition of the input or release was not expected to contribute to any of the impact categories. For example, a waterborne release of mercury with a disposition going to treatment assumes that the mercury was treated prior to being released to the environment. However, since inventory data for subsequent treatment/disposal processes could not be obtained, it was assumed the mercury (or other inventory item) had been removed to a level such that the subsequent release of treated wastewater would not contribute significantly to aquatic toxicity impacts. Similarly, impact scores were not calculated for releases going to recycling/reuse or for those designated as a product.

The life-cycle mercury-based outputs from LCDs had a broader affect on the environment than those from CRTs, impacting a wider group of impact categories. Impacts to both solid and hazardous waste landfill use, as well as to the chronic health effects of workers, all directly result from the use of mercury in the LCD backlights. No mercury is required for the fabrication of a CRT. Although the quantities are not large (see Tables 4-11 through 4-13), they cannot be discounted, given the toxicity of mercury to both human health and the environment.

Chronic occupational toxicity impacts were only calculated for mercury inputs to processes in the CDP. The overall impact scores (3.99E-06 tox-kg for LCD, none for CRT) likely underestimate the chronic occupational impacts for mercury, because they are based on inputs only and do not consider chronic occupational impacts from outputs in other processes such as aluminum production or fluorescent lamp recycling, which may result in emissions of mercury that originate within the workplace.

The contribution of mercury-based impacts for each computer display technology to the overall impacts for each individual impact category is shown in Table 4-16. Values in the table are expressed in the percent contribution the material made to the overall impact score for all materials (e.g., liquid crystals, fuel oil, glass) for each category. The percent contributions give an indication of the importance of mercury-based impacts relative to the life-cycle impacts from other materials or outputs from the computer display.

Table 4-16. Summary of percent contributions from mercury-based materials to individual impact categories

Impact category	CRT	LCD
Hazardous waste landfill use	N/A	NA
Solid waste landfill use	N/A	3.65E-08
Chronic health effects- public	2.64E-05	3.45E-05
Chronic health effects- occupational	N/A	5.80E-07
Aquatic toxicity	4.01E-01	1.05E-02
Terrestrial toxicity	2.64E-05	3.48E-05

N/A = Not applicable

The results from Table 4-14 and 4-15 indicate that the mercury impacts from a CRT exceed the impacts from an LCD in categories common to both technologies. This was not expected, because mercury is used intentionally in an LCD, but not in a CRT. However, the results are not surprising because mercury emissions from coal-fired power plants are known to be one of the largest anthropogenic sources of mercury in the United States. Because the CRT consumes significantly more electricity in the use stage than the LCD, its use stage emissions of mercury are proportionately higher than those of the LCD. In fact, the mercury emitted from the generation of power consumed by the CRT exceeds the entire amount of mercury emissions from the LCD, including both the mercury used in LCD backlights and the mercury emissions from electricity generation in the use stage that can be attributed to the LCD.

The impacts resulting from mercury and mercury-based materials do not appear to be significant relative to the total impacts of all of the computer display materials (e.g., liquid crystals, lead solder), as shown in Table 4-16. The largest contribution is 0.4% of the total aquatic toxicity impacts for CRTs, and 0.01% of the total aquatic toxicity impacts for LCDs. Impacts to other categories from both LCDs and CRTs were minimal.

4.2.4 Exposure Summary

Mercury may pose a threat to human health anytime there is the potential for human exposure throughout the life cycle of a computer display. Exposure occurs anytime a chemical or physical agent, in this case mercury or mercury compounds, come into contact with an organism, be it human or ecological. This section qualitatively identifies potential exposures for workers in facilities using mercury (occupational exposures), the general public, who may be exposed to mercury releases into the ambient environment, and the ecological population.

4.2.4.1 Occupational exposures

About 4 mg of elemental mercury (combined total of all mercury contained within the backlights) is used to manufacture the fluorescent backlight for the LCD backlight unit assembly. Workers manufacturing the backlights may be exposed to the mercury used for these lights. This study found no information on the specific manufacturing processes that are used to make CCFLs or the specific worker exposures that could occur, but did find manufacturing information for generic fluorescent lamps. We assume the processes are similar and have included a brief discussion of the fluorescent lamp manufacturing process and potential sources of worker exposure, below.

In fluorescent lamp manufacturing, pre-cut bulbs are washed, dried, and coated with a liquid phosphor emulsion that deposits a film on the inside of the bulb. Mount assemblies are then fused to each end of the bulb and the bulb is transferred to an exhaust machine. The bulb is then exhausted and mercury is injected into the bulb. Some of the mercury combines with the emulsion on the interior of the bulb where it remains over the life of the bulb. The glass bulb is then filled with an inert gas and sealed (EPA, 1997).

During the lamp manufacturing process, emissions of mercury can occur from transfer and parts repair during mercury handling, by the mercury injection operation, and from broken lamps, spills, and waste materials. Workers can be exposed to mercury from any of these sources, but mercury air levels can be reduced by process modifications, containment, ventilated inclosures, local exhaust ventilation, and temperature control (EPA, 1997).

There were no other inputs of mercury reported in the LCD life-cycle inventory, and none were reported in the CRT life cycle. Workers may also be exposed to inorganic mercury in the fluorescent backlights when processing LCDs at the end-of-life. Family members of workers may be exposed as well, from a worker's clothing or shoes if they are contaminated with mercury and brought home.

The processes associated with LCI mercury inputs and releases are presented in supplemental tables in Appendix N. It is important to note that while this list gives an indication of where likely mercury exposures may occur, it is not exhaustive. Many processes and subprocesses may be contained within a process listed, each of which may pose its own potential for occupational mercury exposures.

4.2.4.2 General population exposures

Mercury is a persistent biaccumulative toxic (PBT) chemical, as designated by EPA (EPA, 2001b). PBT pollutants are highly toxic, long-lasting substances that can build-up in the food chain to levels that are harmful to human and ecosystem health. The general public may be exposed to metallic mercury that is not safely contained (although it is unlikely that the backlight would break to release mercury during normal LCD use) or to methylmercury-contaminated foods. Mercury also can be passed from a pregnant woman to developing child through the placenta, and from a mother to nursing infant through breast milk.

Most of the mercury released to the environment throughout the CRT and LCD life cycles results from electricity generation required for use, manufacturing, and materials processing life-cycle stages. A total of approximately 4 mg of mercury and mercury compounds are released to air for an LCD, and approximately 12 mg are released to air for a CRT. Mercury is naturally present in coal and becomes airborne when coal is burned to generate electricity. Airborne mercury can stay in the atmosphere for up to a year, and can travel thousands of miles (EPA, 2001a). EPA modeling suggests that "a substantial fraction" of the mercury released to air by utilities is dispersed "well beyond the local area" due to the fine particulate nature of the emissions and tall stacks (EPA, 1998). Mercury in the atmosphere moves to land and water by settling out with particles and being washed out by rain (dry and wet deposition). It may be deposited directly to water or be carried by runoff to a lake, stream, or ocean. In the LCIs, in addition to the air releases of mercury, 0.6 mg of mercury and mercury compounds are released directly to surface water in the LCD life cycle, and 1 mg in the life cycle of the CRT. Ultimately, at the end of life, the 4 mg of mercury in the LCD backlight will most likely be released to the environment during LCD recycling or disposal processes.

Surface water is the environmental medium of most concern for mercury. In a surface water environment, inorganic mercury can be transformed into methylmercury, a form which readily bioaccumulates in fish (inorganic mercury does not tend to bioaccumulate). An EPA study of mercury supports a "plausible link" between releases of mercury from industrial and combustion sources and methylmercury found in fish[3] (EPA, 2001c). Methylmercury

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[3] The mercury released to the environment from the CRT and LCD life cycles are only part of the overall burden of mercury released to the environment from coal-fired power plants for all uses of electricity. The proportion of mercury in fish that is due to coal-fired power generation is not known. In addition, there are other natural and anthropogenic sources of mercury to the environment.

concentrations at the top of the food chain (such as in predatory fish or fish-eating animals) can be thousands or even millions of times greater than that in the surface water itself (EPA, 2000a).

The most important mercury exposures to the general public result from eating fish that are contaminated with methylmercury. The populations of most concern are children and women of child-bearing age (the developing fetus may be the most sensitive to the effects of methylmercury). Also of concern are people whose diet largely depends on fish, such as with some native cultures. The overall amount of exposure to mercury from eating fish depends on both the concentration of mercury in the fish, and on the amount of fish a person regularly eats. Fish advisories due to methylmercury contamination have been issued by EPA[4], 39 states, and some tribes, providing consumption limits for certain species of fish (EPA, 2000a, 2001c).

Freshwater fish are most affected, but some saltwater fish have also been found to be contaminated with methylmercury. The Food and Drug Administration (FDA) has issued a fish consumption advisory for pregnant women, nursing mothers, and small children to avoid eating certain large saltwater fish (shark, swordfish, king mackerel, and tilefish), and to limit overall weekly fish consumption, due to methylmercury contamination (FDA, 2001).

4.2.4.3 Exposure and effects to ecological populations

In addition to the fish themselves being contaminated, wildlife that eat fish also may be at risk from exposure to methylmercury. Species of concern include loons, eagles, mink, otter, wood stork, and the endangered Florida panther. Adverse effects of mercury to wildlife include death, reproduced reproductive success, impaired growth and development, and behavioral abnormalities. Levels have been measured in some individual wild animals that are comparable to those levels seen to cause harmful effects in laboratory tests with the same species (EPA, 2001c). Ambient water criteria have been developed by EPA under the CWA. Criteria for the protection of aquatic life for mercury are presented in Table 4-17.

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[4] "EPA is issuing a national advisory concerning risks associated with mercury in freshwater fish caught by friends and family. The groups most vulnerable to the effects of mercury pollution include: women who are pregnant or may become pregnant, nursing mothers, and young children. To protect against the risks of mercury in fish caught in fresh waters, EPA is recommending that these groups limit fish consumption to one meal per week for adults (6 ounces of cooked fish, 8 ounces of uncooked fish) and one meal per week for young children (2 ounces cooked fish or 3 ounces of uncooked fish)." – EPA Office of Water, January 2001

Table 4-17. EPA water quality criteria for mercury

Type of criteria	Criteria value (µg/L)	Notes
For protection of aquatic life		
Freshwater Criteria Maximum Concentration (CMC)	1.4 [a]	the acute limit for the priority pollutant in freshwater
Freshwater Criterion Continuous Concentration (CCC)	0.77 [a]	the chronic limit for the priority pollutant in freshwater
Saltwater Criteria Maximum Concentration (CMC)	1.8 [a]	the acute limit for the priority pollutant in saltwater
Saltwater Criterion Continuous Concentration (CCC)	0.94 [a]	the chronic limit for the priority pollutant in saltwater

Source: Water Quality Criteria and Standards, EPA Office of Water. Revised: 06/21/2001 http://oaspub.epa.gov/wqsdatabase/epa.rep_parameter; report for mercury

[a] Criteria for metals are expressed in terms of the dissolved metal in the water column. This recommended water quality criterion was derived from data for inorganic mercury (II), but is applied here to total mercury. If a substantial portion of the mercury in the water column is methylmercury, this criterion will probably be under-protective (EPA is updating the ambient water quality criteria on methylmercury.) In addition, even though inorganic mercury is converted to methylmercury and methylmercury bioaccumulates to a great extent, this criterion does not account for uptake via the food chain because sufficient data were not available when the criterion was derived.

4.2.5 Human Health Effects

Mercury affects the nervous system, brain, and kidneys. Effects on the nervous system vary depending on the form of mercury. Inorganic mercury salts, for instance, do not enter the brain as readily as elemental mercury or methylmercury. Symptoms of mercury effecting the brain and nervous system include personality changes, tremors, changes in vision such as narrowing of the visual field, deafness, loss of muscle coordination, loss of sensation, and problems with memory (ATSDR, 1999).

The fetus, infants, and young children are especially susceptible to the effects of mercury on the nervous system. As mentioned above, mercury (especially methylmercury in food) can be passed from a pregnant woman to the unborn developing child, and from a mother to a nursing infant through breast milk. The developmental effects of mercury vary in severity depending on the amount of exposure. Children exposed in this way may show small decreases in IQ or may be slower to walk and talk. More severe effects might include brain damage with mental retardation, blindness, muscle weakness or seizures, and inability to speak (ATSDR, 1999).

Mercury accumulates in the kidneys and all forms of mercury can cause kidney damage at higher exposures (ATSDR, 1999). Short term exposure (hours) to high levels of mercury vapor, as might occur through an accidental spill in the workplace, include damage to the lining of the mouth, irritated lungs and airways, nausea, vomiting, diarrhea, increased blood pressure or heart rate, skin rashes, and eye irritation. Skin contact may cause an allergic reaction (skin rashes) in some people (ATSDR, 1999).

4.2.5.1 Chronic effects (noncancer)

A reference dose (RfD) is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure through ingestion to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime (in mg/kg-day). Similarly, a reference concentration (RfC) is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime (in mg/m^3) (Barnes and Dourson, 1988). RfDs and RfCs established by EPA for mercury and mercury compounds are presented in Table 4-18.

Table 4-18. Chronic toxicity reference values for mercury and mercury compounds

Form of mercury[a]	**Ingestion: reference dose (RfD) (mg/kg-day)**[b]	**Inhalation: reference concentration (RfC) (mg/m^3)**[c]	**Notes, Source**
Elemental mercury (Hg)	not available	0.0003	Based on hand tremor, memory disturbances, and other effects seen in human occupational inhalation studies (IRIS, 2001).
Methylmercury (CH_3Hg^+)	0.0001	not available	Based on developmental neuropsychological impairment seen in human epidemiological studies (IRIS, 2001).
Mercuric chloride (HgCl)	0.0003	not available	Based on autoimmune effects in rats (IRIS, 2001).

[a] Forms of mercury for which EPA has established an RfD or RfC
[b] milligrams per kilogram of body weight per day for oral exposure (ingestion)
[c] milligrams per cubic meter of air, assuming continuous inhalation exposure for a 70-kg adult

4.2.5.2 Carcinogenicity

EPA has determined that mercury chloride and methylmercury are Possible Human Carcinogens (cancer weight of evidence [WOE] classification C) based on limited evidence of carcinogenicity in animals and inadequate or lack of human data. Elemental mercury is classified by EPA as Not Classifiable as to Human Carcinogenicity (WOE class D) based on inadequate or no evidence of carcinogenicity (IRIS, 2001).

4.2.6 Environmental Regulations for Mercury

This section presents a brief summary of the U.S. regulations for mercury and mercury compounds that may affect facilities that manufacture materials for the computer display or are otherwise affected by the life cycle of computer displays. It should be noted that many of the parts that go into the computer display are manufactured in other countries with their own regulations which may differ significantly from those presented below.

Air emissions of mercury are regulated under the CAA of 1970 and the amendments of 1977 and 1990. Under the CAA, mercury is regulated as a hazardous air pollutant (HAP), which is by definition a chemical that is either known or is suspected to cause serious health problems for humans. EPA established National Emission Standards for HAPs (NESHAPs) for mercury emissions based on risk under the pre-1990 version of the Clean Air Act. These NESHAPS [40 CFR 61 Subpart E] cover three source categories: ore processing facilities, mercury cell chlor-alkali plants, and sewage sludge driers. Specific source requirements are specified for, among other things, municipal waste combusters, hazardous waste combusters, and mercury ore processing facilities. These source requirements could take the form of either a NESHAP or a maximum achievable control technology (MACT) requirement.

OSHA has established standards for protecting worker health through the maintenance of a safe working environment. The OSHA permissible exposure limit (PEL) for workplace exposure to mercury is 0.1 mg/m^3 (8-hour time weighted average). NIOSH has also established recommended exposure limits (RELs) for several mercury compounds including a REL of 0.05 mg/m^3 for mercury vapor.

Mercury emissions to surface water are regulated under the CWA, which lists mercury as a priority pollutant [40CFR 401.15], requiring the limitation of mercury in point source discharges. For mercury discharges, CWA regulations specify technology-based effluent limits for classes and categories of industries (see 40 CFR 401, 403, Appendix B), and describe the rights of states to establish effluent limits more stringent than technology-based standards. Technology-based standards are listed for the following specific industries and point sources involved in computer display manufacturing: nonferrous metals production, including primary precious metals and mercury (40 CFR 250); secondary mercury (40 CFR 421.200); steam electric power generation (40 CFR 423- Appendix A); and mercury ore mining (40 CFR 440.40). The CWA also requires that new and existing points sources of mercury obtain a NPDES permit, which will establish effluent limits for mercury discharges to surface waters.

To protect human health and preserve the nations drinking water supply, EPA has been tasked by the SDWA to establish safe drinking water standards for toxic chemicals. In accordance with the SDWA, EPA has established a safe drinking water standard for mercury of 2 μg/L.

The release or disposal of solid or hazardous waste containing mercury is regulated under RCRA, which outlines specific classification and disposal requirements for products and wastes that contain mercury. Mercury is both a characteristic and a listed waste under RCRA. A solid waste containing mercury may be considered a D009 characteristic hazardous waste if, when subjected to a TCLP test, the extract exceeds 0.2 mg/L [40 CFR 261.24] for mercury. Other mercury-contaminated wastes may be considered hazardous if they are specifically listed in 40 CFR 261.30-33, unless they are specifically excluded. Listed wastes for mercury include leachate resulting from the disposal of more than one restricted waste classified as hazardous (F039), and wastewater treatment sludge and brine purification muds resulting from the mercury cell process in chlorine production (K106 and K071 respectively). Hazardous wastes are subject to land disposal restrictions requiring that wastes be treated to below regulatory threshold levels before they may be land-disposed.

In order to reduce the amount of hazardous waste in a landfill, EPA established the Universal Waste Rule (UWR) in 1995. The rule was intended to encourage the recycling and proper disposal of common hazardous waste components found in municipal waste streams, and reduce the regulatory burden on businesses who produce these wastes. The rule allows for less stringent standards for storing, transporting, and collecting wastes. However, the waste must comply with full hazardous waste requirements for final recycling, treatment, or disposal. Batteries and fluorescent lamps are included in the rule.

EPA also has regulated the air emissions of mercury from hazardous waste combustion and from industrial boilers and furnaces under RCRA. EPA has issued new standards for mercury emissions from these sources.

In December 2000, EPA announced plans to require coal-fired power plants to cut their emissions of mercury. EPA plans to propose the regulations by 2003, with final rules in place by 2004 (EPA, 2000a). More recently, in April 2001 the Bush administration sought to dismiss an electric industry lawsuit that would stop the EPA from regulating mercury and other toxic air pollutants (Doggett, 2001).

Manufacturer’s who emit mercury are required to report the quantity of the emissions under the Emergency Planning and Community Right-to Know-Act (EPCRA). EPA has established a reportable quantity threshold of 10 pounds for a facility that manufactures, processes, or otherwise uses mercury. A similar threshold of 10 pounds exists for facilities that manufacture, process, or otherwise use mercury compounds. Data that has been reported by facilities for mercury is made available to the public through the publication of the Toxics Release Inventory (TRI).

4.2.7 Alternatives to Mercury Use in LCDs

In an effort to minimize or even eliminate the quantity of mercury used during the fabrication of LCDs, manufacturers have begun to develop mercury-free alternatives to mercury vapor backlights. One such alternative is a flat lamp which is filled with inert gas xenon in place of the typical mercury vapor lamps. The lamp has the appearance of a large white tile about one centimeter in thickness. Its dimensions are the exact same as the screen itself, illuminating the image evenly, hence eliminating the need for complex optical systems to distribute the light. The new lamp is capable of emitting enough light to make the monitor twice as bright, making it possible to use the screen during daylight, while also extending the viewing angle (OSRAM, 1998).

The new lamps generate light in a fashion similar to conventional backlight lamps. An electrical current passed through a gas discharge produces ultra-violet light which is then converted to visible light by phosphors. Unlike mercury gas which causes ‘greying’ in the phosphors over time, the xenon gas does not affect the phosphors, extending the life of the lamp. The lights have an average lifetime of up to 50,000 hours compared to only about 20,000 hours for the conventional mercury backlights, extending the life of computer LCD displays before they have to be replaced (OSRAM, 1998).

A drawback of the lamps, and the current subject of research is the reduced energy efficiency of the new mercury-free lamps. The luminous efficiency of the new mercury-free lamp is only about half of the efficiency of a conventional backlight, due to less efficient conversion of the UV light to visible light by the phosphors (OSRAM, 1998).

4.3 LIQUID CRYSTALS

One of the most significant differences between the two computer displays is the use of liquid crystals in the LCD to generate an image. The toxicity of liquid crystals in LCDs has been alluded to in literature indicating the potential for human health concerns. Because of relative lack of information about these compounds, this section provides a more detailed look a liquid crystals to better understand their potential impacts on human and ecological populations,

4.3.1 Liquid Crystals in Computer Displays

Liquid crystals (LCs) are organic compounds with the optical and structural properties of crystals, but with the mechanical features of fluids. There are hundreds of LC compounds that may be used in an LCD, each with different physical and optical characteristics. They are typically classified by molecular weight, with low molecular weight LCs typically used for LCD computer displays. LCs are not required for the fabrication of CRTs.

LCs are responsible for forming and transmitting the image produced by an LCD. The LC portion of an LCD typically consists of as many as 20 different LC substances, mixed together to form a white, opaque liquid that flows easily (Merck, 1999). The mixture consists of elongated molecules that are held together at their ends by polar forces and aligned in the same direction. The molecules move together in a series of flexible molecular chains, with each chain influencing the alignment of other chains. By exposing the molecular chains to electric fields, the alignment of the chains, and by extension their ability to transmit light, can be manipulated (SEMI, 1995).

LCDs are fabricated using a complex multi-step process in a clean room (refer to Chapter 1 for a more detailed description of the fabrication process). Once the front and back layers have been manufactured and assembled into a display cell, the LC is ready to be added. The assembled display cells are placed into a vacuum chamber containing a reservoir of the LC mixture, and the chamber is evacuated. A corner of the empty display cell is lowered into the LC mixture using a remote control. Nitrogen gas is then introduced into the evacuated chamber to bring the pressure up to approximately 1 atmosphere, exerting pressure on the surface of the LC mixture, forcing it up into the display cell (SEMI, 1995). Approximately 0.6 mg of LC is required for every square centimeter of panel surface (Merck, 1999). The display cell is sealed once the LC fully penetrates the cell.

4.3.2 Life-Cycle Inputs and Outputs of Liquid Crystals for Computer Displays

Data on LC compounds were collected and compiled as part of the life-cycle inventory. The data were aggregated by material from individual processes and presented by life-cycle stage for LCDs in Table 4-19**.**

The individual LC compounds identified in Table 4-19 formed the ingredients of the liquid crystal mixture used in the LCD. These compounds, used in varying quantities, are mixed together in a liquid crystal manufacturing process to develop a mixture with the desired optical characteristics for the LCD. While the above inputs illustrate the quantities of individual LC compounds found in the LCD evaluated in this LCA, LC mixtures found in other LCDs could be comprised of up to 20 or more liquid crystal compounds selected from the hundreds of compounds currently available for use in LCDs. A small quantity of the liquid crystal mixture (1.2 grams) is then used in the fabrication of the LCD.

Table 4-19. Life-cycle stage liquid crystal inputs

Life-cycle stage	Inputs [a]	Quantity	Units	Type
Manufacturing	Liquid crystal A	0.26	g	Primary material
Manufacturing	Liquid crystal B	0.37	g	Primary material
Manufacturing	Liquid crystal C	0.22	g	Primary material
Manufacturing	Liquid crystal D	0.33	g	Primary material
Manufacturing	Liquid crystal E	0.070	g	Primary material
Manufacturing	Liquid crystal F	0.34	g	Primary material
Manufacturing	Liquid crystal G	0.19	g	Primary material
Manufacturing	Liquid crystal mixture, for 15" LCD	1.2	g	Primary material

[a] Identities of liquid crystal compounds have been masked to protect the confidentiality of the compound names.

Life-cycle inventory data indicate that LCs are primarily released at the time of the product's final disposition. Although other outputs of liquid crystals surely exist, they are likely minimal and were not identified in the life-cycle inventory collected for LCDs. Evaporative LC emissions during the manufacturing and mixture formulation processes are minimal due to the typically low vapor pressures of LC compounds (Becker, 2001). Releases resulting from broken or defective LCDs during manufacture are also likely to be small because of the strong adhesives forces between LCs and the polymer film covering the outer layer of the displays (Becker, 2001). However, small amounts of LC compounds were observed to present in the waste of one LCD manufacturing facility during data collection (Overly, 2001). Because data were not provided from manufacturers on manufacturing releases, and no data were available for releases at end-of-life, it is difficult to definitively quantify the releases or their significance to the environment.

4.3.3 LCD Life-Cycle Impacts of Liquid Crystals

The life-cycle impacts of LC compounds calculated for LCDs during the LCIA are summarized in Tables 4-20. Impact values in the table are expressed in units specific to each impact category (see Chapter 3.1 for a discussion of impact category units and weighting). The total impact score for each category from LCs is presented at the bottom of the table.

Table 4-20. Summary of LCD liquid crystal impacts

Life-cycle stage	Material	Chronic health effects- occupational (tox-kg)
Manufacturing	Liquid crystal A	5.29E-04
Manufacturing	Liquid crystal B	4.35E-04
Manufacturing	Liquid crystal C	3.89E-04
Manufacturing	Liquid crystal D	1.40E-04
Manufacturing	Liquid crystal E	6.84E-04
Manufacturing	Liquid crystal F	6.53E-04
Manufacturing	Liquid crystal G	7.31E-04
Total category impact score		**3.56E-03**

Impact scores have been calculated based on the inventory item, release type, and its reported disposition. Occupational impacts to workers as a result of LC inputs are shown in the Table 4-20. Impacts were not calculated for LCs which end up as part of the product because users of the product are not expected to become exposed to the LC compounds during the typical operation of the LCD. In addition, because releases of LCs to the environment were not provided by the manufacturers in the LCI, potential impacts resulting from these releases were also not assessed in this project. LCs are not used to fabricate CRTs and so have no environmental impacts in the CRT life cycle.

LCs do not appear to contribute significantly to any of the impact categories defined for this study. The total score for occupational impacts based on potential worker exposure to LCs of 4.18 tox-grams represents less than 0.01% of the total overall chronic occupational health effects impact score of 898 tox-kg for the functional unit of one LCD.

4.3.4 Exposure Summary

Like any materials classified as potentially toxic, LCs have the potential to pose a threat to human health anytime there is the potential for human or ecological exposure throughout the life cycle of a LCD. Exposure occurs anytime a chemical or physical agent, in this case LC compounds, come into contact with an organism, be it human or ecological. This section qualitatively identifies potential exposures for workers in facilities using LCs (occupational exposures), the general public, who may be exposed to LC releases into the ambient environment, and the ecological population.

4.3.4.1 Occupational exposures

Occupational exposures to LCs during the fabrication of the LCD panels are not expected to be significant. LCD panels are fabricated in a clean room environment. The previously assembled but empty display cells are placed into a vacuum chamber containing a reservoir of the LC mixture, and lowered into the LC mixture using a remote control. Approximately 1.2 grams of LC compounds are used to develop the LCD panel. The enclosed nature of the chamber combined with the equipment (e.g., gloves, aprons) worn by workers in a clean room environment may both act to minimize exposures.

However, the potential for other occupational exposures still exist. Workers could become exposed to LCs during other manufacturing process steps, such as during the formulation of the LC mixture (approximately 1.8 grams from Table 4-31), the handling and disposal of broken or defective panels, or during the recycling or disposal of an LCD at the end of its useful life. Because of the physical nature of the LCs (e.g., they are not volatile), typical worker exposures are likely to be through dermal or ingestion (e.g., accidentally ingesting LC present on a workers hands) routes. Worker exposure to LCs via dermal exposure is expected to be minimal for workers who wear gloves while handling LCs.

4.3.4.2 General population

Because of the enclosed nature of the LCD panel, it is unlikely that consumers could become exposed to LC compounds contained within the display through normal usage. LCs may be released into the environment should the panel become fractured, either through accident or through final disposal. No other releases of LC compounds into the environment were identified by the LCI data collected for the LCD, making it difficult to assess any possible exposures to nearby populations.

4.3.4.3 Ecological populations

Potential exposure to ecological populations could typically only occur through the migration of LCs through the environment after being released during manufacturing or disposal (either at LCD end-of-life, during disposal of broken or damaged panels during manufacturing, or during disposal of containers or equipment contaminated with LCs). The potential for transport of the LC through the environment is dependent on the identity of the chemical compound. The number of choices of LC compounds along with the unavailability of data on disposal quantities make it difficult to accurately assess the potential exposures which might result.

4.3.5 Human Health Effects

There are at least ten meaningful groups of liquid crystal compounds representing several hundred LC substances. Each of these substances is chemically unique, each having the potential to affect human health. Because of the number of LC compounds potentially present in the LCD, it is not possible to provide a comprehensive review of the human health effects of the universe of liquid crystal substances. However, a review of a small sample of LC compounds, those which appeared in the project LCI collected for the LCD, was conducted by EPA and the results presented below.

Toxicological testing of LC substances and mixtures was conducted by three manufacturers responsible for roughly 90% of LC production. Testing of their chemical products included testing for acute toxicity effects, and effects on skin and eyes. Results of the testing indicated that of 588 LC substances tested, only twenty-five LC compounds had an LD_{50}[5] less

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[5] LD_{50} represents the dose of chemical which is lethal to 50% of the test population. By comparison, the LD_{50} for sodium chloride (table salt) is 3,000 mg/kg of body weight.

than 2,000 mg/kg of body weight (classified as exhibiting harmful effects to humans by the European Union), and only one had a LD_{50} of less than 200 (classified as toxic by the European Union). The remaining 562 LC substances did not have any acute toxic potential. Of the twenty-five harmful LCs, only twenty-two substances are produced and all are present at less than 10% concentration by weight, meaning that the resulting LC mixtures are not expected to exhibit harmful properties to humans (Becker, 2000). The remaining three harmful chemicals along with the lone toxic chemical were discontinued and excluded from further development. Several compounds, but still a minority, were found to be skin or eye irritants (Merck, 1999).

4.3.5.1 Chronic effects (noncancer)

EPA conducted a review of existing toxicological data for the LC substances listed in Table 4-31. The review failed to identify a RFD, RFC, NOAEL, or LOAEL for any of the LC substances shown. This typically indicates that insufficient testing of these chemical compounds has been performed to accurately determine their potential for chronic human effects.

4.3.5.2 Carcinogenicity and mutagenicity

An EPA review of toxicological studies for the liquid crystals identified in the life-cycle inventory for LCDs failed to identify an existing slope factor for any of the LC compounds. A lack of carcinogenicity data usually does not indicate that a compound is not carcinogenic, but only that sufficient testing to ascertain carcinogenicity has yet to be performed.

Toxicological testing of LC substances for mutagenic effects was conducted by three manufacturers responsible for roughly 90% of LC production. In a bacterial mutagenicity test of 615 LC substances, one LC compound showed mutagenic potential, with the remaining compounds displaying no mutagenic effects. The lone chemical that failed the test was excluded from further development and was never marketed (Becker, 2000). Additionally, 10 LC compounds representing each of the significant groups of LCs, underwent mutagenicity testing using mammalian cells. None of the tests indicated mutagenic activity. Based on both sets of data, the manufacturer concluded that there does not appear to be a suspicion of mutagenic potential in the liquid crystals it produces (Merck, 1999).

4.3.6 Environmental Regulations for Liquid Crystals

No regulations exist specifically for liquid crystals compounds. However, regulations may exist for individual liquid crystal compounds. Because of the number of possible LC compounds available for use in a LCD, a comprehensive review of U.S. regulations could not be provided.

4.4 CONCLUSIONS

The purpose of this chapter was to provide a more detailed analysis of a few select materials of interest to EPA and industry that was intended to better understand the potential exposures and chemical risks to both human and ecological populations. The materials selected for further analysis included lead, mercury, and liquid crystals, each selected for its known or suspected toxicity to humans and the environment, or because they are of particular interest to indsutry or the U.S. EPA. The analysis of each material summarized or evaluated the following key areas:

- Use of the materials in computer displays;
- Life-cycle inputs and outputs of the materials from computer displays;
- Life-cycle impacts associated with the material inputs and outputs;
- Potential exposures to the material including occupational, public, and ecological exposures;
- Potential human health effects;
- U.S. environmental regulations for the material; and
- Alternatives to reduce the use of the material in computer displays.

The following are the conclusions drawn from the analyses of lead, mercury, and liquid crystal use in the life cycle of both CRTs and LCDs.

4.4.1 Lead

Lead is found in glass components of CRTs, as well as in electronics components (printed wiring boards and their components) of both CRTs and LCDs. It is also a top priority toxic material at the U.S. EPA and the subject of electronics industry efforts to reduce or eliminate its use. The following conclusions were drawn from a focused look at lead's role in the life cycle of the computer display, and its effects on human health and the environment:

- Due to the much greater quantity of lead in the CRT than the LCD, lead-based life-cycle impacts from the CRT ranged from moderately to significantly greater than those from the LCD in every category, with the exception of solid waste landfill use. The most significant difference was in non-renewable resource consumption, where the CRT consumed over 40 thousand times the mass of non-renewable resources over the course of its life cycle than those consumed by the LCD. Other categories where CRTs had notably greater differences in impacts occurred in hazardous waste landfill use, chronic public health effects, and terrestrial toxicity.
- Contributions of lead-based impacts are small relative to the total life-cycle impacts from other materials in the CRT (e.g., glass, copper wire), with the greatest impacts from lead-based CRT outputs occurring in the categories of non-renewable resources, aquatic toxicity, and chronic public health effects (ranging from 0.1 to 0.2% of the overall impact scores in each category).
- For workers, inhalation is the most likely route of exposure to lead which may result in health concerns. General population exposure to lead is most likely to come from incidental ingestion of lead in the soil, or ingestion of lead brought into the household on

workers clothing or on shoes. Studies have discovered potentially high concentrations of lead in households within close proximity to certain facilities that use lead.

- Significant worker exposures to lead have been documented by existing studies of several processes which contribute to the life-cycle of the computer displays (e.g., lead smelting). These exposures have been as high as 90 times the OSHA recommended safety levels for exposure to workers at lead smelters. The resulting occupational chronic health effects to workers from lead exposure likely have been underestimated by the CDP LCIA methodology, which uses material inputs, and not outputs, as surrogates for exposure.
- Lead and lead compounds pose serious chronic health hazards to humans who may become over-exposed either in the workplace, or through the ambient environment. Lead exposure is associated with a range of adverse human health effects, including effects on the nervous system, reproductive and developmental problems, and cancer. Lead persists in the environment, but is relatively immobile in water under most surface and groundwater conditions.
- Alternatives are being developed, such as lead-free solders and glass components, that will potentially minimize the future lead content in both CRTs and LCDs.

4.4.2 Mercury

Mercury is contained within the fluorescent tubes that provide the source of light in the LCD. Mercury is also emitted from some fuel combustion processes, such as coal-fired electricity generation processes, which contribute to the life-cycle impacts of both CRTs and LCDs. EPA's concern with mercury and the potential for exposure during manufacturing and end-of-life processes warranted a more detailed analysis of mercury in the CDP. The following conclusions were drawn from a focused look at mercury's role in the life cycle of the computer display, and its effects on human health and the environment:

- The mercury emitted from the generation of power consumed by the CRT (7.75 mg) exceeds the entire amount of mercury emissions from the LCD, including both the mercury used in LCD backlights (3.99 mg) and the mercury emissions from electricity generation (3.22 mg). Although this was not expected because mercury is used intentionally in an LCD, but not in a CRT, the results are not surprising since mercury emissions from coal-fired power plants are known to be one of the largest anthropogenic sources of mercury in the United States. Because the CRT consumes significantly more electricity in the use stage than the LCD, its use stage emissions of mercury are proportionately higher than those of the LCD.
- Contributions from mercury-based impacts are not significant relative to the total life-cycle impacts from other materials (e.g., glass, copper wire) in the CRT or LCD, with the greatest impacts from mercury-based outputs occurring in the aquatic toxicity category (0.4% for CRTs, 0.01% for LCDs)
- Possible pathways of worker exposure during backlight fabrication include inhalation of mercury vapors, and dermal exposure or ingestion of mercury on skin. The most likely pathway for general population exposure is inhalation of mercury released into the air.
- Exposure data relevant to the manufacturing of mercury backlights were not available, therefore specific conclusions about the potential magnitude of worker exposures could not be made. Occupational chronic health effects to workers from mercury exposures

calculated during the impact assessment (3.99e-06 tox-kg for LCD, none for CRT) likely have been underestimated by the CDP LCIA methodology, which uses material inputs as surrogates for exposure.

- Mercury and mercury compounds pose serious chronic health hazards to humans who are exposed. EPA has determined that mercury chloride and methylmercury are possible human carcinogens. Mercury poses serious chronic health hazards to humans, affecting the nervous system, brain, and kidneys.
- Alternative backlights have been developed that not only eliminate mercury from the light, but also improve on many of the optical characteristics of the displays. Current development is focused on improving the energy efficiency of the alternative lights.

4.4.3 Liquid Crystals

Liquid crystals are organic compounds responsible for generating the image in an LCD. LCs are not present in CRTs. The toxicity of the LCs in LCDs has been alluded to in the literature, yet there is very little known about the toxicity of these materials. By including LCs in a more detailed analysis, this section attempted to better characterize any potential hazard and/or potential exposure of LCs from the manufacturing, use, and disposal of LCD monitors. The following conclusions were drawn from a focused look at LCs role in the life cycle of the computer display, and its effects on human health and the environment.

- LCs are combined into mixtures of as many as 20 or more compounds selected from hundreds of potential liquid crystal compounds. Because of the possible variations in mixtures and the sheer number of compounds available, a select number of liquid crystals were used to assess potential human health hazards.
- LCs do not appear to contribute significantly to any of the impact categories defined for this study. The total score for LCD occupational impacts based on potential worker exposure to LCs of 4.18 tox-grams, calculated using default toxicity values, represents less than 0.01% of the total overall chronic occupational health effects impact score of 898 tox-kg for the functional unit of one LCD.
- Impacts were not calculated for LC releases in the CDP LCIA because data regarding LC outputs were not available to the project. LCs are not used to fabricate CRTs and so have no environmental impacts in the CRT life cycle.
- Occupational exposures to LCs during the fabrication of the LCD panels are not expected to be significant. The enclosed nature of the chamber in which the LCDs are assembled, combined with the equipment (e.g., gloves, aprons) worn by workers in a clean room environment, are both expected to act to minimize exposures. Other occupational exposures may exist that have not been identified.
- Toxicological testing by a manufacturer of LC substances and mixtures showed that 95.6% (562 of 588) of the liquid crystals tested displayed no acute toxic potential to humans. Twenty-five of the remaining twenty-six chemicals had the potential to exhibit harmful effects to humans, while the remaining crystal was classified as toxic (EU classification) and thus was discontinued. An EPA review of toxicity data for the confidential LC compounds was unable to identify any relevant toxicity information. Insufficient toxicity data exist to assess the toxicity of specific LC compounds.

- Testing for mutagenic and carcinogenic effects by the supplier showed that 99.9% (614 out of 615) of the liquid crystal compounds tested displayed no mutagenic effects. The remaining chemical that showed mutagenic potential was excluded from further development. Additionally, mutagenicity testing of ten LC substances using mammalian cells showed no suspicion of mutagenic potential.

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Chapter 5

SUMMARY AND CONCLUSIONS

The purpose of the CDP, as stated in Chapter 1, is to provide a scientific baseline of life-cycle environmental impacts of CRTs and LCDs, help manufacturers identify areas to focus improvement assessment activities, and to develop a life-cycle model for future analyses. The primary targeted audience is the electronics industry, for whom results may provide insight into improvement opportunities in the life cycle of CRTs and/or LCDs. In addition, the general public may also find results useful when considering environmental impacts of each display type. This chapter briefly summarizes the results and draws conclusions based on those results. This report, however, does not include direct comparative assertions or improvement assessments based on the results. Alternatively, results and conclusions are described in terms of the overall LCI versus the LCIA, and details of the impact assessment, including the additional assessments of lead, mercury and liquid crystals, and the sensitivity analyses. Major uncertainties, cost and performance considerations, suggestions for improvement opportunities, and suggestions for further research are also provided.

5.1 LCI vs. LCIA

In this LCA, a life-cycle inventory (LCI) was compiled from many data sources, including both primary and secondary data sources. The primary data were obtained from component and monitor manufacturers of CRTs and LCDs. In an LCA, inventory data provide information on how much material is being consumed in the life cycle (i.e., inputs) and how much material is generated/released (i.e., outputs). The LCI results of this report are detailed in Chapter 2. The LCI provides inventory data grouped by inventory type (e.g., primary material, energy, air emission, solid waste).

The LCI alone, however, does not always translate directly into impact categories that may be of interest. That is, a given amount of one material may have different impacts (for a certain impact category) than the same amount of another material. Furthermore, some materials may affect more than one impact category. For example, an air emission could affect air acidification as well as being toxic to humans breathing it. Therefore, a life-cycle impact assessment (LCIA) is conducted to reveal potential impacts in several impact categories. In this CDP LCIA, described in detail in Chapter 3, impacts are sometimes driven by materials other than the top inventory contributors. For example, the top air emission for LCDs is carbon dioxide (Table 2-49), however the greatest global warming impact score is from SF_6 in the LCD monitor/module manufacturing process (Table 3-25).

To illustrate that the inventory results may not directly translate into impact results, the first two columns in Table 5-1 show which monitor has greater inventory amounts for each inventory type in the LCI, and the last two columns show which monitor has greater impact scores for each impact category in the LCIA. The impact categories that are affected by each inventory type are in the same rows as the associated inventory type. As seen in Table 5-1, some impact categories associated with ancillary material and water pollutant inventory types had opposing outcomes in the LCI versus the LCIA. For example, the three impact categories affected by the ancillary material inventory had greater impacts for the CRT, although the ancillary material inventory had greater amounts of inputs for the LCD. In this case, both primary and ancillary materials contribute to the impact categories, causing differing results.

Considering the wastewater outputs, which are greater for the LCD than the CRT, the impacts related to water releases are in some cases greater for the CRT than the LCD. Note that although the wastewater volume is greater for the LCD, the total mass of water pollutants in the LCI is greater for the CRT (see Table 2-24). In the LCIA, the LCD has greater impacts for water eutrophication and aquatic toxicity, but not for the two water quality categories (BOD and TSS), chronic health effects to the public, nor terrestrial toxicity, all of which include water emissions in calculating the impact score.

Table 5-1. Baseline LCI vs. LCIA: monitor with greater inventory amount and impact

Baseline life-cycle inventory (LCI)		Baseline life-cycle impact assessment (LCIA)	
Inventory type	**Monitor with greater inventory results**	**Potential impact category(ies) associated with inventory type**	**Monitor with greater impact results**
Primary materials	CRT	Renewable resource use	CRT
		Nonrenewable resource use	CRT
		Chronic health effects, occupational	CRT
Ancillary materials	LCD	Renewable resource use	CRT
		Nonrenewable resource use	CRT
		Chronic health effects, occupational	CRT
Water inputs	CRT	Renewable resource use	CRT
Fuel inputs	CRT	Energy use	CRT
		Chronic health effects, occupational	CRT
Electricity inputs	CRT	Energy use	CRT
Total energy inputs	CRT	Energy use	CRT
Air pollutant outputs	CRT	Global warming	CRT
		Ozone depletion	*a*
		Photochemical smog	CRT
		Acidification	CRT
		Air particulates	CRT
		Chronic health effects, public	CRT
		Aesthetics (odor)	CRT
		Terrestrial toxicity	CRT

Table 5-1. Baseline LCI vs. LCIA: monitor with greater inventory amount and impact

Baseline life-cycle inventory (LCI)		Baseline life-cycle impact assessment (LCIA)	
Inventory type	**Monitor with greater inventory results**	**Potential impact category(ies) associated with inventory type**	**Monitor with greater impact results**
Wastewater outputs	LCD	*none*	NA
Water pollutant outputs	CRT	Water eutrophication	LCD
		Water quality, BOD	CRT
		Water quality, TSS	CRT
		Chronic health effects, public	CRT
		Aquatic toxicity	LCD
		Terrestrial toxicity	CRT
Hazardous waste outputs	CRT	Hazardous waste landfill use	CRT
Solid waste outputs	CRT	Solid waste landfill use	CRT
Radioactive waste outputs	CRT	Radioactive waste landfill use	CRT
Radioactivity outputs	CRT	Radioactivity	CRT

[a] The LCIs for both the CRT and LCD contain data for substances that were phased out of production by 1996 due to their ozone depletion potential. Whether these emissions still occur in countries that were signatories to the Montreal Protocol and its Amendments and Adjustments (such as the United States and Japan) is not known, but considered to be unlikely. When phased-out substances are included in the inventory, the CRT has greater ozone depletion impacts than the LCD. However, if phased-out substances are removed from the inventories, the results are switched, with the LCD having greater impacts.

5.2 LCIA RESULTS

5.2.1 CRT and LCD Baseline Results

The LCIA results, presented in detail in Chapter 3, showed that the CRT has greater total life-cycle impact indicators in most of the impact categories (see Table 3-10). In the baseline scenario, the CRT has greater impacts than the LCD in all but two impact categories (eutrophication and aquatic toxicity). However, note that for the ozone depletion category, the LCIs for both the CRT and LCD contain data for substances that were phased out of production by 1996 due to their ozone depletion potential. Whether these emissions still occur in countries that were signatories to the Montreal Protocol and its Amendments and Adjustments (such as the United States and Japan) is not known, but considered to be unlikely. When phased-out substances are included in the inventory, the CRT has greater ozone depletion impacts than the LCD. However, if phased-out substances are removed from the inventories, the results are switched, with the LCD having greater impacts.

When considering which life-cycle stage has greater impacts, the LCIA results showed that the manufacturing life-cycle stage dominates impacts for most impact categories for both the CRT and LCD (refer to Section 3.3). Table 5-2 summarizes which life-cycle stages have the greatest impacts for each impact category for the CRT and LCD. As shown in Table 5-2, the CRT has nine and the LCD has 11 impact categories with greatest impacts from the manufacturing life-cycle stage. Only six categories (solid waste landfill use, global warming, ozone depletion, acidification, air particulates, and chronic public health) have greatest impacts from the CRT use stage, and four categories (solid waste landfill use, acidification, air particulates, and chronic public health) have greatest impacts from the LCD use stage. The CRT has three categories with greatest impacts from the upstream life-cycle stage and the LCD has three. The end-of-life (EOL) life-cycle stage is greatest for the same two impact categories for both the CRT and LCD (hazardous waste landfill use and radioactive waste landfill use). Note that the EOL stage impacts are generally very small contributors to the overall impacts. This is likely because of the small inventories associated with the EOL processes, but also may be a function of the incomplete and/or secondary data for the EOL (i.e., no remanufacturing data, and secondary data not completely specific to the monitors evaluated in this study).

A more detailed evaluation of lead, mercury, and liquid crystals was completed in Chapter 4. As expected, the CRT, which has lead in the glass, frit, and printed wiring boards (PWBs), has greater impacts from lead than did the LCD, which only has lead in the PWBs. Regarding mercury, there were greater inventories of mercury in the CRT life cycle than in the LCD life cycle, despite the fact that only the LCD has mercury directly in the product. The greater amount of mercury is from the release of mercury and mercury compounds from the generation of electricity. And as the CRT life cycle uses more electricity than the LCD, there was a greater quantity of mercury releases reported for the CRT than the LCD. Liquid crystals are only found in LCDs, and therefore, there are no associated impacts for the CRT. Little conclusive information was available on the liquid crystal materials. A detailed literature search was conducted, however very little data were available on the toxicity of these materials. Based on the limited toxicity data obtained, liquid crystals currently do not appear to be a significant human health or environmental hazard in the LCD life cycle. However, there were insufficient toxicity data available to make a definitive conclusion about liquid crystal toxicity.

Table 5-2. Monitor type with greatest impacts for each life-cycle stage and impact category (baseline scenario)

Impact category	Monitor type with greatest impacts			
	Upstream	Manufacturing	Use	EOL
Renewable resource use	LCD	CRT		
Nonrenewable resource use		CRT, LCD		
Energy use		CRT, LCD		
Solid waste landfill use			CRT, LCD	
Hazardous waste landfill use				CRT, LCD
Radioactive waste landfill use				CRT, LCD
Global warming		LCD	CRT	
Ozone depletion		LCD	CRT	
Photochemical smog	LCD	CRT		
Acidification			CRT, LCD	
Air particulates			CRT, LCD	
Water eutrophication	CRT	LCD		
Water quality, BOD		CRT, LCD		
Water quality, TSS		CRT, LCD		
Radioactivity	CRT, LCD			
Chronic health effects, occupational		CRT, LCD		
Chronic health effects, public			CRT, LCD	
Aesthetics (odor)		CRT, LCD		
Aquatic toxicity	CRT	LCD		
Terrestrial toxicity		CRT, LCD		
TOTALS	CRT=3 LCD=3	CRT=9 LCD=11	CRT=6 LCD=4	CRT=2 LCD=2

5.2.2 CRT Results

For the CRT, many of the impacts were driven by a single material in the inventory. As stated in Section 3.3.15 and shown in Table 3-57, in 14 of the 20 impact categories, the top individual contributor to the impacts was responsible for greater than 50% of the impacts. This shows that the CRT data are highly sensitive to a few data points. Major conclusions from the CRT LCIA are as follows:

- Energy used in glass manufacturing and associated production of LPG are driving the baseline CRT results (they dominate ten impact categories, including overall life-cycle energy use).

- The large amounts of fuel used as energy sources are driving occupational health effects. Occupational impacts are calculated from inventory input amounts, and therefore there may or may not actually be exposure to these fuels (e.g., they may be contained); however, the results illustrate the potential for health effects, especially under spill or upset conditions.
- The generation of electricity for the use stage dominates seven impact categories.
- Air emissions of sulfur dioxide from electricity generation (for the use life-cycle stage) drive chronic public health effects, acidification, and terrestrial toxicity impacts. This may be a concern, for example, in areas in nonattainment of regulated levels of sulfur dioxide in the United States.

The use of LPG fuel in glass manufacturing dominated ten impact categories: two directly from the LPG used in glass/frit manufacturing (energy use impacts and chronic occupational health effects) and eight from LPG production (renewable resource use, nonrenewable resource use, photochemical smog, air particulates, water eutrophication, BOD water quality, TSS water quality, and aesthetics). In addition, impacts from the generation of electricity during the use stage dominated seven impact categories: solid waste landfill use, radioactive waste landfill use, global warming, ozone depletion, acidification, chronic public health, and terrestrial toxicity. The CRT tube manufacturing process, which represents the most functionally and physically (by mass) significant component of the CRT monitor, only dominated one impact category (aquatic toxicity). Twenty-six percent of the aquatic toxicity score was from phosphorus outputs from tube manufacturing, while most of the rest were from the materials processing life-cycle stage. The remaining two impact categories (hazardous waste landfill use and radioactivity) had greatest impacts from the landfilling of the assumed hazardous proportion of CRT monitors, and the release of Plutonium-241 in steel production, respectively (Table 3-57). The radioactivity impacts are driven by the radionuclide Pu-241, due to the electric grid inventory included in the steel production secondary data set, which includes nuclear fuel reprocessing.

The large amount of LPG reported for glass manufacturing was originally questioned during the data collection and verification stage of this project. While no compelling reason could justify removing the LPG data in the baseline case, a sensitivity analysis was conducted in which the glass energy data were modified. Other sensitivity analyses were also conducted (i.e., manufactured life, modified LCD monitor manufacturing energy, and modified LCD EOL distributions). However, the only scenario that substantially altered the comparative results was the modified glass energy scenario (see Table 3-62 and Section 3.4.5).

The overall energy in the baseline scenario was nearly seven times greater than that in the modified scenario (from 20,800 MJ to 3,020 MJ), and the amount of LPG dropped to zero, while other energy sources increased. The basis for the modified data was removing the energy inputs from one suspect data set. As a result, the CRT modified glass energy scenario had greater energy use impacts in the *use* stage than in the *manufacturing* stage for the CRT. The amount of LPG used in glass manufacturing in the baseline scenario is 351 kg/monitor of LPG, which alone costs about $71.[1] This is a significant amount of the cost of a complete CRT monitor (the range of a few currently selling 17" CRTs is $158-316, and the average cost from primary data collected in the CDP was $541, which are presented in Section 5.4). Therefore, it is likely that the actual energy inputs to the glass manufacturing process is somewhere between the baseline and modified glass scenarios. In conclusion, more information is needed on energy used in glass manufacturing, which is driving CRT baseline results.

The additional analyses for the CRT of lead and mercury also revealed that the use of lead could present health risks, but the method of using only inputs to evaluate occupational impacts (see Section 3.1.2.13) may not adequately represent occupational exposures and risks. Further refinement of the occupational impact analysis may be warranted.

Although there is no mercury in the CRT monitor, mercury emissions from electricity generation in the CRT life cycle were greater (in mass) than the mercury used in the LCD. Therefore, to reduce mercury emissions from the CRT life cycle, efforts to reduce electricity consumption could be taken. Additionally, changes to the electric grid could also reduce mercury emissions from the CRT life-cycle.

5.2.3 LCD Results

The LCD impact results were less sensitive to an individual input or output than the CRT results, although in 11 of the 20 impact categories an individual input was still responsible for greater than 50% of the total impacts (Table 3-58). In general, the LCD results are less uncertain than the CRT results. This is because most of the CRT results are being driven by either glass input data or data from secondary sources, while LCD impacts are being driven more by data from primary sources. Some results to note are as follows:

- The LCD monitor/module manufacturing process group had greatest impacts in six impact categories (Table 3-58).
- Although the top contributor to the energy impact category was electricity consumed in the use stage (30%), the overall energy impacts were greater from the manufacturing stage than the use stage.
- In the glass energy sensitivity scenario, the use stage had greatest energy impacts, although only by a small margin over the manufacturing stage (see Figure 3-26).
- Sulfur dioxide [emitted from electricity generation for the use stage, and constituting only 0.37% of the air emission inventory (see Table 2-49)] dominates the acidification, chronic public health, and terrestrial toxicity impact categories (Table 3-58). The high public health and terrestrial toxicity scores are due to its low non-cancer toxicity value and resulting high hazard value (HV).
- Sulfur hexafluoride (SF_6) from LCD monitor/module manufacturing was the single greatest contributor to the global warming impact score; however, carbon dioxide from the use stage and the materials processing stage also contributed significantly to the global warming impacts (Table 3-25).

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[1] Based on a “daily market price” on August 29, 2001, of $0.4160/gallon of LPG (http://www.americanpowernet.com/pub_energy/futures.html). For 351 kg/functional unit in the CRT manufacturing life-cycle stage, the cost is about $71 per functional unit (i.e., one monitor), assuming a density of LPG of 2.053 kg/gallon. For the LCD, the 16.8 kg/functional unit of LPG would cost about $3.40 per monitor.

- The glass energy inputs did not directly dominate any impact categories, as they did for the CRT (due to the smaller mass of glass in the LCD); however, LPG production (required for the glass energy fuel) dominated two categories: TSS water quality and aesthetics (Table 3-58).
- LNG as an ancillary inventory material was questionably very large and had greatest impacts in two categories: nonrenewable resource use and photochemical smog (Table 3-58; shown there as "Natural Gas Production" due to that process being used as a surrogate for LNG production).

The additional analyses of lead, mercury, and liquid crystals showed that the LCIA alone is not adequate enough to determine all the potential impacts within the life-cycle of the LCD monitors. Similar to the conclusion for the CRT, lead-based occupational impacts would require further refinement of the LCIA methodology. The LCIA method in this LCA used inputs as surrogates for occupational exposure. There are outputs, within the occupational setting, that should also be considered.

For mercury, which is found in the backlights of the LCD monitors, there is nearly the same amount of mercury by mass emitted to the air during electricity generation as there is mercury used to make the backlight unit. The mass of mercury input for backlights is only about 20% greater than the mercury air emissions from electricity generation (across all life-cycle stages).

Liquid crystals were also identified by the CDP Core Group as a material for which additional information would be reviewed. The LCIA did not find the liquid crystals to be significant contributors to any impact categories; however, this could partially be due to the lack of information on them. The additional analysis also revealed limited information, but qualitatively, did not show significant potential risk.

5.2.4 CRT vs. LCD Sensitivity Analysis Results

The only sensitivity analysis to show significant difference in the results was the modified glass energy scenario. In comparing the CRT and LCD, the CRT *baseline* scenario had greater impacts than the LCD in all but two impact categories (eutrophication and aquatic toxicity) and possibly three (ozone depletion). In the *modified glass energy scenario*, nine of the 20 categories had greater impacts from the LCD life-cycle than the CRT. Energy use remained greater for the CRT; however, nonrenewable resource use, global warming, photochemical smog, eutrophication, BOD and TSS water quality, chronic occupational health effects, and aesthetics all reversed such that the LCD had greater impacts than the CRT (Table 3-62). As stated above, it is believed that a more true representation of the monitor life cycles lies somewhere between the baseline and modified glass energy scenario. Further work is recommended in clarifying and refining glass energy input information.

5.3 UNCERTAINTIES

As with any LCA, it is not uncommon for there to be uncertainty associated with such a large data collection effort. Two of the largest sources of uncertainty in this LCA that have a significant effect on the results are as follows:

- *CRT and LCD glass manufacturing energy inputs (from primary data)*: The larger amount of glass used in CRTs than LCDs results in the CRT having greater associated uncertainty than the LCD results.
- *Secondary data for upstream and fuel production processes*: When any one material is used in the life-cycle of either monitor in large quantities, the impacts associated with the inputs and outputs from the production of that material may become significant. For example, LPG and LNG production were both used in significant enough amounts to influence some impact categories. Therefore, the uncertainty in the secondary data becomes important. This highlights the need for a consistent, national (or international) LCI database that is updated regularly.

Other uncertainties associated with individual data points collected from primary data sources may be found in the data for this analysis. However, they had less effect on the overall results than the uncertainties mentioned above. For manufacturers interested in conducting improvement assessments, closer review of such uncertainties may be warranted.

Other uncertainties in the LCA pertain to uncertainties inherent in LCIA methodology. The purpose of an LCIA is to evaluate the *relative potential* impacts of a product system for various impact categories. There is no intent to measure the *actual* impacts or provide spatial or temporal relationships linking the inventory to specific impacts. Uncertainties are inherent in each impact category, and the reader is referred to the baseline LCIA results in Section 3.3 for a detailed discussion of uncertainties by impact category.

Another point that should be recognized in the overall comparison of CRTs and LCDs is that CRTs are a more mature technology than LCDs. Changes in LCD manufacturing processes have likely occurred during the development and publication of this report. Therefore, comparisons must be carefully drawn when evaluating the mature CRT to the newer LCD technology.

5.4 COST AND PERFORMANCE CONSIDERATIONS

The focus of this study has been on the environmental effects associated with CRTs and LCDs. The environmental attributes or burdens of a product are not expected to be considered alone when evaluating the marketability and commercial success of a product. The cost and performance of each monitor type are obviously critical components to a company's or consumer's decisions of whether to produce or purchase a product. This section briefly addresses a few direct costs associated with the monitors. A complete cost analysis, including all direct costs (e.g., material costs) and indirect costs (e.g., environmental costs to society) are beyond the scope of this report. Direct retail costs of the monitors and electricity costs are presented herein.

The average retail price of 1997-2000 model year monitors, collected from the manufacturers who supplied data for this project, as well as the performance information, are presented in Table 5-3. Costs collected from current monitors on the market are presented in Table 5-4. From Table 5-3, which represents primary data collected on the actual monitors included in this study, the LCD is approximately 2.7 times more costly. More recent data show that prices have come down, and the difference in prices between the CRT and LCD has also been reduced.

Table 5-3. Primary cost and performance data collected from manufacturers for the CDP

Monitor	Display Size	Resolution	Brightness range	Contrast ratio range	Number of Colors	Average cost from primary data
	(inches)	(pixels)	(cd/m^2)			(US$)
CRT monitor (functional unit aggregate)	17	1024x768	86-154	----	"Full color"	$541
LCD monitor (functional unit aggregate)	15	1024x768	200-300	200:1 - 300:1	"Full color"	$1,450

---- Not reported or not applicable.

A complete cost analysis would require assessing the costs from each life-cycle stage. The costs presented above are retail costs that presumably represent the manufacturing costs, but probably not external environmental costs, for example. The costs from the use stage can be represented by the electricity costs during the use stage. The average cost of residential and commercial electricity in the United States is approximately $0.021/MJ,[2] and the CRT and LCD monitors use about 2,290 and 853 MJ/functional unit, respectively, in the use stage baseline scenario, which assumes a total of 13,547 hours per life over a period of 6.5 years (see Section 2.4.1.2). Therefore, the electricity costs to consumers during the use stages are $48 for the CRT and $18 for the LCD. The amount of electricity consumed and the associated cost of that electricity for each life-cycle stage in the baseline scenario are presented in Table 5-5.

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[2] This number was calculated from a value found at the following Web address: www.eia.doe.gov/cneaf/electricity/ esr/t11.txt.

Table 5-4. Cost and performance data for some currently selling CRTs and LCDs[a]

Monitor	Display Size	Resolution	Brightness	Contrast ratio	Number of Colors	2001 Cost
	(inches)	(pixels)	(cd/m^2)			($US)
CRTs						
Monitor 1	17/16	1280x1040	----	----	----	$158
Monitor 2	17/16.1	1280x1040	----	"High contrast, anti-static, anti-glare coating."	----	$171
Monitor 3	17/16	1600x1200	----	----	----	$316
LCDs						
Monitor 1	15.1	1024x768	----	200:1	16.7 million	$349
Monitor 2 [b]	15.1	1024x768	200	250:1	16.7 million	$400
Monitor 3	15.1	1024x768	200 [c]	200:1 [c]	16+ million	$439
Monitor 4 [b]	15.1	1024x768	200	250:1	16.7 million	$499
Monitor 5	15	1024x768	210 [c]	350:1	----	$554

[a] All information from Vol. EC23 of the eCOST.com catalog, except where noted otherwise.

[b] Data from the manufacturer's Web site except for prices, which where obtained from http://www.cdw.com on 8/29/01.

[c] Data are from the manufacturer's Web site.

---- Not reported or not applicable.

Table 5-5. Life-cycle electricity costs (baseline scenario)

	CRT			LCD		
Life-cycle stage	**Electricity use (MJ/functional unit) (see Table J-3)**	**unit cost ($/MJ)**	**Cost ($US)**	**Electricity use (MJ/functional unit) (see Table J-12)**	**unit cost ($/MJ)**	**Cost ($US)**
Upstream	73.2	0.012 [a]	$1.3	8.55	0.012 [a]	$0.10
Manufacturing	129	0.012 [a]	$1.5	278	0.012 [a]	$3.4
Use	2,290	0.021 [b]	$48	853	0.021 [b]	$18
EOL	0.229	0.012 [a]	$0.003	0	0.012 [a]	0
Total	2,492	---	$51	1,140		$22

[a] 1999 U.S. average cost of electricity for the industrial sector is $0.0443/kWh. Assuming 3.6 MJ/kWh, ($0.0443/kWh)/(3.6 MJ/kWh) = $0.012/MJ. Source: www.eia.doe.gov/cneaf/electricity/esr/t11.txt. Note that the use of the *U.S.* average cost is simply to compare costs among life-cycle stages, although the actual costs would be mostly from *Asia*.

[b] 1999 U.S. average cost of electricity for the residential and commercial sectors is $0.0771/kWh. Assuming 3.6 MJ/kWh, ($0.0771/kWh)/(3.6 MJ/kWh) = $0.021/MJ. Source: www.eia.doe.gov/cneaf/electricity/esr/t11.txt.

5.4 COST AND PERFORMANCE CONSIDERATIONS

The LCA is defined such that the monitor assessments are performed on a functionally equivalent basis. To the extent possible, data were collected on functionally equivalent monitors. The data presented in Table 5-3 are the range of specifications provided by the monitor assemblers, but not necessarily from the manufacturers of all of the component parts. Therefore, we are unsure if the specifications provided by the monitor assemblers also represent those of the component parts, since the component parts manufacturers did not consistently supply performance data as requested in the data collection questionnaire used in this study. However, when companies were approached to participate in the study, they were informed of the performance specification parameters within which the study boundaries were defined. Therefore, it is assumed that they meet the specifications as presented in Chapter 1 (Table 1-2) and in Table 5-3 and they perform relatively equivalently. In the primary data, the reported brightness of the CRT was less than the LCD, otherwise, they are functionally similar.

5.5 IMPROVEMENT ASSESSMENT OPPORTUNITIES AND TARGETED AUDIENCE USES OF REPORT

To meet the primary objective of providing the display industry with data to perform improvement assessments, the industry should look at the manufacturing life-cycle stage, while recognizing the influences of the other stages. CRT improvement opportunities could include improved energy efficiency during glass manufacturing and display use, as well as reductions in lead content. LCD improvement opportunities could also include improved energy efficiency, especially during manufacturing. Certain materials, such as SF_6 and its contribution to global warming, may also be of concern and an area to focus on in future improvement assessments.

In addition, any improvement assessment should consider how changes in one life-cycle stage will affect impacts in other stages. For example, in Chapter 4 we saw that the mercury inputs and outputs from the intentional use of mercury in an LCD backlight are less than (by mass) the mercury emissions from the CRT use stage, due to the relatively high energy usage by the CRT and the emissions of mercury from electricity generation. In this example, we can see that on a pure mass basis, a product's energy efficiency is a key consideration and any changes in manufacturing should consider if it will affect changes in use. However, this project did not conduct a quantitative risk assessment to determine where the greatest potential for mercury exposure (and therefore risk) might occur. Consequently, we cannot definitively say whether it is better to have a potentially less energy-efficient backlight that does not contain mercury or a more energy-efficient backlight that does. Nonetheless, this analysis highlights the life-cycle trade-offs that must be considered in an improvement assessment.

Another objective of this study was to provide an LCA model for future analyses. Companies or individuals who have more current data for the CRT or LCD can apply them to the model presented here. For example, changes in an individual process can be identified and incorporated into the model. The other processes that are not expected to change significantly can be left unchanged, and only limited data would need to be altered. This would reduce the time and resources that would normally be required for a complete analysis.

Finally, those interested in comparing the results of the two monitors can apply their own set of importance weights to each impact category to determine their individual decision. For example, if energy impacts are much more important than aesthetics to a particular person, they can weigh energy more heavily in concluding which monitor may have fewer environmental impacts, while keeping in mind the data limitations and uncertainties, as well as cost and performance considerations.

5.6 SUGGESTIONS FOR FUTURE RESEARCH

Areas where future research could be conducted to refine and/or continue the use of the results in this study are as follows:

- gather more information on energy use in glass manufacturing;
- develop consistent materials and fuel processing data in a national (or international) LCI database that is updated regularly;
- refine and/or update some of the LCD manufacturing data (e.g., LNG data);
- collect more complete EOL data (e.g., remanufacturing data, and primary data for incineration and landfilling) to determine better representation of the EOL impacts;
- conduct more research on EOL options for LCDs;
- collect more detailed data on landfilling and other treatment processes, such as water treatment where no impacts were calculated;
- update manufacturing data to meet more recent monitor model years;
- conduct a more focused analysis on selected areas for detailed improvement assessments; and
- evaluate process changes or other alternatives against an “average 1997-2000 model year” to evaluate impacts of changes or improvements over time.

APPENDIX A

FLAT PANEL DISPLAY TECHNOLOGIES

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FLAT PANEL DISPLAY TECHNOLOGIES

1. Background

Flat panel displays (FPDs) are increasingly gaining a presence in the computer display market. They provide, for example, a more compact display as used in laptop computers and are viable substitutes for cathode ray tube (CRT) displays. Other advantages over the CRT are higher contrast, sunlight readable, more reliable, and more durable (i.e., require much less maintenance) Koch and Keoleian, 1995). In general, the major disadvantages have been that the resolution and quality of the image did not match that of CRTs. Several different types of FPD technologies have been demonstrated and are in use to varying degrees. The major categories are liquid crystal displays (LCD), plasma display panels (PDP), electroluminescent (EL), field emission displays (FED), vacuum fluorescent displays (VFD), digital micromirror devices (DMD), and light emitting diodes (LED). Table A-1 briefly describes each FPD technology. Although each technology has its own performance characteristics and is manufactured using different materials and processes, most are generally comprised of two glass plates surrounding a material that filters external light or emits its own light. These technologies use manufacturing techniques more similar to the production of semiconductor chips than televisions. Most FPDs control the color and brightness of each pixel (picture element) individually, rather than from one source, such as the electron gun in the CRT. The different types of electronic information display devices and how they are categorized are depicted in Fig. A-1.

1.1 Elimination of FPD Technologies from this Study

While there are several types of FPDs, two LCD technologies will be included in this LCA, based on their applicability to be used as substitutes in the computer display market. LCDs comprise approximately 87% of the FPD market (OTA, 1995). Currently, the largest market for FPDs is in notebook computers and CRTs monopolize the desktop computer market. However, FPDs are already moving into the desktop computer market. The LCD technology that best meets the purpose and needs of this study is the amorphous-silicon thin film-transitor (a:Si TFT) active matrix LCD (AMLCD). There are two variations of the a:Si TFT AMLCD that are expected to dominate the desktop monitor market for LCDs: the traditional twisted nematic (TN) mode and the in-plane switching (IPS) mode. Table A-1 describes these technologies. Various subtechnologies of LCDs are presented in Fig. A-2. The IPS mode is a non-nematic amorphous silicon AMLCD. Note that all the subtechnologies listed in Fig A-2 are not described here; the purpose is simply to show the complexity of different types of LCDs.

The PDP technology could be incorporated into the desktop computer market, especially if computers and televisions begin to merge. However, plasma technology is generally designed for large screens, and does not meet the specifications (e.g., diagonal size) of the functional unit defined for this project. Therefore, PDP technology will not be included in the scope of this project. FED and EL technologies are targeted toward military, medical, and high-end commercial products because they possess particular characteristics (such as size, durability, and high image quality) for those niche markets. Because these other FPD technologies are a small fraction of the market, not targeted toward the desktop computer market, and/or do not meet the specifications of our functional unit, they are not included within the scope of this project. Table A-1 presents brief descriptions of various FPD technologies and whether or not they are included in this LCA.

Table A-1. Flat panel display technologies

Technology	Description	Applicability to Project
Liquid Crystal Displays (LCD)	A liquid crystal material, acting like a shutter, blocks, dims, or passes light unobstructed, depending on the magnitude of the electric field across the material (OTA, 1995). A backlight provides the light source.	Included in this study. Descriptions of the subtechnologies and whether or not they are included in the study are presented below.
(1) Passive matrix (PMLCD)	Liquid crystal (LC) material is sandwiched between two glass plates, which contain parallel sets of transparent electrical lines (electrodes) in a row and column configuration to form a matrix. Every intersection forms a pixel, and the voltage across the pixel causes the LC molecules to align and determines the shade of that pixel (OTA, 1995).	Traditionally for low-end applications (e.g., calculators, wrist watches). Higher end applications use a super-twisted nematic (STN)[1] construction. The liquid crystal material is twisted between 180 and 270 degrees which improves the contrast between the "on" and "off" states, resulting in a clearer display than with the twisted nematic (twisted only 90 degrees) (OTA, 1995; MCC, 1997). However, cost and performance issues limit this technology from wide application in the desktop market and therefore, it will not be evaluated in this study.
(2) Active matrix (AMLCD)	Similar to the PMLCD except an electronic switch at every pixel provides faster switching and more shades. The addressing mechanism eliminates the viewing angle and brightness problems suffered by PMLCD. Requires more backlight than PMLCD due to the additional switching devices on the glass (at each pixel). Various switching types are listed below:	Provides vivid color graphics in portable computer and television screens (OTA, 1995). This technology meets the functional unit specifications in this study. Specific subcategories are described below.

---

[1] Traditional light modulating methods for LCD technologies include twisted nematic (TN), super-twisted nematic (STN), double STN, triple STN, and film-compensated STN (OTA, 1995). The STN is the current standard for high-end PMLCD applications.

Table A-1. Flat panel display technologies

Technology	Description	Applicability to Project
	AMLCD Switch Types:	
	(2a) Thin-film transistor (TFT): The transistor acts as a valve allowing current to flow to the pixel when a signal is applied. The transistors are made of various materials including: amorphous silicon (a:Si), polycrystalline silicon (p:Si), non-Si[CdSe] (Castellano, 1992). Two different TFT light modulating modes are twisted nematic (TN) and in-plane switching (IPS) (DisplaySearch 1998). In comparison to the TN mode, the IPS mode requires more backlight but fewer manufacturing steps.	The current standard AMLCD switching mechanism for computer displays is a:Si TFT. Polycrystalline Si is not suitable for larger than about 5" displays. Both the TN and IPS a:Si TFT AMLCD technologies are analyzed in this project.
	(2b) Diode matrix: The diode acts as a check valve. When closed, it allows current to flow to the pixel charging it. When opened, the pixel is disconnected and the charge is maintained until the next frame (Castellano, 1992).	The diodes are found to short easily and must be connected in series to achieve long life usability. The diode displays are also limited in size smaller than that of the functional unit.
	(2c) Metal-insulator metal (MIM): The MIM is a diode type switch using metal-insulated-metal fabrication techniques (OTA, 1995).	Temperature sensitive, which creates gray scale nonuniformities. They are also size limited like other diode type displays and therefore not included in this study.
(3) Active addressed LCD	Hybrid of passive and active matrix. The pixels are addressed using signals sent to the column and row as determined using an algorithm encoded into an integrated circuit (IC). The IC drives each row of pixels more or less continuously and drives multiple rows at one time (OTA, 1995)	Employed in notebook and desktop monitors >12.1". However, they need special drivers (OTA, 1995), have slow response times, and their contrast worsens as panel size increases (Young, 1998). Therefore, this technology does not meet the specifications of the functional unit and is excluded from evaluation in this study.
(4) Plasma-addressed liquid crystal (PALC)	The pixel is addressed using row electrodes, which send the signal, and column gas channels, which conduct a current when ionized (OTA, 1995).	PALC displays are in development to be used as large low cost displays. Production of the displays have not yet occurred and they are not included in this study.
(5) Ferroelectric LCDs (FLCD or FELCD)	The pixel is addressed using positive or negatives pulses to orient the crystals. The positive pulse allows light to pass (light state) and the negative pulse causes the blockage of light (dark state) (Castellano, 1992). A ferroelectric liquid crystal is bistable and holds it polarization when an electric field is applied and removed (Peddie, 1994). They are also called surface stabilized ferroelectric (SSF) LCD.	Has high resolution with very good brightness, but limited color palette (Peddie, 1994). Limited color palette does not meet color specification of functional unit.

Table A-1. Flat panel display technologies

Technology	Description	Applicability to Project
Plasma Display Panels (PDP)	An inert gas (e.g., He, Ne, Ar) trapped between the glass plates emits light when an electric current is passed through the matrix of lines on the glass. Glow discharge occurs when ionized gas undergoes recombination. Ionization of atoms occurs (electrons are removed), then electrons are recombined to release energy in the form of light. Full color plasma displays use phosphors that glow when illuminated by the gas (OTA, 1995).	Established technology. Good for large screens (e.g., wall-mounted televisions), but are heavier and require more power than LCDs (OTA, 1995). Designed for large screens and are larger displays than specified for desktop applications. Therefore, not included in this study.
Electroluminescent Displays (EL)	A phosphor film between glass plates emits light when an electric field is created across the film (OTA, 1995). EL uses a polycrystalline phosphor (similar to LED technology which is also an electroluminescent emitter, but uses a single crystal semi-conductor). ELs are doped (as a semiconductor) with specific impurities to provide energy states that lie slightly below those of mobile electrons and slightly above those of electrons bound to atoms. Impurity states are used to provide initial and final states in emitting transitions (Peddie, 1994). Also referred to as thin-film EL (TFEL). Variations: AC thin-film EL (AC-TFEL), active matrix EL (AMEL), DC EL, organic EL.	Lightweight and durable. Used in emergency rooms, on factory floors, and in commercial transportation vehicles (OTA, 1995). Problems found in the power consumption and controlling of gray levels. Targeted toward military, medical, and high-end commercial products, therefore not included in the scope of this project.
Field Emission Displays (FED)	Flat CRT with hundreds of cathodes (emitters) per pixel (form of cathodeluminescent display); eliminates single scanning electron beam of the CRT. Uses a flat cold (i.e., room temperature) cathode to emit electrons. Electrons are emitted from one side of the display and energize colored phosphors on the other side (OTA, 1995; Peddie, 1994).	Not commercially available, but anticipated to fill many display needs (OTA, 1995). Could potentially apply in all LCD and CRT applications. High image quality as with CRT, but less bulky and less power use than with CRT. A number of roadblocks to this technology taking over the AMLCD market include proven manufacturing processes (problems found in the reliability and reproducibility of the devices), efficient low-voltage phosphors, and high voltage drivers. The technology is targeted toward military, medical and high-end commercial products and not included in current study.
Vacuum Fluorescent Displays (VFD)	Form of cathodeluminescent display that employs a flat vacuum tube, a filament wire, a control grid structure, and a phosphor-coated anode. Can operate at low voltages since very thin layers of highly efficient phosphors are coated directly onto each transparent anode (Peddie, 1994).	VFDs offer high brightness, wide viewing angle, multi-color capability and mechanical reliability. Used in low information content applications (e.g., VCRs, microwaves, audio equipment, automobile instrument panels, etc.). No significant uses seen for computer displays (Peddie, 1994).

Table A-1. Flat panel display technologies

Technology	Description	Applicability to Project
Digital Micromirror Devices (DMD)	Miniature array of tiny mirrors built on a semiconductor chip. The DMD is used in a projector that shines light on the mirror array. Depending on the position of a given mirror, that pixel in the display reflects light either onto a lens that projects it onto a screen (resulting in a light pixel) or away from the lens (resulting in a dark pixel) (OTA, 1995).	Just beginning to be used mainly as projection devices and has not been developed for use that would match the functional unit (OTA, 1995).
Light Emitting Diodes (LED)	The LED device is essentially a semiconductor diode, emitting light when a forward bias voltage is applied to a p-n junction. The light intensity is proportional to the bias current and the color dependent on the material used. The p-n junction is formed in a III-V group material, such as aluminum, gallium, indium, phosphorous, antimony, or arsenic.	For low information display applications, which makes it not capable of meeting the requirements of the functional unit. Color, power, and cost limitations prevent the emergence into the high information display market (Castellano, 1992).
Electrochromic display	Open-circuit memory using liquid electrolytes (Peddie, 1994, p. 214). Non-emitter (as LCDs), as opposed to emitters (e.g., EL, FED, PDP).	Outstanding contrast and normal and wide viewing angles; open-circuit memory. Complex and costly involving liquid electrolytes, poor resolution, poor cycle life, lack of multicolor capability, etc. Not suitable for computer displays in past; however, new technology may be promising (Peddie, 1994).
Light Emitting Polymers	Developing technology (Holton, 1997).	Developing technology.

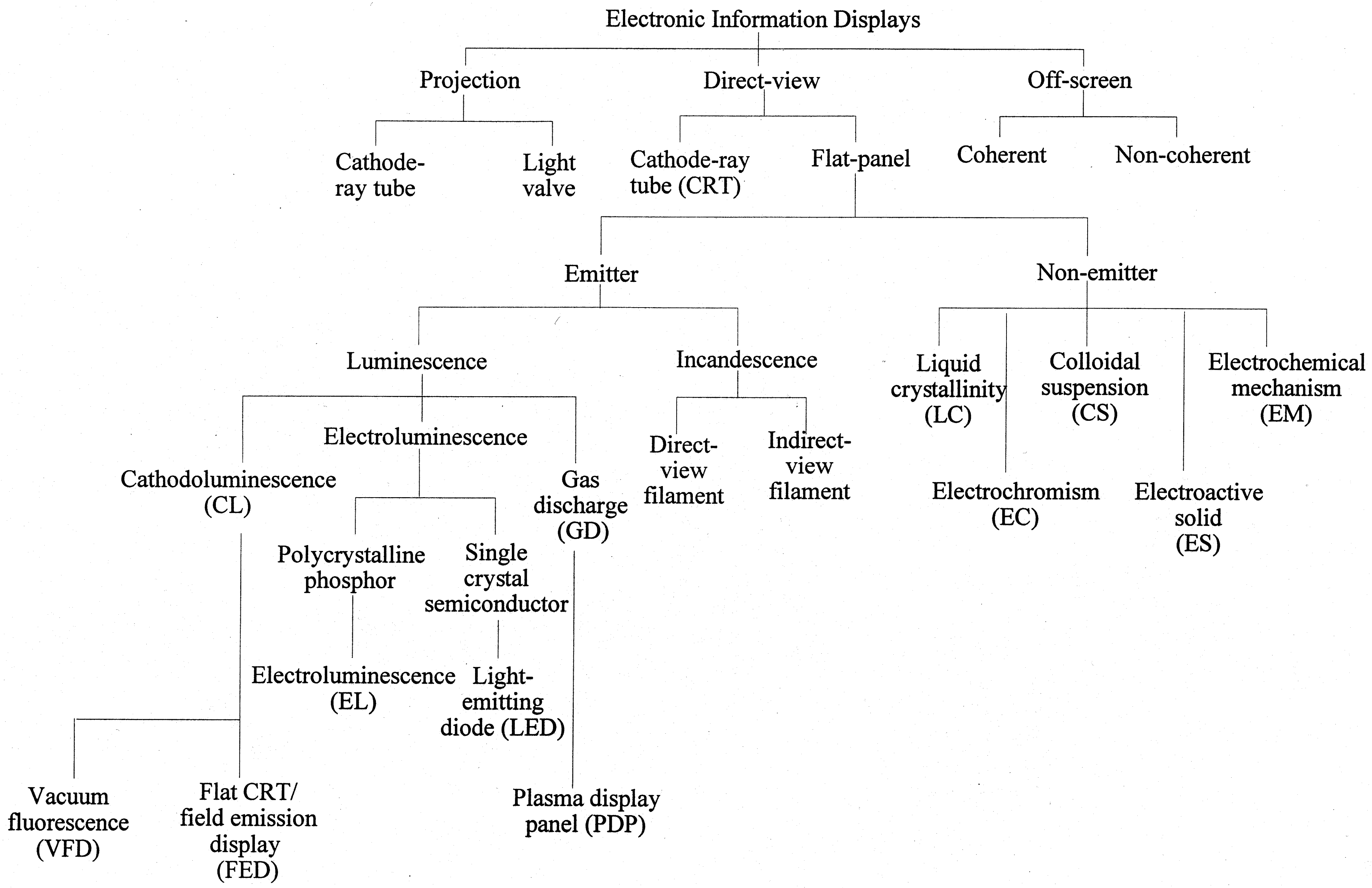

Figure A-1. Classification of Electronic Information Displays. *Source:* **Adapted from Tannas 1985.**

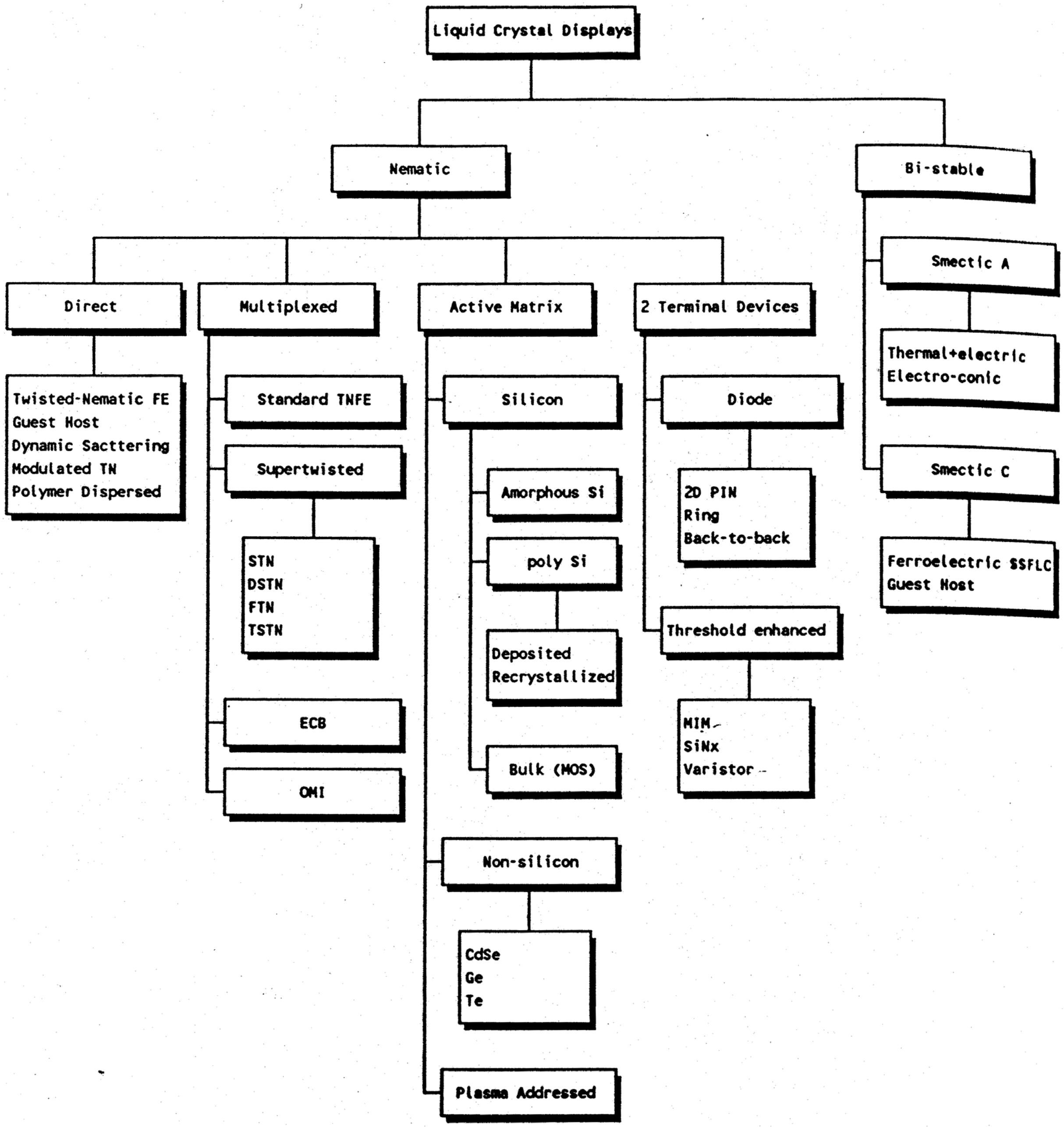

Figure A-2. LCD subtechnologies. Source: Catellano 1992.

APPENDIX B

DESCRIPTIONS OF LIQUID CRYSTAL DISPLAY (LCD) TECHNOLOGY AND AMORPHOUS SILICON THIN-FILM TRANSISTOR (a:Si TFT) TECHNOLOGY

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PRODUCTS

WHAT IS A LIQUID CRYSTAL?

PRINCIPLES OF LCD TECHNOLOGY

LCD PRODUCTION METHODS

AMORPHORUS -Si TFT TECHNOLOGY

PROJECTORS

PANELS AND DIRECT VIEW MONITORS

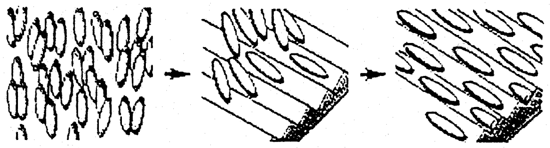
PRO VIDEO PRODUCTS

PRINCIPLES OF LCD TECHNOLOGY

In this section, we will explain everything ranging from the properties of liquid crystal molecules to the basic principle of display technology by using TN type liquid crystals as an example.

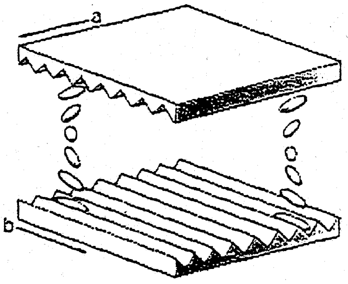
The parallel arrangement of liquid crystal molecules along grooves

When coming into contact with grooved surface in a fixed direction, liquid crystal molecules line up parallel along the grooves.



Natural State Molecules are arranged in a loosely ordered fashion with their long axes parallel.	When coming into contact with a finely grooved surface (alignment layer).	Molecules line up parallel along grooves.

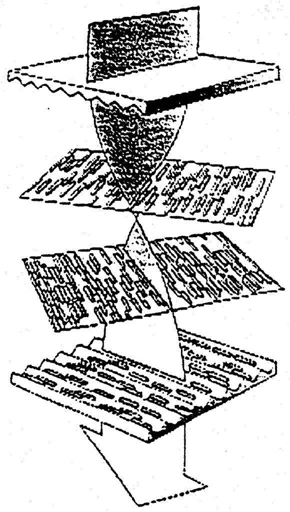
When liquid crystals are sandwiched between upper and lower plates, they line-up with grooves pointing in directions 'a' and 'b,' respectively



The molecules along the upper plate point in direction 'a' and those along the lower plate in direction 'b,' thus forcing the liquid crystals into a twisted structural arrangement.
(figure shows a 90-degree twist)
(TN type liquid crystal)

Light travels through the spacing of the molecular arrangement

The light also "twists" as it passes through the twisted liquid crystals

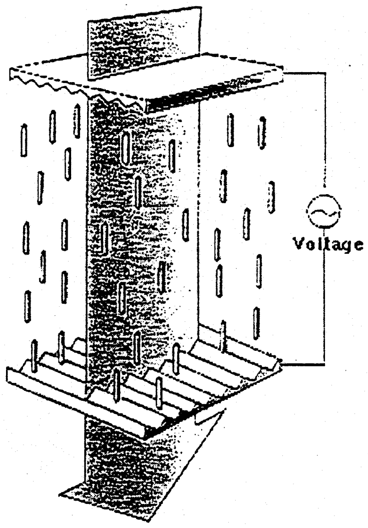


Light passes through liquid crystals, following the direction in which the molecules are arranged. When the molecule arrangement is twisted 90 degrees as shown in the figure, the light also twists 90 degrees as it passes through the liquid crystals.

Light bends 90 degrees as it follows the twist of the molecules

Molecules rearrange themselves when voltage is applied

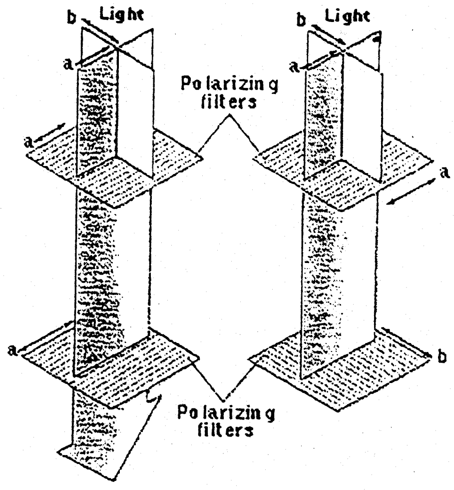
When voltage is applied to the liquid crystal structure, the twisted light passes straight through.



The molecules in liquid crystals are easily rearranged by applying voltage or another external force. When voltage is applied, molecules rearrange themselves vertically (along with the electric field) and light passes straight through along the arrangement of molecules.

Blocking light with two polarizing filters

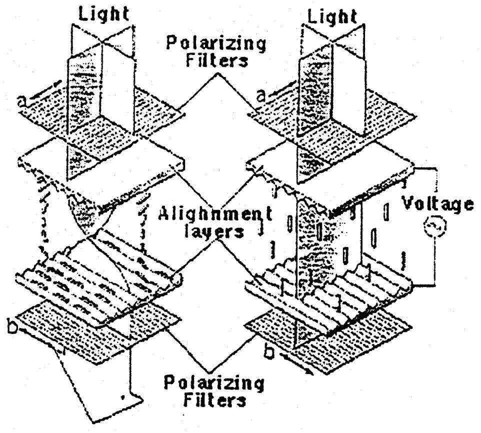
When voltage is applied to a combination of two polarizing filters and twisted liquid crystal, it becomes a LCD display.



Light passes when two polarizing filters are arranged with polarizing axes as shown above, left.
Light is blocked when two polarizing filters are arranged with polarizing axes as shown above, right.

TN type LCDs

A combination of polarizing filters and twisted liquid crystal creates a liquid crystal display.



When two polarizing filters are arranged along perpendicular polarizing axes, light entering from above is re-directed 90 degrees along the helix arrangement of the liquid crystal molecules so that it passes through the lower filter.	When voltage is applied, the liquid crystal molecules straighten out of their helix pattern and stop redirecting the angle of the light, thereby preventing light from passing through the lower filter.

This figure depicts the principle behind typical twisted nematic (TN) liquid crystal displays. In a TN type LCD, liquid crystals in which the molecules form a 90-degree twisted helix, are sandwiched between two polarizing filters. When no voltage is applied, light passes; when voltage is applied, light is blocked and the screen appears black. In other words, the voltage acts as a trigger causing the liquid crystals to function like the shutter of a camera.

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AMORPHUS-SI TFT TECHNOLOGY

Active matrix LCDs, which are typically used in products such as LCD projectors, are controlled by a switching element known as a thin-film transistor or thin-film diode placed at each pixel.

The fundamental concept was revealed in 1961 by RCA of America, a U.S. company, but basic research only began in the 1970's. Amorphous Si TFT LCDs introduced in 1979 and 1980 have become the mainstream for today's active matrix displays. These units place an active element at each pixel, and taking advantage of the non-linearity of the active element, are able to apply sufficient drive-voltage margin to the liquid crystal itself, even with the increase in the number of scan lines.

As shown in Figure 1, TFT LCDs that use amorphous Si thin-film transistors (TFTs) as the active elements are becoming the mainstream today, and full-color displays achieving contrast ratios of 100:1 and which compare favorably to CRTs are being developed.

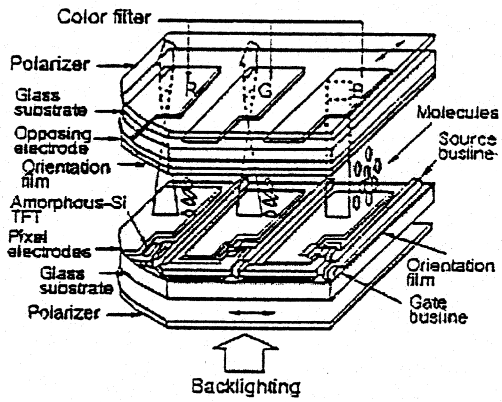

Figure 1 Construction of TFT LCD

The driver electronics for TFT LCDs consist of data-line drive circuitry that applies display signals to the data lines (source drivers) and scanning line drive circuitry that applies scanning signals to the gate lines (gate drivers). A signal control circuit to control these operations and a power supply circuit complete the system.

Liquid crystal materials used in TFT LCDs are TN (twisted nematic) liquid crystals, but despite the fact that pixel counts have increased and a drive element is placed at each pixel, we have still been able to rapidly increase the contrast, viewing angle, and image quality of these displays.

However, manufacturing technologies to fabricate several hundred thousand such elements onto the surface of a large screen are extremely problematic, and the fundamental approach developed in 1987 is still being used today.

In 1988, Sharp developed a 14-inch TFT color TV, and with this development of a futuristic wall-mount TV, TFT LCDs created the foundation for manufacture and introduction of large-screen color displays.

Reinitzer discovered liquid crystals almost 100 years ago, and today, bolstered by customer needs and the new and special technologies and materials that a manufacturer can offer to meet those needs, liquid crystals have made huge strides.

At this opportunity, we would to make the whole world aware of the potential of LCDs, and as new manufacturers enter the market, become the trigger that raises this awareness to new levels.

In the evolution of LCD display manufacturing, the burden of undertaking aggressive development of application products has been considerable. In addition to notebook and sub-notebook PCs that have been the mainstream applications for LCDs in the past, there has been significant growth in areas which take advantage of the unique characteristics of LCD displays, such as compact size, thin profile, and low power consumption to create products which could not be produced using CRTs, such as LCD TVs, ViewCams, new portable information tools, etc. In addition, for large projection TVs, it has now become possible to develop products that are more compact and lighter in weight than conventional CRT-based models, and LCDs are rapidly becoming the mainstream display device in this field.

In this way, LCD displays have expanded into application areas that were once niches belonging solely to CRTs, and the development of numerous key technologies that have the potential to further expand their application product areas continues.

Thanks to the development of TFT LCD displays and the synergistic evolution (spiral evolution) with LCD application devices and equipment, such as PC notebooks and computer monitors, A/V equipment, car navigation systems, game devices, etc., we can anticipate the growth of new demand-generating products. LCDs have emerged as the likely winner among flat-panel displays for the new information-oriented society. As we approach the dawn of the multimedia era which will see the convergence of video, computers, and communications, a critical need is emerging for innovations in displays that link man and machine through our sense of sight.

The driving force behind LCD manufacturing are recently developed amorphous-Si TFT LCD technologies which represent breakthroughs in the areas of 1) higher aperture ratios, 2) wider viewing angles, and 3) EMI (electromagnetic interference) reduction, as well as low-temperature polycrystalline Si TFT LCD display technologies. Thanks to these breakthroughs, a new direction has emerged in 1996 which will make the best use of these key technologies in LCD applications. For example, higher aperture ratio technologies are being used in LCD displays intended for PC notebooks, wider viewing angle and lower EMI technologies are being used in LCDs destined for LCD monitors, and low-temperature polycrystalline Si TFT LCD technologies are being used as super-fine dot-pitch light valves for high-definition projection TV systems.

In the future, promising new technologies can be expected to spawn the next generation of new LCD application products based on high-performance LCD display systems ("systems-on-panel") that takes full advantage of integrated drive and control circuitry.

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References

Sharp. 1998. Information found on a Web page from Sharp USA. Web site available at: <http://www.sharp-usa.com/products/pro/tech/>.

APPENDIX C

CRITICAL REVIEW

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APPENDIX C

CRITICAL REVIEW

Table C-1. Computer Display Project Core Group* and Technical Work Group Members

Contact	Organization	Location
Salla Ahonen	Environmental Issues, Nokia Research Center, Nokia	Helsinki, Finland
Heather Bowman	Electronics Industry Alliance	Arlington, VA
Reggie Caudill	New Jersey Inst. of Tech. Research Center	Newark, NJ
Bob Donofrio	Display Device Consultants	Ann Arbor, MI
Holly Evans Co-Chair, Core Group	Electronics Industry Alliance	Arlington, VA
Bruce Gnade	DARPA	Arlington, VA
Tony Hainault	Minnesota Office of Environmental Assistance	St. Paul, MN
Kathy Hart* Co-Chair, Core Group	US EPA, Office of Prevention Pesticides and Toxic Substances	Washington, DC
Edwin Henderson*	US EPA, Office of Prevention Pesticides and Toxic Substances [a]	Washington, DC
David Isaacs* former Co-Chair, Core Group	Electronics Industry Alliance [a]	Arlington, VA
Mikko Jalas	Environmental Issues, Nokia Research Center, Nokia	Helsinki, Finland
Tim Jarvis	The SemiCycle Foundation	Austin, TX
Greg Keoleian	U. of Michigan, School of Natural Resources and the Env.	Ann Arbor, MI
Lori Kincaid*	Univ. of TN Center for Clean Products and Clean Technologies	Knoxville, TN
J. Ray Kirby	IBM	Research Triangle Park, NC
Jonathan Koch	GE Power Systems	Schenectady, NY
David Lear	Compaq Computer Corp.	Houston, TX
Clare Lindsay	U.S. EPA, Office of Solid Waste	Arlington, VA
John Lott	DuPont Electronic Materials	Research Triangle Park, NC
Jeff Lowry	Techneglas	Columbus, OH
Carole McCarthy	McCarthy Environmental Consulting	Duxbury, MA
Timothy Mann	IBM	Loganville, GA

Table C-1. Computer Display Project Core Group* and Technical Work Group Members

Contact	Organization	Location
Frank Marella Co-Chair, Technical Work Group	Sharp Electronics Corporation	Mahwah, NJ
John Mathews	Envirocycle	Hallstead, PA
Jay Mathewson	Eastman Kodak Co.	Rochester, NY
Colleen Mizuki*	Microelectronic & Computer Technology Corporation [a]	Austin, TX
Amanda Monchamp	Electronics Industry Alliance [a]	Arlington, VA
Rick Nolan	Motorola	Austin, TX
Bob Pinnel*	U.S. Display Consortium	San Jose, CA
Greg Pitts*	Microelectronic & Computer Technology Corporation [a]	Austin, TX
Gene Proch	Corning Asahi	
Gloria Schuldt	Microelectronic & Computer Technology Corporation [a]	Austin, TX
Eileen Sheehan	U.S. EPA, P2 Team, Region 9	San Francisco, CA
Dipti Singh* Co-chair, Technical Work Group	US EPA, Office of Prevention Pesticides and Toxic Substances	Washington, DC
Doug Smith	Sony Electronics Inc.	San Diego, CA
Ted Smith*	Silicon Valley Toxics Coalition	San Jose, CA
David Spengler*	Digital Equipment Corporation	Maynard, MA
Maria Socolof*	Univ. of Tennessee Center for Clean Products & Clean Technologies	Knoxville, TN
Dan Steele	Motorola MD FPD 10 ESIH and Chemical Operations Flat Panel Display Division	Tempe, AZ
Larry Stone	Compaq Computer Corp.	Houston, TX
Butch Teglas (Delmer F.)	Philips Consumer Electronics	Knoxville, TN
Valerie Thomas	Princeton Univ. Ctr. For Energy & Env. Studies	Princeton, NJ
David Thompson	Matsushita Electronic Corporation of America	Secaucus, NJ
Donna Timmons	Eastman Kodak Co.	Rochester, NY
Dani Tsuda*	Apple Computer Inc.	Cupertino, CA
Lucian Turk	Dell Computer	Austin, TX
Laura Turbini	Georgia Institute of Technology	Atlanta, GA
Victoria Wheeler	Eastman Kodak Co.	Rochester, NY

Table C-1. Computer Display Project Core Group* and Technical Work Group Members

Contact	Organization	Location
Ross Young former Co-Chair, Technical Work Group	Display Search	Austin, TX

* Core Group members (subset of Technical Work Group)

[a] Affiliation at time of involvement in project.

Table C-2. U.S. EPA Design for the Environment Workgroup Members for the Computer Display Project

Name	Division/Branch
Andrea Blaschka	Risk Assessment Division/Existing Chemicals Assessment Branch
Susan Dillman	National Program Chemicals Division/Technical Branch
Franklyn Hall	Economic, Exposure, and Technology Division/Chemical Engineering Branch
Kathy Hart	Economics, Exposure, and Technology Division/Design for the Environment
Karen Hogan	Risk Assessment Division/Science Support Branch
Susan Krueger	Economics, Exposure, and Technology Division/Economic and Policy Analysis Branch
Fred Metz	Economics, Exposure, and Technology Division/Industrial Chemistry Branch
Dipti Singh	Economics, Exposure, and Technology Division/Design for the Environment
Jerry Smrchek	Risk Assessment Division/Existing Chemicals Assessment Branch

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APPENDIX D

TECHNICAL MEMORANDUM:
Life-Cycle Inventory Approach for Materials Extraction and Materials Processing Life-Cycle Stages

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APPENDIX D

TECHNICAL MEMORANDUM:
Life-Cycle Inventory Approach for Materials Extraction and Materials Processing Life-Cycle Stages

1. INTRODUCTION

1.1 Background

The U.S. Environmental Protection Agency's Design for the Environment Program Computer Display Project (CDP) is conducting an environmental life-cycle assessment (LCA) that will evaluate the relative environmental impacts of cathode ray tubes (CRT) and liquid crystal display (LCD) computer monitors. The major life-cycle stages of a product system include materials extraction, materials processing, product manufacturing, product use, and final product disposition (end-of-life). An LCA evaluates the relative environmental impacts of a product system and is defined in greater detail in Chapter 1 of the main report. An LCA generally consists of four phases: goal definition and scoping, life-cycle inventory (LCI), life-cycle impact assessment (LCIA), and life-cycle improvement assessment.

The activity of quantifying the inputs (e.g., materials, utilities) and outputs (e.g., emissions, wastes) of a product system is the LCI phase of an LCA. A product system is made up of the multiple processes that help produce, use, or dispose of the product. Each process typically has an inventory that consists of inputs and outputs for each process. Therefore, an LCI of a product system consists of several inventories for processes throughout the life-cycle of the product. This technical memorandum (TM) addresses the LCIs related to two major life-cycle stages: materials extraction and materials processing, which together will be referred to as the life-cycle stages that are "upstream" of the product manufacturing stage. Ideally, transportation associated with those stages is also included. This TM will describe the approach to choosing the upstream data from secondary sources that will be included in the CDP analysis.

1.2 Purpose and Scope of this Technical Memorandum

The purpose of this TM is to present the approach for obtaining process-specific inventory data related to extraction and processing of the materials needed to produce a CRT and LCD computer monitor. Collecting these upstream inventory data can involve dozens of upstream processes because there are dozens of materials used to produce CRTs and LCDs. Therefore, decision rules are typically used to limit which materials to include in the scope of the LCA, and existing data from secondary sources are generally relied upon. For inventories related to materials extraction and materials processing, various databases with input and output LCI data exist for materials commonly used in industry. The existence of these inventories, and the limited resources available for collecting primary inventory data for the entire life cycle, result in the use of secondary data for upstream processes. In the CDP, more emphasis will be given to collecting primary data for product manufacturing and end-of-life processes. This TM identifies initial materials considered for inclusion in the upstream life-cycle stages. Actual material lists from the inventories collected from the primary data collection efforts were not available until after data collection had to begin for the upstream processes. Therefore, initial materials were identified to help determine which secondary data to obtain. Once actual materials from the manufacturing stage inventory were identified, the selected secondary data source was checked for the appropriate data sets to be included in the study. This TM addresses the initial steps for choosing which upstream data source to use, by identifying and prioritizing several data sources. The remainder of this TM will present a brief summary of results, the methodology for selecting secondary upstream data for the CDP, detailed results in terms of preferred data sources, and the limitations to using the upstream data for the CDP.

2. RESULTS SUMMARY

Based on initial material lists and project decision rules, approximately 40 materials (including some material groups) were initially identified as materials for which upstream data inventories should be included in the CDP LCA. Nine data sources (i.e., studies and/or databases) were evaluated to determine which upstream data would be used for these and other materials that might be identified in the CDP. Two databases were disregarded because the data are not or will not be available to the public. The remaining seven were reviewed for their applicability to the CDP. Complete inventory data for all currently identified CDP materials were not available from any one of the databases/studies alone. Therefore, a hierarchy of preferred data has been chosen for upstream data from secondary sources. The most preferred data is that from the Environmental Information and Management Explorer (EIME) database developed by *Ecobilan* (Ecobalance), a company based in France.

EIME is an LCA software package that specializes in electronics and the electronics industry and currently includes 18, with forthcoming updates expected to bring it to 21 materials specific to the CDP. The database is immediately available, and although it is relatively expensive, it may be attainable at a negotiated price (Glazebrook 1999). The EIME data do not fulfill all the CDP's upstream data requirements and therefore, other databases will be needed. Twelve materials were not found in any of the databases and may require additional research from secondary or primary sources to complete the CDP product system inventories. It appears, however, that EIME, supplemented with Ecobalance's Database for Environmental Analysis and Management (DEAM) will cover most materials needed in the CDP.

3. METHODOLOGY

The method for determining the upstream data that will be used for the CDP depends on which materials need to be included in the upstream evaluation and what existing databases are currently available for those materials. This section consists of three subsections that present the following: (1) how the preliminary list of materials were identified; (2) which data sources were considered for use as CDP upstream inventory data; and (3) the selection criteria for choosing which upstream data to include in the CDP.

3.1 Materials Selection

The first step to selecting upstream data sources is to identify what materials are of interest to the project. Primary data collected from manufacturing facilities will provide a list of upstream materials to consider in the upstream stages. However, the materials inventory from the CDP product manufacturing stage was not yet complete when upstream data collection needed to begin to meet project time and budget constraints. Therefore, a preliminary list of materials used to manufacture the monitors was identified by disassembling a CRT and LCD and by reviewing the literature on manufacturing processes. The list was then slightly reduced based on decision rules to limit the scope of the project. This preliminary list is then used to help choose preferred sources of upstream data for materials of interest in the CDP. The following subsections describe the bills of materials of the LCD and CRT, the decision rules applied to the bills of materials, and the list of selected materials for upstream data collection.

3.1.1 Bills of Materials

A 15" CRT and a 15" LCD desktop monitor were disassembled, to the extent they could be manually separated, into their component parts/materials and each of these parts was weighed using Mettler analytical balances. A 17" CRT (the CDP functional unit) was not available for disassembly and therefore it is assumed that the percent contribution of materials in the 15" CRT and the 17" CRT are equivalent, which is an adequate assumption for the purposes of identifying major product materials.

Primary (also referred to as “product”) materials are defined as those that become part of the final assembled monitor. Bills of materials of the CRT and LCD monitors were compiled to quantify the mass contribution of each primary material and component in each monitor. Where individual materials could not be discerned, component parts consisting of multiple materials were identified and weighed. These bills of materials are presented in the CDP’s Industry and Technology Profile Document (MCC 1998). The material makeup of some component parts [e.g., thin-film transistors (TFTs) on LCD glass substrate or phosphors on CRT glass substrate] were identified from published literature (i.e., secondary sources) (O’Mara 1993, DisplaySearch 1998, FCR 1996, MCC 1993, ECT 1980). Simultaneous and subsequent work on the CDP involved obtaining more details on the makeup of certain component parts from manufacturers (i.e., primary sources) through data collection questionnaires.

The next step was to identify common ancillary (also referred to as “process”) materials used in product manufacturing, which were found from secondary sources (O’Mara 1993, DisplaySearch 1998, FCR 1996, MCC 1993, ECT 1980) and reviewed by industry experts. These ancillary materials were added to the primary bills of materials for consideration in the LCA (MCC 1998). Additional ancillary materials were identified from primary sources during concurrent manufacturing data collection activities.

3.1.2 Decision Rules

Due to the complexity of the CRT and LCD monitors, and for any LCA, the boundaries of the analysis must be clearly defined. Thus, the following decision rules for choosing the materials to be evaluated were developed and applied to the primary and ancillary bills of materials. Three major categories of decision criteria were used to select materials for detailed analysis in the LCA: (1) mass contribution; (2) potential environmental and/or energy significance; and (3) technological importance. A priority hierarchy was developed (Figure 1) using a combination of these criteria.

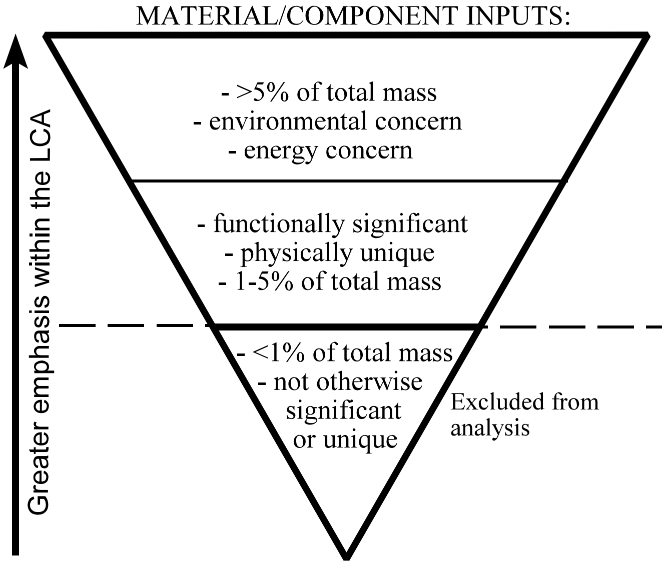

Figure 1. Decision rule hierarchy

The first criterion is applied by including materials that constitute greater than or equal to 1% of the monitor by mass. Materials constituting more than 5% will be given greater emphasis in the LCA. Mass is a simple measure by which to select important materials for consideration in the LCA because in many cases, the larger the material, the greater the impact. This is true for resource consumption impacts which are equivalent to the amount of material used. However, other impact categories may not be equivalent to the amount of material consumed, and simply eliminating materials based on mass alone may exclude important impacts from an environmental life-cycle perspective. Therefore, under the second criterion, materials were also included if they have a potential environmental/health impact (e.g., they may be toxic) or use large amounts of energy to produce. The environmental criterion decision rule refers to materials that may pose risks to the public, occupational workers, or the ecosystem from manufacturing, use, or disposal of the material. The primary and ancillary materials were reviewed by a team of experts at the University of Tennessee and were compared to regulatory lists and other sources (Klaassen et al. 1986, EPA 1998, ChemFinder 1998, SRC 1998) to identify materials with known or potential environmental concerns. When impacts are calculated in the LCIA, a more rigorous review of toxicity data and environmental parameters will be conducted to provide quantitative impact measures.

The third decision rule criterion applies to materials that are critical to the technology (e.g., LCD TFT materials or the CRT phosphors). This is intended to ensure that other materials of potential importance are not overlooked in the LCA. Furthermore, because the LCA will be comparative in nature, greater emphasis will be placed on materials that are physically unique to a display technology.

For the materials meeting the top tier of the decision rule hierarchy (Figure 1) in the CDP, attempts are made to obtain secondary data for those upstream material processes. Materials in the middle segment of the triangular hierarchy scheme are given lower priority, but included, if available. Finally, the last segment of the triangle would contain materials excluded from the analysis.

3.1.3 Material Selection Results

The materials identified here are for selecting which materials require the collection of input and output inventory data from materials extraction, materials processing, and associated transportation, collectively referred to as the "upstream" life-cycle stages. The inventories from each of these life-cycle stages are then used to calculate impacts of the various impact categories considered in the analysis.

The total masses of the CRT and LCD that were disassembled were approximately 12.8 kg and 5.15 kg, respectively. The printed wiring boards (PWBs) and their components were excluded from these weights and from the following materials analysis because they are treated as complex display components not broken down by individual materials. The CRT consists of approximately 17 primary materials and the LCD is comprised of about 23 primary materials (MCC 1998). The major primary materials by weight (≥1%) in the CRT and LCD are listed in Table 1 with their corresponding components. Figures 2 and 3 depict the percent contribution of each of those materials to the overall monitor. For the CRT, eight materials were greater than or equal to 1% and only three [glass, steel, and high impact polystyrene (HIPS)] were greater than 5% of the weight of the monitor. The LCD had seven materials greater than or equal to 1%, five of which were greater than 5% [steel, polycarbonate, acrylonitrile butadiene styrene (ABS), polyester, and glass]. The items in bold in Table 1 represent the materials that are >5% for both the CRT and LCD. Other primary materials to be included in the LCA, based on the environment and technology decision rules, are presented in Table 2. The primary materials that were excluded due to mass are presented in Table 3.

Ancillary materials, such as those required for photolithography, are used in greater quantities for LCDs than CRTs. Preliminary literature searches (O'Mara 1993, DisplaySearch 1998, FCR 1996, MCC 1993, ECT 1980) found four ancillary materials for CRTs and 12 for LCDs (MCC 1998). The latter portion of Table 2 presents the ancillary materials that are included for either technological or environmental importance. The mass criterion for ancillary materials will be identified through responses to data collection questionnaires distributed to manufacturers participating in the project. Table 3 shows the ancillary materials that were preliminarily excluded based on environmental and technical criteria because mass data for ancillary materials are not yet available.

Table 1. Primary materials comprising ≥1% by mass of a CRT or LCD monitor and associated components [a]

Material	Associated component(s)	
	CRT	LCD
ABS	-----	Base/stand
Aluminum (Al)	Aluminum shielding, power board heat sink, connectors	Power supply heat sink, TFT metal
Copper (Cu)	Deflection yoke	-----
Ferrite-magnet	Deflection yoke	-----

Table 1. Primary materials comprising ≥1% by mass of a CRT or LCD monitor and associated components [a]

Material	Associated component(s)	
	CRT	LCD
Glass (e.g., borosilicate) [b]	-----	LCP panel
Glass (lead oxide)	Panel, funnel, neck, frit	-----
Lead (Pb) [c]	Funnel & neck glass, frit	-----
Plexiglas	-----	Backlight clear protector
Polycarbonate	-----	Backlight light pipe
Polyester	-----	Power supply & rear cover insulators
Polystyrene, high-impact (HIPS)	Casing	-----
Silicone	Potting material in flyback transformer	-----
Steel	Base, right, left & back shields; shadow mask	Base/stand weight & brackets, backlight plates, rear cover metal plate, power supply housing

[a] See Figures 2 and 3 for material percent contributions to total mass of monitor, excluding PWBs.

[b] Includes materials that could not be easily separated from the glass (e.g., frit, phosphors, transistors) and subtracts the estimated lead content of the glass for the CRT.

[c] The mass of lead was estimated from the total mass of the different glass components and approximate lead levels in the CRT glass components (MCC 1994). On average, approximately 10% of the total mass of CRT glass was assumed to be lead.

NOTE: Materials in bold are >5% of the monitor by weight.

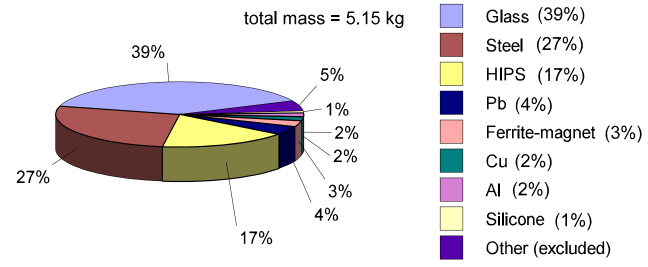

Fig. 2. CRT product materials meeting mass decision rule

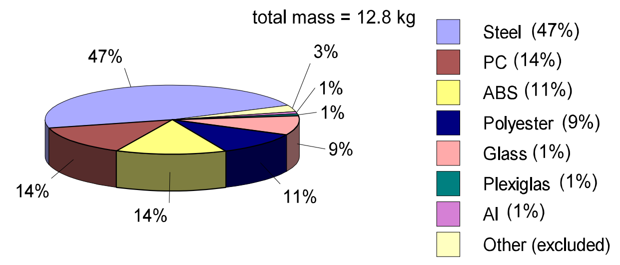

Fig. 3. LCD product materials meeting mass decision rule

Table 2. Primary and ancillary materials or components meeting technology (T), environment (Env), or energy (E) criteria

Materials	Associated components or process		Decision criteria	
	CRT	LCD	CRT	LCD
Primary materials				
Aluminum oxide (Al_2O_3)	Electron gun wire heater	-----	Env	-----
Aquadag	Faceplate black matrix coating	-----	T	-----
Beryllium (Be)	-----	Be-Cu metal clips	-----	Env
Bismuth oxide	Shadow mask back coating	-----	Env	-----
Color filters (acryl epoxy resins)	-----	Front panel glass color filters	-----	T
Divinylbenzene resin	-----	Spacers in AMLCD cell	-----	Env
Frit (lead solder glass)	Glass solder joints	-----	Env, E	-----
Indium-tin oxide (ITO)	-----	Electrode	------	T
Liquid crystals (e.g., polycyclic aromatic halogenated hydrocarbons, cyanobiphenyl, phenylcyclohexane compounds)	-----	Light-modulating material	-----	T, Env
Mercury	-----	Cold cathode fluorescent tube in backlight	-----	Env
Nickel	Electron gun cathodes	-----	T, Env	-----
Phosphors (e.g., ZnS, Y_2O_2)	Illuminating material	-----	T, Env	-----
Polyimide	-----	AMLCD cell alignment layer	-----	T
TFT metals (e.g., Al, Cr, Mo, W)	-----	Transistor	-----	T, Env
TFT silicon materials (e.g., SiO_2, SiNx, doped Si)	-----	Transistor	-----	T
Tungsten (W)	Electron gun wire heater	Transistor	T, Env	T, Env
Ancillary materials				
Boron trichloride (BCl_3)	-----	Photolithographic etchant	-----	Env
Carbon tetrafluoride (CF_4)	-----	Photolithographic etchant	-----	Env
Carbon trifluoride (CHF_3)	-----	Photolithographic etchant	-----	Env
Chloride (Cl_2)	-----	Photolithographic etchant	-----	Env
Ferric chloride ($FeCl_3$)	Photolithographic etchant (shadow mask)	-----	Env	-----
Hydrochloric acid (HCl)	-----	Photolithographic etchant	-----	Env
Isopropyl alcohol (IPA)	-----	Glass cleaner	-----	Env
N-methyl pyrrolidone (NMP)	-----	Photolithographic developer	-----	Env
Polyvinyl alcohol	Photolithographic application of phosphors	-----	Env	-----
Sulfur hexafluoride (SF_6)	-----	Photolithographic etchant	-----	Env

Table 2. Primary and ancillary materials or components meeting technology (T), environment (Env), or energy (E) criteria

Materials	Associated components or process		Decision criteria	
	CRT	LCD	CRT	LCD
Tetramethyl ammonium hydroxide (TMAH)	-----	Photolithographic developer	-----	Env

The materials identified for inclusion in the CDP (Tables 1 and 2) are then prioritized based on the decision rule hierarchy triangle. Those materials that are either: (1) >5% by mass; or (2) of environmental/energy concern, fit into the top priority of the upstream data collection effort. Those materials that are either: (1) between 1-5% by mass; or (2) functionally important and/or physically unique, fit into a lower priority of upstream data collection, but are still included in the project. Those materials that are less than 1% by mass and do not meet the other criteria listed above are excluded from the analysis. Currently, the materials falling into each segment of the decision rule hierarchy are listed in Table 4.

Table 3. Materials excluded from analysis

Material	Associated component/application	
	CRT	LCD
Primary materials		
Aluminized mylar		Corner tape on backlight assembly
Brass	Brass ring on neck assembly	Brass threaded standoff in backlight assembly
Foam rubber		Foam gasket in backlight assembly
Nylon		Cable clamp, strain relief in backlight assembly, clamp in backlight, bushing in base/stand assembly
Paper		Caution label on rear plate assembly
Polysulphone	Insulating rings on neck assembly	
Silicone rubber		Gaskets in LCD panel assembly, shock cushion in light assembly, rubber feet in base/stand assembly
Ancillary materials		
Nitrocellulose binder	For frit application	
Amyl acetate	For frit application	
O_2		Metal etchant
N_2		Metal etchant
Iodine		Polarizer coating

For the top priority materials, we obtained upstream inventory data from secondary sources where available. If no secondary sources were available, we attempted to collect primary data or conduct further research from the literature. For materials in the middle tier, we attempted to collect secondary data but gave less emphasis on including them if too many resources were required. The top tier consists of materials greater than 5% by mass and all the materials in Table 2. Each material in Table 2 was added to the list of materials for either environmental or technological reasons and all except tungsten (W) were unique to a technology. However, tungsten is also included in the top tier for potential environmental concern. As a result, all the materials in Table 2 are of potential environmental concern and/or are both functionally important and physically unique (see Figure 1).

Table 4. Summary table of preliminary CDP materials in priority hierarchy

Top tier	Middle tier	Lowest tier (excluded)
Steel, CRT glass, HIPS, Polycarbonate, ABS, Polyester, LCD glass, lead, Al_2O_3, Aquadag, Be, Bismuth oxide, Acryl epoxy resins (color filters), Divinylbenzene resin, Frit, ITO, Liquid crystals, Hg, Ni, Phosphors, Polyimide, TFT metals, TFT silicon materials, W, BCl_3, CF_4, CHF_3, Cl_2, $FeCl_3$, HCI, IPA, NMP, Polyvinyl alcohol, SF_6, TMAH	Ferrite-magnet, Silicone, Plexiglas, Al, Cu	Aluminized mylar, Brass, Foam rubber, Nylon, Paper, Polysulphone, Silicone rubber, Nitrocellulose binder, Amyl acetate, N_2, O_2, Iodine

3.2 Data Sources Evaluated

In order to identify upstream inventory data to be used for the CDP, nine different data sources (databases or studies) were evaluated. The following nine were chosen based on UT's experience in LCA, which included a comprehensive review of LCA databases (Menke et al. 1996), and from the scoping process for this project:

- American Plastics Council (APC)
  The APC is a major trade association for the U.S. plastics industry. APC is comprised of 24 of the leading plastics manufacturers in the United States with many members having a strong global market presence. APC's membership represents 80% of the U.S. resin production capacity (APC 1999). APC has collected LCI data that are expected to be released in 1999 for polyethylene (PE), polypropylene (PP), high impact polystyrene (HIPS), polyethylene terephthalate (PET), and polyvinyl chloride (PVC) resins and polyurethane precursors (Hentges 1999). Data are mostly vintage 1991 or 1993 and cover production in North America (Hentges 1999). Additional inventories from APC have not yet been identified, although they are presumed to exist.

- Association of Plastics Manufacturers in Europe (APME)
  APME is an industry body that has published inventory data on olefins, polystyrene (PS), PE, PP, PVC, PET and polymethanes (APME 1999), as well as ABS, Plexiglas, polycarbonate, polyester, and polyimide (Karlsson 1999).
- Boustead
  Dr. Ian Boustead is a well known LCA practitioner who developed the Boustead model and database that allows users to produce LCIs of complete systems. Boustead's focus areas are aerosols, automotive products, beverage containers, building materials, and the plastics industry. The organization is based in the United Kingdom (Boustead 1999).
- BUWAL
  BUWAL is the Swiss Agency for the Environment, Forests and Landscape (BUWAL 1999). They have several published reports on LCA. BUWAL 250 is an English version of their LCI database of several common industrial materials.
- Environmental Information and Management Explorer (EIME)
  This software design tool was developed by the *Ecobilan* group in conjunction with IBM, Alcatel, Legrand, Schneider, and Thompson. *Ecobilan* was founded in 1990 and has offices in Europe and in the United States (*Ecobilan* 1999). Version 1.4 of EIME has been released and the embedded database contains 170 modules on the most commonly used materials and subcomponents of the electronic and electric industry (EIME 1999).
- Industrial DEsign MATerials (IDEMAT)
  Dr. J.A.M. Remmerswaal and J. Rombouts of the Delft University of Technology's Section for Environmental Product Development produced this software with a database of LCI data for various industrial materials. There is a student version that was released in 1995 that is available to the public at no cost, but the availability and cost of the complete version is yet undetermined by UT. This evaluation focuses on the student version that was available to UT.
- New Jersey Institute of Technology (NJIT) Report
  NJIT's "Lifecycle Assessment of Television CRTs," (Caudill 1998) report is not a database of upstream inventory data *per se*, however, it is a preliminary LCA that includes LCI data for a CRT and therefore it was considered for use in the CDP as an upstream data source.
- Personal Computer (PC) Ecolabel Report
  This study was developed by Atlantic Consulting and IPU (Institute for Product Development of the Technical University of Denmark) for the Ecolabel Unit of the European Commission (AC and IPU 1998). The purpose of the report was to study personal computers so that an ecolabel could possibly be established. Similar to the NJIT report, this is an LCA with inventory data applicable to the CDP, but it is not a traditional database of upstream inventory data. Analysis of the inventory in the PC Ecolabel Report for the purposes of the CDP was based on Version 1.11 of the report downloaded from their website in January of 1998.
- United States Automotive Materials Partnership (USAMP)
  Formed in June 1993, this partnership set out to conduct vehicle-oriented research and development in materials and materials processing to improve the competitiveness of the U.S. auto industry (USAMP 1999). The USAMP is conducting joint research to further the development of lightweight materials for improved automotive fuel economy. The major technology groups being studied are polymer composites, light metals (including

aluminum, magnesium, etc.), engineered plastics, cast iron, steel and ceramics (USAMP 1999). The aluminum, plastics, steel and automotive industries are participating in a collaborative LCI project to produce a quantitative database of information regarding all the resources used to make, operate and dispose of a generic 3200-pound vehicle (USAMP 1999).

3.3 Selection Criteria

For choosing which upstream data to use for the CDP, the following 11 criteria were considered. Descriptions of each criterion and what is preferred for that category are presented below:

1. **Geographic boundaries** – Describes whether the data are representative of Europe and/or the United States. In general, U.S. data are preferred for this project, assuming most of the materials for the monitors are extracted and processed in the U.S. However, because some of the CDP manufacturing is in Asia, materials may originate from non-U.S. locations/countries.

2. **Origin of data** – Describes whether or not the data originate from primary or secondary sources. Primary sources that are clearly identified are preferred.

3. **Currency of data** – This refers to the dates that represent the actual inventory data. More recent data are preferred. If the date of the inventory data is not known, the date the database was released is considered.

4. **Public availability** – Data are categorized as either public or private. Publicly available data can be considered for the CDP.

5. **When available** – This describes whether or not the data are currently available and if not, when they are expected to be available. Immediately available means the data are available from the appropriate company or individual; however, more time may be required for UT to obtain the data. Also provided under this criterion will be whether UT currently has some of the data applicable to the CDP. Immediately available is preferred and further consideration is given to data that UT already has in house.

6. **Cost** – Due to limited resources, cost is an important factor for determining which upstream data should be obtained for the CDP. However, if possible, negotiations for or donations of data can be pursued as this is a collaborative project with industry and other stakeholders. Least costly data are preferred.

7. **Upstream life-cycle stages** – Which upstream life-cycle stages are included from each data source are identified, if possible. In some cases, the databases or reports address more than only upstream stages and other stages included will also be noted under this criterion. In the results of this analysis, we will present the names of the life-cycle stages as they are labeled in each respective data source. However, such labels may not be consistent with the specific

terminology used in this report. For use in the CDP, we prefer data sources that include materials extraction, materials processing, and associated transportation.

8. Aggregation of data – This describes whether or not the data from the various life-cycle stages are aggregated into one set of inventory numbers or how the data are aggregated. With less aggregation, the CDP will better be able to predict impacts particular to a specific life-cycle stage. Therefore, less aggregation is preferred. For some of the reports considered in this analysis, processes may also be aggregated for an entire product or component and therefore it is difficult to separate out the inventory for one particular material. The advantage of material-specific LCI databases is that the data are not aggregated into a larger component or product.

9. Input/output categories – This lists which categories of inputs and outputs are included in the database or report (e.g., non-renewable resources, fuel and energy inputs, water use, air emissions, water effluents, solid/hazardous wastes). Ideally, the input and output categories would match those defined for the CDP that will be used to calculate the impacts. The LCIA TM (Socolof 1999) describes the impact categories and how the inventory data will be used to calculate impacts. Also of interest is whether the outputs within each category are chemical specific. The more speciated the chemicals, the more desirable the data. In some cases, chemical groups or categories of chemicals are provided. The CDP LCIA methodology requires chemical-speciated data to calculate most impacts.

10. Data quality indicators – If the data source provides an indication of its data quality, this will help determine the data quality of the CDP. In several cases, we were not able to discern whether there were data quality indicators for a particular data set. If the data source provides some indication of data quality, this can then be incorporated into the CDP's data quality indicators for the upstream data.

11. CDP materials included – These are the materials that have been identified in Set. 3.1.3, which constitute the initial list of materials of interest in the CDP. They were cross-referenced with each data source under consideration. Preferred data sources are those with the greatest number of materials of interest to the CDP.

Each database or report was reviewed based on available information, and in some cases, limited information was available. This exercise was not intended to be a comprehensive review of each database, because we were not able to purchase each source. It was intended to be a cursory review of available data sources to assist in the decision of which inventory data to obtain and include in the CDP for the upstream life-cycle stages. When we could not obtain a database, our review was based on information available on company websites, other available literature on the database, personal contacts with company representatives, or third parties who have had experience with using a particular database.

Based on all this information, preferred data sources were identified. All factors were considered, including expected data quality and cost. The first most important criterion was whether the data source included many of the materials of interest to the CDP. Although additional materials may be identified during the concurrent CDP data collection efforts, we expect that the majority of materials of interest have already been identified.

4. RESULTS

Using the CDP decision rules, we initially identified approximately 40 materials (including some material groups) for which upstream data inventories should be included in the CDP LCA (Sect. 3.1.3). Nine data sources were evaluated to determine which upstream data would be used for these and other materials that might be identified. Tables 5 and 6 present a comparison of the data sources evaluated. Table 5 lists the first ten criteria presented in Sect. 3.3, which are related to the type of data provided, availability of the data, and cost. Table 6 cross-references the materials of interest in the CDP to the materials found in the various data sources (the 11th criterion in Sect. 3.3). Together this information was used to identify which data are preferred for use in the CDP as upstream inventory data. Brief discussions of each data source and a final conclusion are presented below.

Referring to Table 5, APC data are not yet available and it is uncertain if they will be available as scheduled, as they were expected to be released in previous years but were not. Therefore, APC is not considered further in this analysis. USAMP inventory data, which were intended only for participating organizations is not a publicly available data set. Therefore, USAMP as a source of upstream data for the CDP is also excluded from further analysis. The remaining seven data sources are evaluated by analyzing Tables 5 and 6.

The eleven criteria described above (Sect. 3.3) can be condensed into three major areas:

- Cost;
- Data quality; and
- Applicability to CDP.

Each source will be described in terms of these criteria, without giving a particular weight to any one over another. Note that the “data quality” criterion is a combination of the origin of the data, the currency of the data, the upstream life-cycle stages included, data quality indicators, and to some extent, the geographic boundaries of the data (see Table 5). The “applicability to the CDP” criterion depends on which upstream life-cycle stages are included, how the data are aggregated, what input and output categories are included (including whether or not the output data are speciated), whether data quality indicators are provided, and which materials of interest to the CDP are included.

Table 5. Selected criteria of upstream data sources

	APC	**APME**	**Boustead**	**BUWAL 250**	**EIME**	**IDEMAT**	**NJIT LCA**	**PC Ecolabel**	**UPAMP**
Geographic boundaries	U.S.	Europe	Europe	Europe	U.S. & Europe	Netherlands & Europe	U.S.	Europe	U.S.
Origin of data	Unknown	Primary	Primary	Secondary	Majority is primary, some secondary	Unknown	Secondary	Secondary	Unknown
Currency of data	1990s	1990s (varies per material)	Unknown	1996	1990s (varies)	Second Student version, released in 1995	1970s - 1990s	Not completely determined, but most appear to be 1990s	1990s
Public availability	Public	Public	Public	Public	Public	Public (student version); unknown for complete version	Public	Public	Public
When available	Expected to be released in 1999	Immediate (UT has 2 applicable materials)	Immediate	Immediate (UT has 6 applicable materials)	Immediate	Immediate (UT has 9 applicable materials; unknown if complete version can be obtained)	Interim report immediately available (UT has copy)	Version 1.11 immediately available (UT has copy)	Not available to public
Cost	No cost	No cost	~$10,000	~$250	~$7,500; > $5,700 for universities (Negotiable)	No cost, unknown for complete version	No cost	Version 1.11 no cost; ~$75 for final report	Not available to public
Upstream life-cycle stages	Unknown	Raw material extraction, material processing, transport	Process operations (including fuel production) and transport operations	Pre-combustion, combustion + processes, transports	Extraction, processing, transportation	Production, which includes transportation when noted, and not clear if extraction included	Material extraction and material synthesis	Material production, manufacturing, transport, use, EOL	Unknown

Table 5. Selected criteria of upstream data sources

	APC	APME	Boustead	BUWAL 250	EIME	IDEMAT	NJIT LCA	PC Ecolabel	UPAMP
Aggregation of data	Unknown	Some data presented as process-specific e.g., fuel production, transport, process)	Often classified into several processes: fuel production, fuel use, transport operations, process operations	Aggregated as "LCI" or "energy consumption," latter subclassified (e.g., final energy source, energy supply, final process energy, transport)	Aggregated over all upstream life-cycle stages for each module (material) into impact categories, system administration can access LCI data separately	Each material aggregated for all life-cycle stages for the following categories: processes, thermal energy, electrical energy, and transports	Process specific; sometimes a few subprocesses are aggregated	Aggregated by major computer components (e.g., monitor) for each life-cycle stage, not process or material specific	Unknown
Input/ Output categories	Unknown	Energy, primary fuels, and raw material inputs; air, water, and solid waste emissions; outputs mostly unspecified	Gross energy, primary fuels & feedstocks: raw materials; water use; air, water solid waste emissions; outputs provided as chemical categories and several speciated chemicals	Commercial fuels resources, feedstock resources, materials used in final stage, main product, co-products, usable wastes, waste treatment; outputs provided as chemical categories and as some speciated chemicals	Natural resources, energy, water inputs; air, water, hazardous waste outputs; outputs relatively well speciated	Material inputs (including water), energy inputs; air, water, and solid outputs; mostly unspeciated outputs	Raw material and energy inputs; solid, air, and waterborne waste outputs; outputs as chemical categories and some speciation	Resource consumption (raw materials), air emissions, water emissions, and waste; includes chemical categories, but also very well speciated	Unknown

Table 5. Selected criteria of upstream data sources

	APC	APME	Boustead	BUWAL 250	EIME	IDEMAT	NJIT LCA	PC Ecolabel	UPAMP
Data quality indicators	Unknown	All calculations were referred back to participating companies before being used	Not provided, but data quality believed to be moderately good (above average as compared to other available sources)	Unknown	Provides high, medium, and low measures of reliability of the data	Unknown	Data were gathered on each material, carefully citing notes and references which document the original sources	Unknown	Unknown

Key:
APC = American Plastics Council
APME = Association of Plastics Manufacturers in Europe
EIME = Environmental Information and Management Explorer
IDEMAT = Industrial DEsign MATerials
NJIT = New Jersey Institute of Technology
USAMP = U.S. Automotive Materials Partnership

4.1 Data Source Reviews

APME data are European-based, of moderate quality, and available for free. However, the data are mostly limited to materials of interest to the plastics industry and therefore only apply to 7 materials of interest to the CDP. The materials covered by APME constitute 17% of the product weight of the CRT described in Figure 2 and 49% of weight of the LCD in Figure 3.

The Boustead data are very expensive, of moderate quality, and include several materials of interest for the CDP, including most of the major product materials by weight of the CRTs and LCDs (55% and 85%, respectively, see Table 6). The significant material missing for the CRT is the leaded glass, which is approximately 39% of the mass of the monitor. The Boustead data include two of the ancillary materials that have been identified for the CDP, but do not include several of the other materials identified for potential environmental concern. The Boustead data are moderately equipped with speciated chemical data as required for the CDP. Data are aggregated for all upstream stages, but are also available as some individual upstream inventories (e.g., transport operations, process operations). Although data quality indicators are not provided by Boustead for the data, the Center for Clean Products and Clean Technologies assesses it as above average based on comparisons with other databases reviewed.

Table 6. Cross-reference of preliminary CDP materials and potential upstream data sources

		APME	**Boustead**	**BUWAL 250**	**EIME**[4]	**IDEMAT**[8]	**NJIT**	**PC Ecolabel**
Primary Materials								
1	ABS	Y	Y		Y (APME)	Y	Y	Y
2	Aluminum		Y	Y	Y	Y	Y	Y
3	Aluminum oxide		Y	Y	Y (BUWAL)			
4	Aquadag							
5	Beryllium					Y		
6	Bismuth oxide					Y (C)[9]		
7	Color filters (acryl epoxy resins)				Y[5]			
8	Copper		Y		Y	Y	Y	Y
9	Chromium (TFT metal)		mining chromite ore		(Y)	Y		
10	Divinylbenzene resin							
11	Ferrite-magnet		Y[2]		Y[6]			Y
12	Frit							Y
13	Glass, borosilicate (LCD)	Y	Y	Y	(Y)	Y		
14	Glass, lead oxide (CRT)						Y	Y
15	Indium-tin oxide - ITO							
16	Lead		Y		Y	Y	Y	Y
17	Liquid crystals				Y			
18	Mercury					Y (C)		
19	Molybdenum (TFT metal)				(Y)	Y		
20	Nickel				Y	Y		Y

Table 6. Cross-reference of preliminary CDP materials and potential upstream data sources

		APME	Boustead	BUWAL 250	EIME [4]	IDEMAT [8]	NJIT	PC Ecolabel
21	Phosphors: e.g., ZnS, Y_2O_2							
22	Plexiglas [polymerization of methyl ester (methyl methacrylate)]	Y			Y (APME)			
23	Polyimide	Y			Y (APME)			
24	Polycarbonate	Y	Y		Y (APME)	Y	Y	Y
25	Polyester	Y			Y (APME)	Y (C)		
26	Polystyrene-HIPS	Y	Y	Y	Y (APME)	Y	Y	Y [11]
27	Silicon TFT materials: e.g., SiNx, SiO2				Y	Y (C)		
28	Silicone				Y			
29	Steel		Y	Y	Y(BUWAL)	Y (C)	Y	Y
30	Tungsten (TFT metal)					Y		Y
Ancillary Materials								
31	Boron trichloride							
32	Carbon tetrafluoride							
33	Chlorine		Y	Y				
34	Ferric chloride							
35	Hydrochloric acid		Y		Y			
36	Isopropyl alcohol							
37	N-methyl pyrrolidone							
38	Polyvinyl alcohol							
39	Surfur hexafluoride							
40	Tetramethyl ammonium hydroxide							
Totals		7	12 [3]	6	18 (21) [7]	12 (17) [10]	8	12
% contribution of CRT primary materials >= 1% by mass [1]		17	55	46	56	25 (52) [10]	91	94
% contribution of LCD primary materials >= by mass [1]		49	85	57	88 (97) [7]	38 (96) [10]	76	76

1. The percent mass contribution of the primary materials were summed to identify the total percent of the monitor by mass that is covered by each data source.
2. Inventory data are available for iron, which is assumed to represent ferrite-magnet.
3. The tally of chemicals for Boustead excludes mining chromite ore for chromium.
4. Cells with a Y and the name of a data source [e.g., "Y (APME)"] indicate the data source that EIME obtained that particular inventory from, if that source is included elsewhere in this table. "(Y)" represents materials that are expected in EIME's forthcoming update.
5. "Epoxy resins" assumed to be for color filters (acryl epoxy resins).
6. The EIME database does not have ferrite-magnet listed, but it does have ferrites MnZn as a mateiral inventory.
7. The first value represents the current EIME dataset and the value in parenthesis indicates materials expected in the forthcoming update.
8. The student version of IDEMAT was the source investigated. "C" (for "complete") indicates cases where IDEMAT has the inventory on a given material only in the complete version.
9. Bismuth
10. The first value is for the student version and the value in parthenthesis is for the complete version.
11. The study only listed polystyrene (PS) and did not indicate if it was high-impact polystyrene (HIPS).

BUWAL 250 is a relatively inexpensive database that is also European data and believed to be from secondary sources. Therefore, the data quality is marginal and its applicability to the CDP is also relatively low as it only appears to cover the least number of materials of interest. Some chemical speciation is provided as output data and the inventories are aggregated over the upstream processes.

EIME appears to be the best candidate for the purposes of the CDP as it is targeted specifically for the electronics industry and includes many of the materials of interest to the CDP (Table 6). The current version includes 18 materials and, with forthcoming updates to the database, there are expected to be 21 materials covered (Karlsson 1999), representing 56% of the materials by mass of the CRT and 97% of the LCD. The low CRT percent is again due to the lack of leaded glass, which is 39% of the CRT. These data also include important materials not included in the weight criterion such as liquid crystals, lead, silicon materials, and color filters. Each of these, with the exception of lead are not found in any other data sources reviewed. The EIME inventory output data appear to be relatively well speciated, but the inventory data in general cannot be separated into each upstream life-cycle stage. The data quality is adequate as some data are from the U.S. and from primary sources. The data specific to the electronics components are from the five industrial partners and their suppliers, while some of the other common industrial materials were obtained from other LCI databases (EIME 1999). The cost is relatively high; however it covers the cost of the entire life-cycle software tool. Discussions with *Ecobilan* representatives have revealed their willingness to negotiate for the use of some material inventory data, provided we supply our results to them in a desirable format. Alternatively, we would be required to purchase the entire software package to obtain the desired inventory data.

The student version of IDEMAT is another free set of data that is European-based. The true quality of the data is not yet well determined by UT. Several (12) CDP materials are included in the student version, and it is believed that 17 would be covered with the complete version. IDEMAT has a few materials, metals in particular, that are not found in any of the other data sources reviewed.

The NJIT LCA report provides only eight material inventories relevant to the CDP; however, because it is an LCA of a television with a CRT, it includes leaded glass, which is not commonly found in existing databases. Some of the inventory data, which are U.S.-based, are from relatively old secondary sources (*circa* 1970). Furthermore, not all outputs are quantified. The report includes two upstream life-cycle stages: materials extraction and “materials synthesis” (referred to as “materials processing” in the CDP). Transportation within these upstream stages is not included. Data are easily identified per material, and some chemical speciation is included. This report does not provide sufficient amount of upstream data to be used exclusively, but given that it is available at no cost, it may supplement missing data (e.g., leaded glass).

The PC Ecolabel LCA is a report that includes 12 of the materials of interest in the CDP in its study and has very well speciated output data. UT has obtained a copy of Version 1.11 at no charge. It is based on European data and of undetermined quality. This was a study that was intended to present results of the life-cycle impacts of a PC and is not intended to be a database of material inventories. UT chose to evaluate this as a potential source for upstream data because of the relevant subject matter of the LCA. And although it covers several materials of interest, the inventory data cannot be separated into individual material inventories. Data are presented for different life-cycle stages, but not provided on a material basis. Therefore, this report could be helpful for checking our final results of the LCA, but not for providing upstream inventories of specific materials.

4.2 Conclusion

To identify the priorities for using upstream data, we would prefer to use as much data from one source as possible to help ensure consistency and thus improve the data quality of the results of the CDP. We have selected to target EIME as the primary source of upstream data. However, what is seen from the information in Table 6 is that no one data source will completely encompass the product materials of the CDP. Twelve of the 40 materials were not covered by any data source. EIME includes the greatest number, yet even including the expected updates to EIME, ten primary materials and nine ancillary materials are not covered by EIME. Four of the ten primary materials and eight of the nine ancillary materials were not covered by any other data sources. Six materials that are not in EIME are believed to be in other data sources. These include the following: beryllium, bismuth oxide, frit, leaded glass, mercury, and tungsten. Beryllium and tungsten are in the student version of IDEMAT and bismuth and mercury are in the complete version of IDEMAT. The NJIT and PC Ecolabel studies include leaded glass and the PC Ecolabel study also includes frit. The NJIT report, however, does not quantify the outputs from leaded glass production. Furthermore, because the PC Ecolabel study's inventory is aggregated over the whole monitor, individual inventory data cannot be produced for the specific materials. Therefore, IDEMAT data and the quantified inputs from the NJIT report may help supplement the EIME data.

Subsequent work for the CDP revealed that Ecobalance also had DEAM data available that supplemented the EIME data, both of which were listed as upstream data sources for this project. Procuring EIME requires negotiations with *Ecobilan* for a reduced price. This will begin subsequent to the final approval of this TM by EPA and the CDP Core and Technical Work Groups. In the event we cannot procure the EIME data for a reduced price, we will try to rely on the no cost options of APME, IDEMAT and NJIT data. Together, these three data sources cover 17 materials with the IDEMAT student version or 20 with the complete version. Relying on several material inventories from each of the three sources will reduce consistency in our upstream data and thus reduce the data quality in the CDP. For materials not included in the data sources obtained, UT will attempt to find the data from primary or secondary sources.

5. LIMITATIONS AND UNCERTAINTIES

Information on the different databases were from personal communications, websites, and in some cases, review of selected inventories obtained for a database. Copies of the NJIT and Ecolabel reports were available for review. This evaluation of upstream sources was not intended to be a comprehensive assessment of each data source, but instead a cursory review to evaluate which data to pursue. Therefore, there remain uncertainties to the information presented in this TM, but it is believed that adequate information was available to make recommendations in this report.

Using secondary data will also have an effect on the limitations of the CDP results. Using secondary data that are not tailored to the specific goals and boundaries of a project limits the quality of the data. However, due to the large data collection efforts in the LCA, priorities are given to collecting data. Thus, secondary sources have been chosen for upstream inventories and primary sources will be approached for monitor and component manufacturing data, as well as some end-of-life processes.

Once the upstream data are incorporated into the CDP, limitations in those databases will be transferred to limitations in the CDP. Furthermore, the use of more than one database (e.g., EIME supplemented by NJIT and IDEMAT) will reduce consistency in our upstream data and thus somewhat reduce the data quality in the CDP. However, it should be noted that the upstream data are only one portion of the overall inventory of the product systems being evaluated.

ACRONYMS/ABBREVIATIONS

ABS = Acrylonitrile butadiene styrene
APC = American Plastics Council
APME = Association of Plastics Manufacturers in Europe
BUWAL = The Swiss Agency for the Environment, Forests and Landscape
CDP = Computer Display Project
CRT = Cathode ray tube
DEAM = Database for environmental Analysis and Management
EIME = Environmental Information and Management Explorer
IDEMAT = Industrial DEsign MATerials
IPA = Isopropyl alcohol
IPU = Institute for Product Development of the Technical University of Denmark
HIPS = High impact polystyrene
LCA = Life-cycle assessment
LCD = Liquid crystal display
LCI = Life-cycle inventory
LCIA = Life-cycle impact assessment
LDPE = Low density polyethylene
NJIT = New Jersey Institute of Technology
NMP = N-methyl pyrrolidone
PC = Personal computer
PS = Polystyrene
PE = Polyethylene
PET = Polyethylene terephthalate
PP = Polypropylene
PVC = Polyvinyl chloride
PWB = Printed wiring board
TFT = Thin-film transistor
TM = Technical memorandum
TMAH = Tetramethyl ammonium hydroxide
USAMP = United States Automotive Materials Partnership

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APPENDIX E

TECHNICAL MEMORANDUM:
Electrical Energy Grid Life-Cycle Inventories for the CDP

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APPENDIX E

TECHNICAL MEMORANDUM:
Electrical Energy Grid Life-Cycle Inventories for the CDP

1. INTRODUCTION

1.1 Background

The U.S. Environmental Protection Agency's (EPA) Design for the Environment (DfE) Program Computer Display Project (CDP) is conducting a combined Cleaner Technologies Substitutes Assessment (CTSA) and life-cycle assessment (LCA) to evaluate the relative environmental impacts, cost, and performance of cathode ray tube (CRT) and active matrix liquid crystal display (AMLCD) desktop computer monitors. Initially the project is conducting an LCA to determine the relative potential environmental impacts of the monitors, including impacts from materials extraction, materials processing, manufacturing (monitor and components), use, and end-of-life disposition. Transportation information is also included within and between each stage.

LCA has four major components:

1. goal definition and scoping,
2. life-cycle inventory (LCI),
3. life-cycle impact assessment (LCIA), and
4. improvement assessment.

The LCI is a collection of inputs (materials, energy, and other resources) and outputs (products, wastes and emissions) for processes throughout the product's life cycle. The LCIA characterizes the potential relative impacts of these inputs and outputs per functional unit, where the functional unit is defined in this project as one monitor over its lifetime. Improvement assessment is the component where those who are in the position to make changes in either the design or manufacture of the product review the results and decide on ways to implement environmental improvements.

The focus of this technical memorandum (TM) is on the LCI component of the LCA. Established LCI methodology accounts for electricity requirements throughout the life cycle of a product system. Wherever electricity is used in a process in the product system, the LCI typically includes the inputs and outputs from the generation of that electricity. This TM presents the input and output inventory data that are used to calculate the impacts from electricity generation for the CDP. The inventory data were developed by the University of Tennessee Center for Clean Products and Clean Technologies (CCPCT) from existing data for the various fuels (e.g., coal, petroleum) used by electric utilities around the United States. Two inventories illustrate the amount of materials consumed (inputs) and pollutants released (outputs) to generate one kilowatthour (kWh) of electricity, based on the average U.S. and the average Japanese electrical grids. The data are presented in units of grams of material input or emission output per kWh (g/kWh) in almost all cases, excluding radioactive emissions which are presented in Becquerels per kWh [Bq/kWh, where a Becquerel is the Système Internationale (SI) unit for radioactivity]. All of the inputs and outputs in the electric grid inventories have been multiplied by the electricity consumption rate for each process in the product system where electricity is used. These input and output data are not used with LCI data collected from secondary sources that already include inputs and outputs from electricity generation. The two electric grid inventory data sets presented in this TM are for the average U.S. electrical grid and the average Japanese electric grid.

1.2 Boundaries of the Analysis

In addition to the geographic boundary (i.e., U.S. and Japanese data only), the boundaries of the data presented in this TM are defined by the generation categories included in the analysis (e.g., coal, nuclear) and the life-cycle stages evaluated for the various generation categories (e.g., extraction, generation). A U.S. electric grid inventory was developed first and the Japanese grid inventory is simply a modification of the U.S. inventory, which applies the average Japanese electric grid to the input and output data found for the United States. This will not account for any effects of different control technologies used in Japan compared to the United States. The majority of this TM focuses on collecting U.S. data, and mentions when the Japanese grid is applied.

Table 1 presents the electricity generation categories, associated fuels types, percent breakdown for U.S. electricity generation in 1997 and whether or not that category is included in this inventory. (While 1998 is the target year for the overall CDP, this TM was targeted for 1997 as almost no data could be obtained that was relative to 1998.) Coal is the dominant generation category and fuel type in the U.S., accounting for over 55 percent of 1997 electricity production. Non-renewable fuels (coal, gas, petroleum, and uranium) plus water (for hydroelectric plants) together provide greater than 99 percent of U.S. electricity. Table 1 also lists the average Japanese breakdown of fuels.

Table 1. Fuel Types Used to Generate Electricity in U.S. and Japan in 1997

Generation Category	Fuel	U.S. Generation % Breakdown	Japanese % Breakdown	Included in Electric Grid Analysis?
Coal	Coal	57.23%	18%	Yes
Gas	Gas	9.07%	20%	Yes
Petroleum	Petroleum	2.53%	21%	Yes
Nuclear	Uranium	20.14%	31%	Yes
Hydro	Water	10.79%	9%	No
Renewables	Wind, biomass, heat from sun, heat from earth	0.24%	1%	No
Total		100%	100%	

Sources: EIA 1999a, EIA 1997.

Individual input and output inventories were developed for each of the generation categories listed in Table 1, except hydro and renewables. Hydroelectric facilities, which constitute nearly 11% of the U.S. electric grid, were excluded due to the scarcity of data on hydroelectric inputs and outputs. Known impacts of hydroelectric facilities primarily relate to reservoir formation, which includes habitat destruction and its concurrent effects on biodiversity, and the generation of the greenhouse gases methane and carbon dioxide from the flooding of wetlands during and after reservoir formation. Habitat destruction is not included as an impact category *per se* within the CDP LCIA methodology (see Chapter 3 of main report), but global warming is included. Furthermore, EPA has concluded there is currently no adequate basis for estimating the emissions and sinks from the flooding of wetlands (EPA 1998a).

Renewables were excluded because they accounted for only a small fraction (0.24%) of total U.S. electricity production in 1997. In addition, little or no data exist on material inputs and pollutant outputs for renewable electricity generation processes.

The following life-cycle stages are associated with electricity generation:

- Extraction of ores and fluids from the earth and any necessary transportation to the initial processing point (Materials Extraction);
- Initial and secondary processing of those ores/fluids into usable fuels, and the associated transportation between processing points and to the generating stations (Materials Processing);
- Combustion or use of the fuel and the onsite control of pollutants, and transmission and distribution of the generated electricity to the points of use (Manufacturing);

NOTE: This description excludes the process flows of renewable energy sources.

Little or no data were available for the extraction and initial and secondary processing of ores and fluids into fuels, except for some data for coal extraction and processing. Therefore, most of the electrical grid input and output data presented in this TM only include the manufacturing life-cycle stage (generation and transmission and distribution of electricity) as shown in Table 2.

Table 2. Fuel Life-Cycle Substages Captured in Electric Grid LCI Data

Life-Cycle Substages	Coal	Gas	Petroleum	Uranium
Extraction	P	N	N	N
Transport to Initial Processing	N	N	N	N
Initial Processing	P	N	N	N
Transport to secondary processing	NA	NA	NA	N
Secondary processing	NA	NA	NA	N
Transport to generating stations	N	N	N	N
Electricity generation	I	I	I	I
Transmission and Distribution	I	I	I	I

I = Included in inventory; P = Partially included in inventory; N = Not included in inventory; NA = Not applicable.

It should also be noted that this electric grid inventory relates only to *utility*-based generation. Electric power generation in the Unites States can be broken down into two main categories: utility and nonutility. In simplified terms, most electricity generating entities that are not classified as utilities fall in the nonutility category, and include many cogeneration facilities and small and independent power producers. About 65% of nonutility production is attributed to the manufacturing sector (EIA 1998a), and nonutility production as a whole constitutes just over 10% of the total power produced by the electric power industry. The inputs and outputs of nonutility electricity production are excluded here due to a lack of detailed data on the associated emissions and wastes.

1.3 Organization of the TM

The remainder of this document provides supporting information on the development of the electric grid data. It is organized into six sections: results summary, methodology, fuel-specific results, data sources and quality, limitations and conclusions. Supporting tables are presented as necessary in the Appendices.

2. RESULTS SUMMARY

Table 3a presents the primary and ancillary materials consumed and products and environmental burdens produced during the generation of 1 kilowatthour (kWh) in the United States, based on the national 1997 generation percent breakdown (see Table 1). Similarly, Table 3b presents the inventory for the Japanese grid. All inputs and outputs listed in Tables 3a and b are presented on a per kWh basis.

Section 3 of this TM discusses the methods used to calculate the nationwide U.S. electric grid inventory data. Spreadsheets were used to organize and manipulate all of the inventory data, and those spreadsheets are shown in Attachments A through E and contain supporting data source, assumptions, and limitations information.

Table 3a. U.S. Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
PRIMARY INPUTS					
Coal, avg. (in ground)	2.83E+02	G	Input	Primary material	
Natural gas	2.20E+01	G	Input	Primary material	
Petroleum (in ground)	5.99E+00	G	Input	Primary material	
Uranium, yellowcake	7.64E-03	G	Input	Primary material	
ANCILLARY INPUTS					
Lime	1.67E+00	G	Input	Ancillary material	
Limestone	3.79E+00	G	Input	Ancillary material	
Water	1.79E+03	G	Input	Water	
PRODUCT					
Electricity	1.00E+00	KWH	Output	Energy	
AIR EMISSIONS					
1,1,1-Trichloroethane	3.02E-06	G	Output	Airborne	air
1,2-Dichloroethane	5.65E-06	G	Output	Airborne	air
2,3,7,8-TCDD	2.02E-12	G	Output	Airborne	air
2,3,7,8-TCDF	7.20E-12	G	Output	Airborne	air
2,4-Dinitrotoluene	3.96E-08	G	Output	Airborne	air
2-Chloroacetophenone	9.89E-07	G	Output	Airborne	air
2-Methylnaphthalene	4.20E-09	G	Output	Airborne	air
5-Methyl chrysene	3.11E-09	G	Output	Airborne	air
Acenaphthene	8.94E-08	G	Output	Airborne	air
Acenaphthylene	3.55E-08	G	Output	Airborne	air
Acetaldehyde	8.05E-05	G	Output	Airborne	air
Acetophenone	2.12E-06	G	Output	Airborne	air
Acrolein	4.10E-05	G	Output	Airborne	air
Anthracene	3.07E-08	G	Output	Airborne	air
Antimony	6.87E-06	G	Output	Airborne	air
Arsenic	5.91E-05	G	Output	Airborne	air
Barium	3.24E-06	G	Output	Airborne	air
Benzene	1.84E-04	G	Output	Airborne	air
Benzo[a]anthracene	1.46E-08	G	Output	Airborne	air
Benzo[a]pyrene	5.37E-09	G	Output	Airborne	air
Benzo[b,j,k]fluoranthene	1.68E-08	G	Output	Airborne	air
Benzo[g,h,i]perylene	5.68E-09	G	Output	Airborne	air
Benzyl chloride	9.89E-05	G	Output	Airborne	air
Beryllium	3.01E-06	G	Output	Airborne	air
Biphenyl	2.40E-07	G	Output	Airborne	air
Bromoform	5.51E-06	G	Output	Airborne	air
Bromomethane	2.26E-05	G	Output	Airborne	air
Cadmium	7.59E-06	G	Output	Airborne	air

Table 3a. U.S. Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
Carbon dioxide	7.00E+02	G	Output	Airborne	air
Carbon disulfide	1.84E-05	G	Output	Airborne	air
Carbon monoxide	1.27E-01	G	Output	Airborne	air
Chloride ions	2.86E-04	G	Output	Airborne	air
Chlorobenzene	3.11E-06	G	Output	Airborne	air
Chloroform	8.33E-06	G	Output	Airborne	air
Chromium (III)	3.83E-05	G	Output	Airborne	air
Chromium (VI)	1.14E-05	G	Output	Airborne	air
Chrysene	1.61E-08	G	Output	Airborne	air
Cobalt	1.91E-05	G	Output	Airborne	air
Copper	1.57E-06	G	Output	Airborne	air
Cumene	7.49E-07	G	Output	Airborne	air
Cyanide (-1)	3.53E-04	G	Output	Airborne	air
Di(2-ethylhexyl)phthalate	1.03E-05	G	Output	Airborne	air
Dibenzo[a,h]anthracene	1.38E-09	G	Output	Airborne	air
Dichloromethane	4.10E-05	G	Output	Airborne	air
Dimethyl sulfate	6.78E-06	G	Output	Airborne	air
Dioxins, remaining unspeciated	9.21E-11	G	Output	Airborne	air
Ethyl Chloride	5.93E-06	G	Output	Airborne	air
Ethylbenzene	1.33E-05	G	Output	Airborne	air
Ethylene dibromide	1.70E-07	G	Output	Airborne	air
Fluoranthene	1.06E-07	G	Output	Airborne	air
Fluorene	1.32E-07	G	Output	Airborne	air
Fluoride	3.08E-05	G	Output	Airborne	air
Formaldehyde	1.33E-04	G	Output	Airborne	air
Furans, remaining unspeciated	1.47E-10	G	Output	Airborne	air
Hexane	9.46E-06	G	Output	Airborne	air
Hydrochloric acid	1.70E-01	G	Output	Airborne	air
Hydrofluoric acid	2.12E-02	G	Output	Airborne	air
Indeno(1,2,3-cd)pyrene	1.04E-08	G	Output	Airborne	air
Isophorone	8.19E-05	G	Output	Airborne	air
Lead	2.01E-05	G	Output	Airborne	air
Magnesium	1.55E-03	G	Output	Airborne	air
Manganese	7.18E-05	G	Output	Airborne	air
Mercury	1.18E-05	G	Output	Airborne	air
Methane	1.02E+00	G	Output	Airborne	air
Methyl chloride	7.49E-05	G	Output	Airborne	air
Methyl ethyl ketone	5.51E-05	G	Output	Airborne	air
Methyl hydrazine	2.40E-05	G	Output	Airborne	air
Methyl methacrylate	2.83E-06	G	Output	Airborne	air

Table 3a. U.S. Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
Methyl tert-butyl ether	4.94E-06	G	Output	Airborne	air
Molybdenum	9.20E-07	G	Output	Airborne	air
Naphthalene	2.88E-06	G	Output	Airborne	air
Nickel	1.08E-04	G	Output	Airborne	air
Nitrogen oxides	1.85E+00	G	Output	Airborne	air
Nitrous oxide	5.35E-03	G	Output	Airborne	air
o-xylene	8.99E-08	G	Output	Airborne	air
PM-10	9.10E-02	G	Output	Airborne	air
Phenanthrene	3.95E-07	G	Output	Airborne	air
Phenol	2.26E-06	G	Output	Airborne	air
Phosphorus (yellow or white)	7.80E-06	G	Output	Airborne	air
Propionaldehyde	5.37E-05	G	Output	Airborne	air
Pyrene	5.25E-08	G	Output	Airborne	air
Selenium	1.84E-04	G	Output	Airborne	air
Styrene	3.53E-06	G	Output	Airborne	air
Sulfur dioxide	3.93E+00	G	Output	Airborne	air
TOCs, remaining unspeciated	9.07E-03	G	Output	Airborne	air
Tetrachloroethylene	6.07E-06	G	Output	Airborne	air
Toluene	4.00E-05	G	Output	Airborne	air
Vanadium	2.77E-05	G	Output	Airborne	air
Vinyl acetate	1.07E-06	G	Output	Airborne	air
Xylene (mixed isomers)	5.23E-06	G	Output	Airborne	air
Zinc (elemental)	2.40E-05	G	Output	Airborne	air
WATER RELEASES					
Sulfate ion (-4)	1.08E-01	G	Output	Waterborne	surface water
Suspended solids	2.80E-03	G	Output	Waterborne	surface water

Table 3a. U.S. Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
WASTE					
Coal waste	8.01E+01	G	Output	Solid waste	landfill
Dust/sludge	3.10E+01	G	Output	Solid waste	landfill
Fly/bottom ash	2.00E+01	G	Output	Solid waste	landfill
Low-level radioactive waste	2.77E-03	G	Output	Radioactive waste	landfill
Uranium, depleted	8.30E-04	G	Output	Radioactive waste	landfill
RADIOACTIVE AIR EMISSIONS					
Argon-41 (isotope)	2.51E+01	Bq	Output	Radioactivity	air
Bromine-89 (isotope)	2.91E-06	Bq	Output	Radioactivity	air
Bromine-90 (isotope)	1.18E-06	Bq	Output	Radioactivity	air
Cesium-134 (isotope)	7.99E-05	Bq	Output	Radioactivity	air
Cesium-137 (isotope)	6.02E-04	Bq	Output	Radioactivity	air
Chromium-51 (isotope)	1.58E-03	Bq	Output	Radioactivity	air
Cobalt-57 (isotope)	4.24E-06	Bq	Output	Radioactivity	air
Cobalt-58 (isotope)	5.41E+00	Bq	Output	Radioactivity	air
Cobalt-60 (isotope)	4.07E-04	Bq	Output	Radioactivity	air
Iodine-131 (isotope)	1.90E-03	Bq	Output	Radioactivity	air
Iodine-132 (isotope)	3.86E-04	Bq	Output	Radioactivity	air
Iodine-133 (isotope)	1.76E+00	Bq	Output	Radioactivity	air
Iodine-134 (isotope)	2.00E-03	Bq	Output	Radioactivity	air
Iodine-135 (isotope)	1.01E-04	Bq	Output	Radioactivity	air
Krypton-85 (isotope)	4.17E+01	Bq	Output	Radioactivity	air
Krypton-85M (isotope)	2.02E+00	Bq	Output	Radioactivity	air
Krypton-87 (isotope)	7.52E-01	Bq	Output	Radioactivity	air
Krypton-88 (isotope)	3.53E+00	Bq	Output	Radioactivity	air
Manganese-54 (isotope)	2.24E-05	Bq	Output	Radioactivity	air
Niobium-95 (isotope)	8.89E-07	Bq	Output	Radioactivity	air
Rubidium-88 (isotope)	8.26E-03	Bq	Output	Radioactivity	air
Silver-110M (isotope)	2.65E-08	Bq	Output	Radioactivity	air
Technetium-99M (isotope)	1.19E-07	Bq	Output	Radioactivity	air
Tritium-3 (isotope)	5.90E+01	Bq	Output	Radioactivity	air
Xenon-131M (isotope)	3.40E+00	Bq	Output	Radioactivity	air
Xenon-133 (isotope)	4.91E+02	Bq	Output	Radioactivity	air
Xenon-133M (isotope)	3.26E+01	Bq	Output	Radioactivity	air
Xenon-135 (isotope)	1.85E+01	Bq	Output	Radioactivity	air
Xenon-135M (isotope)	3.54E-01	Bq	Output	Radioactivity	air
Xenon-138 (isotope)	1.17E+00	Bq	Output	Radioactivity	air

Table 3a. U.S. Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
Zirconium-95 (isotope)	2.30E-06	Bq	Output	Radioactivity	air
RADIOACTIVE WATER RELEASES					
Antimony-124 (isotope)	1.24E-02	Bq	Output	Radioactivity	surface water
Antimony-125 (isotope)	4.95E-02	Bq	Output	Radioactivity	surface water
Barium-140 (isotope)	9.21E-04	Bq	Output	Radioactivity	surface water
Cesium-134 (isotope)	3.32E-02	Bq	Output	Radioactivity	surface water
Cesium-136 (isotope)	3.84E-14	Bq	Output	Radioactivity	surface water
Cesium-137 (isotope)	4.99E-02	Bq	Output	Radioactivity	surface water
Chromium-51 (isotope)	5.98E-02	Bq	Output	Radioactivity	surface water
Cobalt-57 (isotope)	1.45E-03	Bq	Output	Radioactivity	surface water
Cobalt-58 (isotope)	5.90E-01	Bq	Output	Radioactivity	surface water
Cobalt-80 (isotope)	1.55E-01	Bq	Output	Radioactivity	surface water
Iodine-131 (isotope)	2.76E-02	Bq	Output	Radioactivity	surface water
Iodine-132 (isotope)	1.05E-02	Bq	Output	Radioactivity	surface water
Iodine-133 (isotope)	1.18E-02	Bq	Output	Radioactivity	surface water
Iodine-135 (isotope)	8.49E-03	Bq	Output	Radioactivity	surface water
Iron-55 (isotope)	1.41E-01	Bq	Output	Radioactivity	surface water
Iron-59 (isotope)	7.24E-03	Bq	Output	Radioactivity	surface water
Krypton-85M (isotope)	3.73E-02	Bq	Output	Radioactivity	surface water
Lanthanum-140 (isotope)	9.86E-04	Bq	Output	Radioactivity	surface water
Manganese-54 (isotope)	3.94E-02	Bq	Output	Radioactivity	surface water
Molybdenum-99 (isotope)	7.44E+04	Bq	Output	Radioactivity	surface water
Niobium-95 (isotope)	1.02E-02	Bq	Output	Radioactivity	surface water
Ruthenium-103 (isotope)	1.24E-03	Bq	Output	Radioactivity	surface water
Silver-110M (isotope)	1.45E-02	Bq	Output	Radioactivity	surface water
Sodium-24 (isotope)	2.21E-03	Bq	Output	Radioactivity	surface water
Strontium-89 (isotope)	2.39E-03	Bq	Output	Radioactivity	surface water
Strontium-90 (isotope)	5.61E-04	Bq	Output	Radioactivity	surface water
Strontium-95 (isotope)	6.18E-03	Bq	Output	Radioactivity	surface water
Sulfur-136 (isotope)	1.33E-03	Bq	Output	Radioactivity	surface water
Technetium-99M (isotope)	8.66E-04	Bq	Output	Radioactivity	surface water
Tin-113 (isotope)	1.37E-03	Bq	Output	Radioactivity	surface water
Tritium-3 (isotope)	4.41E+02	Bq	Output	Radioactivity	surface water
Xenon-131M (isotope)	4.54E-01	Bq	Output	Radioactivity	surface water
Xenon-133 (isotope)	6.97E+01	Bq	Output	Radioactivity	surface water
Xenon-133M (isotope)	5.71E-01	Bq	Output	Radioactivity	surface water
Xenon-135 (isotope)	5.20E-01	Bq	Output	Radioactivity	surface water

Table 3a. U.S. Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
Zinc-85 (isotope)	6.65E-04	Bq	Output	Radioactivity	surface water

Table 3b. Japanese Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
PRIMARY INPUTS					
Coal, avg. (in ground)	8.88E+01	G	Input	Primary material	
Natural gas	4.85E+01	G	Input	Primary material	
Petroleum (in ground)	5.00E+01	G	Input	Primary material	
Uranium, yellowcake	1.18E-02	G	Input	Primary material	
ANCILLARY INPUTS					
Lime	5.24E-01	G	Input	Ancillary material	
Limestone	1.19E+00	G	Input	Ancillary material	
Water	1.72E+03	G	Input	Water	
PRODUCT					
Electricity	1.00E+00	KWH	Output	Energy	
AIR EMISSIONS					
1,1,1-Trichloroethane	2.51E-06	G	Output	Airborne	air
1,2-Dichloroethane	1.78E-06	G	Output	Airborne	air
2,3,7,8-TCDD	6.53E-13	G	Output	Airborne	air
2,3,7,8-TCDF	2.27E-12	G	Output	Airborne	air
2,4-Dinitrotoluene	1.24E-08	G	Output	Airborne	air
2-Chloroacetophenone	3.11E-07	G	Output	Airborne	air
2-Methylnaphthalene	9.24E-09	G	Output	Airborne	air
5-Methyl chrysene	9.77E-10	G	Output	Airborne	air
Acenaphthene	1.68E-07	G	Output	Airborne	air
Acenaphthylene	1.28E-08	G	Output	Airborne	air
Acetaldehyde	2.53E-05	G	Output	Airborne	air
Acetophenone	6.66E-07	G	Output	Airborne	air
Acrolein	1.29E-05	G	Output	Airborne	air
Anthracene	1.77E-08	G	Output	Airborne	air
Antimony	3.69E-05	G	Output	Airborne	air
Arsenic	2.72E-05	G	Output	Airborne	air
Barium	2.01E-05	G	Output	Airborne	air
Benzene	5.92E-05	G	Output	Airborne	air
Benzo[a]anthracene	3.11E-08	G	Output	Airborne	air
Benzo[a]pyrene	1.69E-09	G	Output	Airborne	air
Benzo[b,j,k]fluoranthene	1.51E-08	G	Output	Airborne	air
Benzo[g,h,i]perylene	1.67E-08	G	Output	Airborne	air
Benzyl chloride	3.11E-05	G	Output	Airborne	air
Beryllium	1.26E-06	G	Output	Airborne	air

Table 3b. Japanese Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
Biphenyl	7.55E-08	G	Output	Airborne	air
Bromoform	1.73E-06	G	Output	Airborne	air
Bromomethane	7.11E-06	G	Output	Airborne	air
Cadmium	5.48E-06	G	Output	Airborne	air
Carbon dioxide	5.98E+02	G	Output	Airborne	air
Carbon disulfide	5.78E-06	G	Output	Airborne	air
Carbon monoxide	1.09E-01	G	Output	Airborne	air
Chloride ions	2.39E-03	G	Output	Airborne	air
Chlorobenzene	9.77E-07	G	Output	Airborne	air
Chloroform	2.62E-06	G	Output	Airborne	air
Chromium (III)	2.15E-05	G	Output	Airborne	air
Chromium (VI)	5.22E-06	G	Output	Airborne	air
Chrysene	2.08E-08	G	Output	Airborne	air
Cobalt	4.60E-05	G	Output	Airborne	air
Copper	1.24E-05	G	Output	Airborne	air
Cumene hydroperoxide	2.35E-07	G	Output	Airborne	air
Cyanide (-1)	1.11E-04	G	Output	Airborne	air
Di(2-ethylhexyl)phthalate	3.24E-06	G	Output	Airborne	air
Dibenzo[a,h]anthracene	1.15E-08	G	Output	Airborne	air
Dichloromethane	1.29E-05	G	Output	Airborne	air
Dimethyl sulfate	2.13E-06	G	Output	Airborne	air
Dioxins, remaining unspeciated	2.90E-11	G	Output	Airborne	air
Ethyl Chloride	1.87E-06	G	Output	Airborne	air
Ethylbenzene	4.61E-06	G	Output	Airborne	air
Ethylene dibromide	5.33E-08	G	Output	Airborne	air
Fluoranthene	6.79E-08	G	Output	Airborne	air
Fluorene	7.11E-08	G	Output	Airborne	air
Fluorides (F-)	2.57E-04	G	Output	Airborne	air
Formaldehyde	3.97E-04	G	Output	Airborne	air
Furans, remaining unspeciated	4.62E-11	G	Output	Airborne	air
Hexane	2.98E-06	G	Output	Airborne	air
Hydrochloric acid	5.33E-02	G	Output	Airborne	air
Hydrofluoric acid	6.66E-03	G	Output	Airborne	air
Indeno(1,2,3-cd)pyrene	1.74E-08	G	Output	Airborne	air
Isophorone	2.58E-05	G	Output	Airborne	air
Lead (Pb, ore)	1.71E-05	G	Output	Airborne	air
Magnesium	4.89E-04	G	Output	Airborne	air
Manganese (Mn, ore)	4.24E-05	G	Output	Airborne	air
Mercury	4.59E-06	G	Output	Airborne	air

Table 3b. Japanese Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
Methane	3.16E-03	G	Output	Airborne	air
Methyl chloride	2.35E-05	G	Output	Airborne	air
Methyl ethyl ketone	1.73E-05	G	Output	Airborne	air
Methyl hydrazine	7.55E-06	G	Output	Airborne	air
Methyl methacrylate	8.88E-07	G	Output	Airborne	air
Methyl tert-butyl ether	1.55E-06	G	Output	Airborne	air
Molybdenum	6.01E-06	G	Output	Airborne	air
Naphthalene	8.60E-06	G	Output	Airborne	air
Nickel	5.72E-04	G	Output	Airborne	air
Nitrogen oxides	1.58E+00	G	Output	Airborne	air
Nitrous oxide	4.34E-03	G	Output	Airborne	air
o-xylene	7.50E-07	G	Output	Airborne	air
Phenanthrene	2.02E-07	G	Output	Airborne	air
Phenol	7.11E-07	G	Output	Airborne	air
PM-10	7.77E-02	G	Output	Airborne	air
Propionaldehyde	1.69E-05	G	Output	Airborne	air
Pyrene	4.90E-08	G	Output	Airborne	air
Selenium	6.25E-05	G	Output	Airborne	air
Styrene	1.11E-06	G	Output	Airborne	air
Sulfur dioxide	3.35E+00	G	Output	Airborne	air
Tetrachloroethylene	1.91E-06	G	Output	Airborne	air
TOCs, remaining unspeciated	7.66E-03	G	Output	Airborne	air
Toluene	5.56E-05	G	Output	Airborne	air
Vanadium	2.22E-04	G	Output	Airborne	air
Vinyl acetate	3.37E-07	G	Output	Airborne	air
Xylene (mixed isomers)	1.64E-06	G	Output	Airborne	air
Zinc (elemental)	2.00E-04	G	Output	Airborne	air
WATER RELEASES					
Sulfate ion (-4)	3.39E-02	G	Output	Waterborne	surface water
Suspended solids	8.82E-04	G	Output	Waterborne	surface water
WASTE					
Coal waste	2.52E+01	G	Output	Solid waste	landfill
Dust/sludge	9.73E+00	G	Output	Solid waste	landfill
Fly/bottom ash	6.30E+00	G	Output	Solid waste	landfill
Low-level radioactive waste	4.29E-03	G	Output	Radioactive waste	landfill
Uranium, depleted	1.29E-03	G	Output	Radioactive waste	landfill
RADIOACTIVE AIR EMISSIONS					
Argon-41 (isotope)	3.89E+01	Bq	Output	Radioactivity	air
Bromine-89 (isotope)	4.50E-06	Bq	Output	Radioactivity	air

Table 3b. Japanese Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
Bromine-90 (isotope)	1.83E-06	Bq	Output	Radioactivity	air
Cesium-134 (isotope)	1.24E-04	Bq	Output	Radioactivity	air
Cesium-137 (isotope)	9.33E-04	Bq	Output	Radioactivity	air
Chromium-51 (isotope)	2.44E-03	Bq	Output	Radioactivity	air
Cobalt-57 (isotope)	6.57E-06	Bq	Output	Radioactivity	air
Cobalt-58 (isotope)	8.38E-05	Bq	Output	Radioactivity	air
Cobalt-60 (isotope)	6.31E-04	Bq	Output	Radioactivity	air
Iodine-131 (isotope)	2.95E-03	Bq	Output	Radioactivity	air
Iodine-132 (isotope)	5.99E-04	Bq	Output	Radioactivity	air
Iodine-133 (isotope)	2.73E+00	Bq	Output	Radioactivity	air
Iodine-134 (isotope)	3.10E-03	Bq	Output	Radioactivity	air
Iodine-135 (isotope)	1.56E-04	Bq	Output	Radioactivity	air
Krypton-85 (isotope)	6.46E+01	Bq	Output	Radioactivity	air
Krypton-85M (isotope)	3.13E+00	Bq	Output	Radioactivity	air
Krypton-87 (isotope)	1.17E+00	Bq	Output	Radioactivity	air
Krypton-88 (isotope)	5.47E+00	Bq	Output	Radioactivity	air
Manganese-54 (isotope)	3.47E-05	Bq	Output	Radioactivity	air
Niobium-95 (isotope)	1.38E-06	Bq	Output	Radioactivity	air
Rubidium-88 (isotope)	1.28E-02	Bq	Output	Radioactivity	air
Silver-110M (isotope)	4.11E-08	Bq	Output	Radioactivity	air
Technetium-99M (isotope)	1.85E-07	Bq	Output	Radioactivity	air
Tritium-3 (isotope)	9.13E+01	Bq	Output	Radioactivity	air
Xenon-131M (isotope)	5.27E+00	Bq	Output	Radioactivity	air
Xenon-133 (isotope)	5.05E+01	Bq	Output	Radioactivity	air
Xenon-133 (isotope)	5.05E+01	Bq	Output	Radioactivity	air
Xenon-133M (isotope)	7.60E+02	Bq	Output	Radioactivity	air
Xenon-135 (isotope)	2.87E+01	Bq	Output	Radioactivity	air
Xenon-135M (isotope)	5.48E-01	Bq	Output	Radioactivity	air
Xenon-138 (isotope)	1.82E+00	Bq	Output	Radioactivity	air
Zirconium-95 (isotope)	3.56E-06	Bq	Output	Radioactivity	air
RADIOACTIVE WATER RELEASES					
Antimony-124 (isotope)	1.92E-02	Bq	Output	Radioactivity	surface water
Antimony-125 (isotope)	7.67E-02	Bq	Output	Radioactivity	surface water
Barium-140 (isotope)	1.43E-03	Bq	Output	Radioactivity	surface water
Cesium-134 (isotope)	5.15E-02	Bq	Output	Radioactivity	surface water
Cessium-137 (isotope	7.73E-02	Bq	Output	Radioactivity	surface water
Chromium-51 (isotope)	9.27E-02	Bq	Output	Radioactivity	surface water
Cobalt-57 (isotope)	2.24E-03	Bq	Output	Radioactivity	surface water
Cobalt-58 (isotope)	9.13E-01	Bq	Output	Radioactivity	surface water

Table 3b. Japanese Electricity Generation Inventory [inputs and outputs per kWh (3.6 MJ)]

Material	Quantity	Units	Input/output	Input/output type	Disposition
Cobalt-80 (isotope)	2.40E-01	Bq	Output	Radioactivity	surface water
Iodine-131 (isotope)	4.28E-02	Bq	Output	Radioactivity	surface water
Iodine-132 (isotope)	1.62E-02	Bq	Output	Radioactivity	surface water
Iodine-133 (isotope)	1.83E-02	Bq	Output	Radioactivity	surface water
Iodine-135 (isotope)	1.31E-02	Bq	Output	Radioactivity	surface water
Iron-55 (isotope)	2.18E-01	Bq	Output	Radioactivity	surface water
Iron-59 (isotope)	1.12E-02	Bq	Output	Radioactivity	surface water
Krypton-85M (isotope)	5.77E-02	Bq	Output	Radioactivity	surface water
Lanthanum-140 (isotope)	1.53E-03	Bq	Output	Radioactivity	surface water
Manganese-54 (isotope)	6.11E-02	Bq	Output	Radioactivity	surface water
Molybdenum-99 (isotope)	1.15E+05	Bq	Output	Radioactivity	surface water
Niobium-95 (isotope)	1.57E-02	Bq	Output	Radioactivity	surface water
Ruthenium-103 (isotope)	1.92E-03	Bq	Output	Radioactivity	surface water
Silver-110M (isotope)	2.24E-02	Bq	Output	Radioactivity	surface water
Sodium-24 (isotope)	3.42E-03	Bq	Output	Radioactivity	surface water
Strontium-89 (isotope)	3.70E-03	Bq	Output	Radioactivity	surface water
Strontium-90 (isotope)	8.69E-04	Bq	Output	Radioactivity	surface water
Strontium-95 (isotope)	9.57E-03	Bq	Output	Radioactivity	surface water
Sulfur-136 (isotope)	2.06E-03	Bq	Output	Radioactivity	surface water
Technetium-99M (isotope)	1.34E-03	Bq	Output	Radioactivity	surface water
Tin-113 (isotope)	2.12E-03	Bq	Output	Radioactivity	surface water
Tritium-3 (isotope)	6.83E+02	Bq	Output	Radioactivity	surface water
Xenon-131M (isotope)	7.02E-01	Bq	Output	Radioactivity	surface water
Xenon-133M (isotope)	8.84E-01	Bq	Output	Radioactivity	surface water
Xenon-135 (isotope)	8.05E-01	Bq	Output	Radioactivity	surface water
Zinc-85 (isotope)	1.03E-03	Bq	Output	Radioactivity	surface water

3. METHODOLOGY

The U.S.-wide inventory was developed by first compiling inventory data for each of the major generation (fuel-specific) categories used to produce electricity in the U.S., and then creating the U.S.-wide inventory from the fuel-specific inventories. The creation of the U.S.-wide data from the fuel-specific inventories required two particular sets of information: 1997 fuel consumption data and 1997 fuel-specific net electricity generation data (see Table 4). In the majority of cases, one or more pieces of information from these two data sets was needed to convert each input or output into the units of grams per kWh (excluding the radionuclides which were converted to Becquerels per kWh).

Table 4. 1997 U.S. Electricity Utility Summary Statistics

Fuel [a]	1997 Fuel Consumption	Units	1997 Net Electricity Generation	1997 Generation % Breakdown
Coal	900,361,000	short tons/yr	1,787,806,000,000	57.23%
Gas	2,968,453	million ft3/yr	283,625,000,000	9.07%
Petroleum	5,256,132	thousand gal/yr	77,753,000,000	2.53%
Nuclear	48,700,000	lbs U_3O_8/yr	628,644,000,000	20.14%
Hydro [b]	--	--	337,233,000,000	10.79%
Renewables [b]	--	--	7,462,000,000	0.24%
Total			3,122,522,000,000	100%

Source: EIA 1999a.

[a] This breakdown exludes nonutility electricity genration (non and Independent Power Producers (NPPs or IPPs), which typically contribute about 11% of the U.S. total (EIA 1999).

[b] Hydro and renewables were exluded from the calculation of inputs and outputs.

Data on the inputs and outputs for electricity generation were obtained from available sources; when multiple sources of the same type of data were found, those data believed to have the highest quality were utilized (Section 5 addresses data quality). Most data obtained were fuel-specific, however some of the data found were already aggregated to the U.S.-wide level, and thus did not need converting from the fuel-specific values. Thus, for some input/output categories, few calculations were necessary; for others, more complex equations were required to calculate the final input or output data.

As stated earlier in this TM, the final electric grid inventory data (in units of grams/net kWh, for example) will be multiplied by energy use values throughout the life cycle (in units of point-of-use kWhs/functional unit). The two kWhs referred to are different, with the difference being net generated kWhs versus point-of-use kWhs. Due to losses that are associated with moving electrical energy from a point of generation to a point of use, known as ‘transmission and distribution (TD) losses,’ these must be accounted for in the calculations. It was found in the research for this TM that for 1997 the nationwide TD losses were on the order of 8% of net generation (EIA 1999b). Therefore, to make the kWhs equivalent, the net generation was divided by a TD factor of 1.08 to effectively convert the net kWhs to point-of-use kWhs. The net kWhs are divided by the 1.08 TD factor in all the equations shown in this TM.

The following subsections provide the methodology used and basic equations utilized to create the U.S.-wide inventory from the fuel-specific input and output values.

3.1 Inputs

3.1.1 Primary Materials

Primary materials are typically considered in LCA to be those materials that become part of the final product of the process being modeled. For the process of electricity generation, the fuels used to produce the electrical energy are usually considered to be the only 'primary' materials. Thus, for the U.S. and Japanese electric grid inventory data, the primary materials include coal, gas, petroleum and uranium. The U.S. nationwide total quantities of these fuels consumed by utilities in 1997 was obtained from the Energy Information Administration (EIA 1999a for coal, gas and petroleum; EIA 1998b for uranium). The Japanese data were obtained from the EIA's Country Energy Data Report (EIA 1997). Note that the primary material for nuclear-based electricity generation is referred to as "yellowcake," which is the most common physical state on which uranium consumption is based. Yellowcake is a yellowish-brown powder that is the product of the initial milling process that follows mining. The input data were provided on a nationwide basis, thus the equation needed to calculate each fuel's use rate in grams per kWh is shown below:

$$UR_{fuel\ i} = \frac{Con_{fuel\ i}}{\frac{Gen_{net}}{TD}} \qquad \textbf{\textit{Eq. 1}}$$

where,

$UR_{\text{fuel } i}$ = nationwide input use rate per unit of electricity for fuel *i*, where the four fuels are coal, gas, petroleum and uranium (grams/kWh),

$Con_{\text{fuel } i}$ = annual consumption rate for fuel *i* (mass or volume/yr; converted to grams using density as necessary, see Attachment E, Table E5),

Gen_{net} = net annual nationwide electricity generation (kWh/yr), and

TD = nationwide average transmission and distribution losses factor (percent).

In calculating the primary material consumption rates for each fuel, material densities and conversion factors for mass, volume and energy were utilized where needed, depending on whether the units of consumption were in mass or volume (see Attachment E, Table E5).

3.1.2 Ancillary Materials

Ancillary materials are considered to be those materials that help the process function or work, yet do not become part of the final product. In generating electricity, all materials used, except the fuel itself, are typically considered to be ancillary materials. The ancillary materials accounted for in the U.S. electric grid inventory data are limestone and lime which are sulfur dioxide removal system catalysts typically used in coal firing, and cooling water which is consumed in generating electricity from all fuel types.

The limestone and lime values were derived by utilizing data from approximately five different sources, primarily the EIA, the Acid Rain database and direct contact with utility employees. In short, individual lime and limestone annual consumption rates were developed in units of pounds per year for each plant in the U.S. that utilizes a lime- or limestone-based flue gas desulfurization (FGD) system, and then those values were added to obtain the total poundage or tonnage consumed annually in the U.S. (tons per year). At that point, Equation 1 could be used (calculating only for coal) to obtain the quantity of lime or limestone consumed in grams per kWh generated. Cooling water consumption in units of gallons per kWh was obtained from the California Energy Commission (CEC 1979; cited in Paul Gipe's *Wind Energy Comes of Age*, John Wiley & Sons, 1995). Since cooling water is consumed during electricity generation for each of the fuel types followed in this inventory data set, one equation was used to calculate the nationwide average cooling water requirements:

$$UR_{water} = \frac{\sum_{i=1}^{4} \left(Con_{water} \times Gen\right)_{fuel\ i}}{\frac{Gen_{net}}{TD}} \qquad \textbf{\textit{Eq. 2}}$$

where,

Ur_{water} = nationwide input use rate per unit of electricity for water (grams/kWh),

Con_{water} = average consumption rate per unit of electricity for water for fuel *i*, where the four fuels are coal, gas, petroleum and uranium (gallons/kWh; converted to grams using density, see Attachment E, Table E5),

Gen = net annual electricity generation rate for fuel *i* (kWh/yr),

Gen_{net} = net annual nationwide electricity generation (kWh/yr), and

TD = nationwide average transmission and distribution losses factor (percent).

3.2 Outputs

3.2.1 Air Emissions

Several sources of air emissions data where evaluated in compiling the electric grid inventory data. The evaluation revealed that AP-42 (EPA 1996) data are the most complete source of speciated air emissions data *that are easily accessible and do not require a substantial investment to obtain*. Thus, AP-42 data were used as the foundation for the air emissions estimates. ('AP-42' is the EPA's emission factors data set that addresses the type and quantity of air pollutants that result from over 200 major industries, point sources and mobile sources.)

The evaluation also revealed a few sources of higher quality data for some pollutants, and in those cases, that information was used to either augment or replace the AP-42 factors. Specifically, the air pollutant release rates for criteria pollutants were obtained from the EPA (1998b) on a nationwide annual basis and used instead of the AP-42 factors for those pollutants (the values covered all fossil fuel-based generation categories and were in units of pounds per year). The criteria pollutants include carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides

(NO_X), carbon monoxide (CO), lead (Pb) and particulate matter ten micrometers or less in diameter (PM-10), and the following equation was used to obtain the emission rates for these pollutants in units of grams/kWh:

$$RR_{air-criteria\ i} = \frac{Rel_{air-criteria\ i}}{\frac{Gen_{net}}{TD}} \qquad \textbf{\textit{Eq. 3}}$$

where,

$RR_{air\text{-}criteria\ i}$ = nationwide release rate per unit of electricity for criteria pollutant *i* (grams/kWh),
$Rel_{air\text{-}criteria\ i}$ = annual release rate for criteria pollutant *i* (lbs/yr),
Gen_{net} = net annual nationwide electricity generation (kWh/yr), and
TD = nationwide average transmission and distribution losses factor (percent).

Nuclear power plants produce electricity without combusting fuel, thus no criteria pollutants are emitted to the local air environment during nuclear power production. However, nuclear-based electricity generation does produce some airborne radionuclides, which are addressed in Section 3.2.4. No airborne releases from nuclear-based generation are addressed here.

The air pollutants accounted for in this inventory calculated from AP-42 air emission factors are shown in Table 5. Of these air emission factors, Table 5 shows the number of pollutants in each category, what fuels AP-42 has release data for, and whether the AP-42 data reflects controlled or uncontrolled release of those pollutants.

The equation used to calculate the nationwide emissions of these non-criteria pollutants is Equation 4. The equation shows a summation of three release and consumption rates, which was adjusted for the number of fuels from which the pollutants were listed in AP-42 (shown in Table 5).

For all of the pollutants in Table 5, AP-42 lists only one emission factor per pollutant per fuel (for example, pounds of benzene released per ton of coal burned). Thus, each factor represents a combined emissions estimate for the various technologies used to fire each fuel.

In augmenting the AP-42 data, it was also determined that the nationwide methane (CH_4) air releases generated during coal mining (EPA 1998c) are significant, and were added to the emissions estimates of CH_4 from coal and petroleum combustion. These emissions were presented in units of nationwide cubic feet of methane released per year.

Table 5. Air Pollutant Information from AP-42

Pollutant Category/Pollutant	# of factors provided	Fuels from Which Pollutants Were Listed in AP-42			Controlled/ Uncontrolled
		Coal	Gas	Petroleum	
Speciated organic compounds	37	✔	✔	✔	Controlled
Trace metals	13	✔	✔	✔	Controlled
Polycryclic aromatic hydrocarbons	16	✔			Controlled
Dioxins & furans	16	✔			Controlled
Methane	1	✔		✔	Uncontrolled
Nitrous oxide	1	✔	✔	✔	Uncontrolled
Hydrogen chloride	1	✔			Uncontrolled
Hydrogen fluoride	1	✔			Uncontrolled
Total organic compounds	1	✔	✔	✔	Uncontrolled
Total nonmethane organic compounds	1	✔		✔	Uncontrolled

Source: EPA 1996.

$$RR_{air-other\,j} = \frac{\sum_{i=1}^{3}\left(Rel_{air-other\,j} \times Con\right)_{fuel\,i}}{\dfrac{Gen_{net}}{TD}} \qquad Eq.\ 4$$

where,

$Rr_{air\text{-}other\,j}$ = nationwide release rate for each pollutant j (grams/kWh),

$Rel_{air\text{-}other\,j}$ = release rate per unit of fuel for each air pollutant j from fossil fuel i (coal - lbs/ton, gas - lbs/million cubic feet, petroleum - lbs/thousand gallons),

Con = annual consumption rate of fuel i (coal - tons/yr, gas - million cubic feet/yr, petroleum - thousand gallons/yr),

Gen_{net} = net annual nationwide electricity generation (kWh/yr), and

TD = nationwide average transmission and distribution losses factor (percent).

3.2.2 Solid Wastes

For the U.S. electric grid inventory data, two types of solid waste exist: coal-fired generation nonhazardous solid wastes and nuclear-based generation radioactive solid wastes. [The term ‘solid waste’ as it is used in this report applies to the Resource Conservation and Recovery Act (RCRA) definition which is defined in the U.S. Federal Code of Regulations (40 CFR 261).] For coal-fired generation, the solid wastes values were obtained from a 1994 Oak Ridge National Laboratory (ORNL) report entitled “Estimating Externalities of Coal Fuel Cycles,” and were provided in units of tons of waste produced per gigawatthour (GWh) generated. The calculation needed to obtain the nationwide releases is as follows:

$$RR_{solid\ i} = \frac{Rel_{solid\ i} \times Gen_{coal}}{\frac{Gen_{net}}{TD}} \qquad \textbf{Eq. 5}$$

where,

$RR_{solid\ i}$ = nationwide release rate per unit of electricity for solid waste *i* from coal-fired generation (grams/kWh),

$Rel_{solid\ i}$ = release rate per unit of electricity for solid waste *i* from coal-fired generation (tons/GWh),

Gen_{coal} = net annual electricity generation rate for coal (MWh/yr),

Gen_{net} = net annual nationwide electricity generation (kWh/yr), and

TD = nationwide average transmission and distribution losses factor (percent).

For the two nuclear-based generation wastes quantified, spent fuel and low-level radioactive waste (LLRW), two data sources were utilized. The spent fuel data information was obtained from the EIA in units of pounds per year and the LLRW data from an expert in the nuclear electricity generation industry (Loiselle 1998) in units of cubic feet per year (see Attachment E, Table E5 for LLRW conversion factor). The calculation used to derive the quantity of both nuclear wastes generated in units of grams per kWh was similar to Equations 1 and 3, and is shown below:

$$GR_{nuclear\ i} = \frac{Gen_{nuclear\ i}}{\frac{Gen_{net}}{TD}} \qquad \textbf{Eq. 6}$$

where,

$GR_{\ nuclear\ i}$ = nationwide generation rate per unit of electricity for nuclear waste *i* (grams/kWh),

$Gen_{nuclear\ i}$ = nationwide annual generation rate for nuclear waste *i* (spent fuel - lbs/yr, LLRW - ft^3/yr; converted to grams using density as necessary, see Attachment E, Table E5),

Gen_{net} = net annual nationwide electricity generation (kWh/yr), and

TD = nationwide average transmission and distribution losses factor (percent).

3.2.3 Water Releases

Water release information was obtained on coal-fired generation. Radioactive water release information is presented in Section 3.2.4. Information on only three water pollutants was obtained (ORNL 1994). Data were in units of tons/GWh, and thus used an equation like Equation 5 to calculate the nationwide release per unit of electricity generated:

$$RR_{water\ i} = \frac{Rel_{water\ i} \times Gen_{coal}}{\frac{Gen_{net}}{TD}} \qquad \textbf{\textit{Eq. 7}}$$

where,

$RR_{water\ i}$ = nationwide release rate per unit of electricity for water pollutant *i* from coal-fired generation (grams/kWh),

$Rel_{water\ i}$ = release rate per unit of electricity for water pollutant *i* from coal-fired generation (tons/GWh),

Gen_{coal} = net annual electricity generation rate for coal (MWh/yr),

Gen_{net} = net annual nationwide electricity generation (kWh/yr), and

TD = nationwide average transmission and distribution losses factor (percent).

3.2.4 Radionuclides

During the operation of nuclear electricity generation facilities, both airborne and waterborne radioactive releases are generated that are not directly related to a facility's capacity to generate power (kWs) or to the quantity of power it generates over time (kWhs). Data were obtained on the radioactive releases of many nuclear facilities in the U.S. from an ORNL report which addressed the externalities of nuclear fuel cycles (ORNL 1995). This report presented averaged release rate information for 31 airborne and 35 waterborne radioactive releases, which were from direct measurements at many U.S.-based nuclear facilities, all of which were presented in units of Curies per year. Although the releases where found *not* to relate directly to power generation or power generating capacity, some scale was needed to convert the quantity of release from multiple facilities to a quantity of release for all the facilities in use in the U.S. Therefore, due to a lack of any other identifiable scaling mechanism, the quantity of power generated was utilized. The Curies per year value for each radioactive release was first converted into Curies per MWh by dividing by the number of MWhs generated by the average facility identified in the report. Then the values were converted into units of Becquerels per kWh. The following equation was utilized for converting airborne and waterborne radionuclides to the nationwide grid:

$$RR_{radionuclide\ i} = \frac{Rel_{radionuclide\ i} \times Gen_{nuclear}}{\frac{Gen_{net}}{TD}} \qquad \textbf{\textit{Eq. 8}}$$

where,

$RR_{radionuclide\ i}$ = nationwide release rate per unit of electricity for radionuclide *i* (Becquerels/kWh),

$Rel_{radionuclide\ i}$ = averaged release rate per unit of electricity for radionuclide *i* (Curies/MWh),

$Gen_{nuclear}$ = annual electricity generation rate for nuclear (MWh/yr),

Gen_{net} = net annual nationwide electricity generation (kWh/yr), and

TD = nationwide average transmission and distribution losses factor (percent).

4. FUEL-SPECIFIC RESULTS

Tables 6 through 9 present the inputs and outputs from each of the individual fuel inventories. The data in those tables were aggregated into the U.S.-wide average data for electricity generation (Table 3a) and Japanese average data (Table 3b). Additionally, the spreadsheets from which Tables 6 through 9 were derived are shown in Attachments A through E and provide some additional information about each inventory.

Table 6. Inputs and Outputs for Coal-Fired Electricity Generation in the United States[a]

Material/pollutant	**Quantity**	**Unit**
INPUTS		
Primary Materials		
Coal	9.00E+08	tons/yr
Ancillary Materials		
Limestone	1.21E+07	tons/yr
Lime	5.31E+06	tons/yr
Cooling water	4.90E-01	gal/kWh
OUTPUTS		
Air Emissions		
Methane	4.00E-02	lbs/ton
Nitrous oxide	3.00E-02	lbs/ton
Hydrogen chloride	1.20E+00	lbs/ton
Hydrogen fluoride	1.50E-01	lbs/ton
TOC	3.00E-01	lbs/ton
TNMOC	6.00E-02	lbs/ton
SPECIATED ORGANIC COMPOUNDS		
Acetaldehyde	5.70E-04	lbs/ton
Acetophenone	1.50E-05	lbs/ton
Acrolein	2.90E-04	lbs/ton
Benzene	1.30E-03	lbs/ton
Benzyl chloride	7.00E-04	lbs/ton
Bis(2-ethylhexyl)phthalate (DEHP)	7.30E-05	lbs/ton
Bromoform	3.90E-05	lbs/ton
Carbon disulfide	1.30E-04	lbs/ton
2-Chloroacetophenone	7.00E-06	lbs/ton
Chlorobenzene	2.20E-05	lbs/ton
Chloroform	5.90E-05	lbs/ton
Cumene	5.30E-06	lbs/ton
Cyanide	2.50E-03	lbs/ton
2,4-Dinitrotoluene	2.80E-07	lbs/ton
Dimethyl sulfate	4.80E-05	lbs/ton
Ethyl benzene	9.40E-05	lbs/ton
OUTPUTS (continued)		
Air Emissions (continued)		
TRACE METALS (continued)		
Beryllium	2.10E-05	lbs/ton
Cadmium	5.10E-05	lbs/ton
Chromium	2.60E-04	lbs/ton
Chromium (VI)	7.90E-05	lbs/ton
Cobalt	1.00E-04	lbs/ton
Magnesium	1.10E-02	lbs/ton
Manganese	4.90E-04	lbs/ton
Mercury	8.30E-05	lbs/ton
Nickel	2.80E-04	lbs/ton
Selenium	1.30E-03	lbs/ton
POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)		
Biphenyl	1.70E-06	lbs/ton
Acenaphthene	5.10E-07	lbs/ton
Acenaphthylene	2.50E-07	lbs/ton
Anthracene	2.10E-07	lbs/ton
Benzo(a)anthracene	8.00E-08	lbs/ton
Benzo(a)pyrene	3.80E-08	lbs/ton
Benzo(b,j,k)fluoranthene	1.10E-07	lbs/ton
Benzo(g,h,i)perylene	2.70E-08	lbs/ton
Chrysene	1.00E-07	lbs/ton
Fluoranthene	7.10E-07	lbs/ton
Fluorene	9.10E-07	lbs/ton
Indeno(1,2,3-cd)pyrene	6.10E-08	lbs/ton
Naphthalene	1.30E-05	lbs/ton
Phenanthrene	2.70E-06	lbs/ton
Pyrene	3.30E-07	lbs/ton
5-Methyl chrysene	2.20E-08	lbs/ton
DIOXINS & FURANS		
2,3,7,8-TCDD	1.43E-11	lbs/ton
Total TCDD	9.28E-11	lbs/ton
Total PeCDD	4.47E-11	lbs/ton

Table 6. Inputs and Outputs for Coal-Fired Electricity Generation in the United States[a]

Material/pollutant	Quantity	Unit	Material/pollutant	Quantity	Unit
Ethyl chloride	4.20E-05	lbs/ton	Total HxCDD	2.87E-11	lbs/ton
Ethylene dichloride	4.00E-05	lbs/ton	Total HpCDD	8.34E-11	lbs/ton
Ethylene dibromide	1.20E-06	lbs/ton	Total OCDD	4.16E-10	lbs/ton
Formaldehyde	2.40E-04	lbs/ton	Total PCDDd	6.66E-10	lbs/ton
Hexane	6.70E-05	lbs/ton	2,3,7,8-TCDF	5.10E-11	lbs/ton
Isophorone	5.80E-04	lbs/ton	Total TCDF	4.04E-10	lbs/ton
Methyl bromide	1.60E-04	lbs/ton	Total PeCDF	3.53E-10	lbs/ton
Methyl chloride	5.30E-04	lbs/ton	Total HxCDF	1.92E-10	lbs/ton
Methyl ethyl ketone	3.90E-04	lbs/ton	Total HpCDF	7.68E-11	lbs/ton
Methyl hydrazine	1.70E-04	lbs/ton	Total OCDF	6.63E-11	lbs/ton
Methyl methacrylate	2.00E-05	lbs/ton	Total PCDFd	1.09E-09	lbs/ton
Methyl tert butyl ether	3.50E-05	lbs/ton	*COAL MINE METHANE EMISSIONS*		
Methylene chloride	2.90E-04	lbs/ton	Methane	1.52E+11	ft^3/yr
Phenol	1.60E-05	lbs/ton			
Propionaldehyde	3.80E-04	lbs/ton	**Solid Wastes**		
Tetrachloroethylene	4.30E-05	lbs/ton	Dust/sludge	5.51E+01	tons/GWh
Toluene	2.40E-04	lbs/ton	Coal waste	1.43E+02	tons/GWh
1,1,1-Trichloroethane	2.00E-05	lbs/ton	Fly/bottom ash	3.57E+01	tons/GWh
Styrene	2.50E-05	lbs/ton			
Xylenes	3.70E-05	lbs/ton	**Water Releases**		
Vinyl acetate	7.60E-06	lbs/ton	Dissolver	2.78E-01	tons/GWh
TRACE METALS			Suspended solids	5.00E-03	tons/GWh
Antimony	1.80E-05	lbs/ton	Sulfate	1.92E-01	tons/GWh

[a] All inputs and outputs have been left in their original units of measure.

Table 7. Inputs and Outputs for Gas-Fired Electricity Generation in the United States

Material/pollutant	Quantity	Unit
INPUTS		
Primary Material		
Gas	3.00E+12	yr 3/yr
Ancillary Material		
Water	2.50E-01	gal/kWh
OUTPUTS		
Air Emissions		
Nitrous oxide	2.20E+00	lbs/Mft3
Filterable PM	1.50E+00	lbs/Mft3
Condensible PM	1.50E+00	lbs/Mft3
TOC	1.70E+00	lbs/Mft3
SPECIATED ORGANIC COMPOUNDS		
Fluoranthene	3.01E-06	lbs/Mft3
Formaldehyde	1.55E-01	lbs/Mft3
2-Methylnaphthalene	9.02E-06	lbs/Mft3
Pollutant	**Quantity**	**Unit**
OUTPUTS (continued)		
Air Emissions (continued)		
SPECIATED ORGANIC COMPOUNDS (continued)		
Naphthalene	2.40E-04	lbs/Mft3
Phenanthrene	1.00E-05	lbs/Mft3
Pyrene	5.01E-06	lbs/Mft3
Toluene	2.20E-03	lbs/Mft3
TRACE METALS		
Arsenic	2.30E-04	lbs/Mft3
Barium	2.40E-03	lbs/Mft3
Chromium	1.10E-03	lbs/Mft3
Cobalt	1.20E-04	lbs/Mft3
Copper	2.51E-04	lbs/Mft3
Manganese	3.81E-04	lbs/Mft3
Molybdenum	5.81E-04	lbs/Mft3
Nickel	3.61E-03	lbs/Mft3
Vanadium	3.21E-03	lbs/Mft3

[a] All inputs and outputs have been left in their original units of measure.

Table 8. Inputs and Outputs for Petroleum-Fired Electricity Generation in the U.S.

Material/Pollutant	Quantity	Unit
INPUTS		
Primary Material		
Petroleum		
Ancillary Material		
Water	4.30E-01	gal/kWh
OUTPUTS		
Air Emissions		
Methane	2.66E-01	lbs/kgal
Nitrous oxide	1.10E-01	lbs/kgal
TOC	9.93E-01	lbs/kgal
TNMOC	7.26E-01	lbs/kgal
SPECIATED ORGANIC COMPOUNDS		
Acenaphthene	2.11E-05	lbs/kgal
Acenaphthylene	2.53E-07	lbs/kgal
Anthracene	1.22E-06	lbs/kgal
Benzene	2.14E-04	lbs/kgal
Benz(a)anthracene	4.01E-06	lbs/kgal
Benzo(b,k)fluoranthene	1.48E-06	lbs/kgal
Benzo(g,h,i)perylene	2.26E-06	lbs/kgal
Pollutant	**Quantity**	**Unit**
OUTPUTS (continued)		
Air Emissions (continued		
SPECIATED ORGANIC COMPOUNDS (continued)		
OCDD	3.10E-09	lbs/kgal
Phenanthrene	1.05E-05	lbs/kgal
Pyrene	4.25E-06	lbs/kgal
Toluene	6.20E-03	lbs/kgal
1,1,1-Trichloroethane	2.36E-04	lbs/kgal
o-xylene	1.09E-04	lbs/kgal
TRACE METALS		
Antimony	5.25E-03	lbs/kgal
Arsenic	1.28E-03	lbs/kgal
Barium	2.57E-03	lbs/kgal
Beryllium	4.71E-05	lbs/kgal
Cadmium	4.67E-04	lbs/kgal
Chloride	3.47E-01	lbs/kgal
Chromium	1.28E-03	lbs/kgal
Chromium (VI)	2.48E-04	lbs/kgal
Cobalt	6.02E-03	lbs/kgal
Copper	1.76E-03	lbs/kgal
Fluoride	3.73E-02	lbs/kgal

Table 8. Inputs and Outputs for Petroleum-Fired Electricity Generation in the U.S.

Material/Pollutant	Quantity	Unit	Pollutant	Quantity	Unit
Chrysene	2.38E-06	lbs/kgal	Manganese	2.94E-03	lbs/kgal
Dibenzo(a,h)anthracene	1.67E-06	lbs/kgal	Mercury	1.31E-04	lbs/kgal
Ethylbenzene	6.36E-05	lbs/kgal	Molybdenum	7.87E-04	lbs/kgal
Fluoranthene	4.84E-06	lbs/kgal	Nickel	8.09E-02	lbs/kgal
Fluorene	4.47E-06	lbs/kgal	Phosphorous	9.46E-03	lbs/kgal
Formaldehyde	3.30E-02	lbs/kgal	Selenium	6.83E-04	lbs/kgal
Indo(1,2,3-cd)pyrene	2.14E-06	lbs/kgal	Vanadium	3.18E-02	lbs/kgal
Naphthalene	1.13E-03	lbs/kgal	Zinc	2.91E-02	lbs/kgal

[a] All inputs and outputs have been left in their original units of measure.

Table 9. Inputs and Outputs for Nuclear-Based Electricity Generation in the U.S.

Material/pollutant	Quantity	Unit	Pollutant	Quantity	Unit
INPUTS			**OUTPUTS** (continued)		
Primary Material			**Waterborne Radionuclide Emissions** (continued)		
Uranium oxide ("yellowcake")	4.87E+07	lbs/yr	Xe-135M	4.40E-08	Curies/MWh
			Cs-137	7.49E-11	Curies/MWh
Ancillary Material			Xe-138	1.46E-07	Curies/MWh
Water	6.20E-01	gal/kWh	**Waterborne Radionuclide Emissions**		
			T-3	5.48E-05	Curies/MWh
OUTPUTS			Na-24	2.75E-10	Curies/MWh
Solid Wastes			Cr-51	7.44E-09	Curies/MWh
Spent fuel	5.29E+06	lbs/yr	Mn-54	4.90E-09	Curies/MWh
LLRW	2.21E+05	ft^3/yr	Fe-55	1.75E-08	Curies/MWh
			Co-57	1.80E-10	Curies/MWh
Airborne Radionuclide Emissions			Co-58	7.33E-08	Curies/MWh
T-3	7.33E-06	Curies/MWh	Fe-59	9.00E-10	Curies/MWh
Ar-41	3.13E-06	Curies/MWh	Co-80	1.92E-08	Curies/MWh
Cr-51	1.96E-10	Curies/MWh	Zn-85	8.27E-11	Curies/MWh
Mn-54	2.78E-12	Curies/MWh	Kr-85M	4.63E-09	Curies/MWh
Co-57	5.27E-13	Curies/MWh	Sr-89	2.97E-10	Curies/MWh
Co-58	6.73E-12	Curies/MWh	Sr-90	6.97E-11	Curies/MWh
Co-60	5.06E-11	Curies/MWh	Nb-95	1.26E-09	Curies/MWh
Kr-85	5.18E-06	Curies/MWh	Sr-95	7.68E-10	Curies/MWh
Kr-85M	2.51E-07	Curies/MWh	Mo-99	9.25E-03	Curies/MWh
Kr-87	9.35E-08	Curies/MWh	Tc-99M	1.08E-10	Curies/MWh
Rb-88	1.03E-09	Curies/MWh	Ru-103	1.54E-10	Curies/MWh
Kr-88	4.39E-07	Curies/MWh	Ag-110M	1.80E-09	Curies/MWh
Br-89	3.62E-13	Curies/MWh	Sn-113	1.70E-10	Curies/MWh
Br-90	1.47E-13	Curies/MWh	Sb-124	1.54E-09	Curies/MWh
Nb-95	1.11E-13	Curies/MWh	Sb-125	6.15E-09	Curies/MWh
Zr-95	2.86E-13	Curies/MWh	I-131	3.43E-09	Curies/MWh
Tc-99M	1.48E-14	Curies/MWh	Xe-131M	5.64E-08	Curies/MWh

Table 9. Inputs and Outputs for Nuclear-Based Electricity Generation in the U.S.

Material/pollutant	Quantity	Unit	Pollutant	Quantity	Unit
Ag-110M	3.30E-15	Curies/MWh	I-132	1.30E-09	Curies/MWh
I-131	2.37E-10	Curies/MWh	Xe-133	8.66E-06	Curies/MWh
Xe-131M	4.23E-07	Curies/MWh	I-133	1.47E-09	Curies/MWh
I-132	4.80E-11	Curies/MWh	Xe-133M	7.10E-08	Curies/MWh
Xe-133	6.10E-05	Curies/MWh	Cs-134	4.13E-09	Curies/MWh
I-133	2.19E-07	Curies/MWh	I-135	1.06E-09	Curies/MWh
Xe-133M	4.06E-06	Curies/MWh	Xe-135	6.46E-08	Curies/MWh
Cs-134	9.93E-12	Curies/MWh	s-136	1.65E-10	Curies/MWh
I-134	2.49E-10	Curies/MWh	Cs-137	6.20E-09	Curies/MWh
Xe-135	2.30E-06	Curies/MWh	Ba-140	1.14E-10	Curies/MWh
I-135	1.25E-11	Curies/MWh	La-140	1.23E-10	Curies/MWh

[a] All inputs and outputs have been left in their original units of measure.

Table 10 presents the number of inventory data points for each fuel type by input or output category. As can easily be seen, most of the fuel-specific inventories are dominated by air pollution data. Of the main categories of air pollutants considered, the following breakdown lists those emissions that are the biggest contributors (have the largest emission rates in overall quantity) to each part of each fuel inventory:

- Coal – Cyanide (speciated organic compounds), magnesium (metal), naphthalene [polycyclic aromatic hydrocarbons (PAH)] and the total octochlorodibenzo-p-dioxins (dioxins and furans)
- Gas – Formaldehyde (speciated organic compound), nickel (metal)
- Petroleum – Formaldehyde (speciated organic compound), chloride (metal)
- Nuclear – Xenon-133 (airborne radionuclide), molybdenum-99 (waterborne radionuclide)

Note that in Tables 6 through 9, the units for the inputs and outputs were left as originally found in their source. All fuel-specific inputs and outputs (excluding radioactive releases) were converted to the units desired for the U.S.-wide electric grid of grams/kWh during aggregation into that inventory data set.

Table 10. Number of Inputs & Outputs Within Each Inventory

Inputs & Outputs	Coal	Gas	Petroleum	Nuclear
Primary materials	1	1	1	1
Ancillary materials	3	1	1	1
Air releases	89	29	51	31
Water releases	3	--	--	35
Solid & hazardous wastes	3	--	--	2
Total	99	31	53	70

5. DATA SOURCES & QUALITY

Source and quality information for the data presented in this TM are detailed in Table 11. In general, data assigned higher quality ratings were directly measured and represent 1997 data. As data required more calculation or estimation, or were from a previous year, data quality was reduced. Additional comments about data source and quality are in the following subsections.

5.1 Nonfuel specific data

The criteria pollutant air emission values used in this inventory all came from the *National Air Quality & Emissions Trends Report, 1997*. While this report does state that the values supplied are "estimates of the amount and kinds of pollutants being emitted … based upon best available engineering calculations," (EPA 1998b) the EPA used measured air emission rates where feasible, and thus these data were given ‘Average’ data quality ratings.

5.2 Coal

As the leading electricity-producing fuel in the U.S., coal has accounted for between 40% and 60% of the kWh produced by utilities in the national grid since the 1930s (NEI 1997). In 1997, coal-fired generation accounted for just over 57% of all utility-generated electricity.

Of the coal inventory data, the coal quantity used annually and the methane generated from coal mining were both directly measured data for 1997 and thus were given ‘Excellent’ data quality ratings. The data for speciated air emissions that came from AP-42 were deemed ‘Poor,’ due primarily to the following two facets of the data. First, in averaging the data quality ratings that the EPA applies to their AP-42 factors, an average rating of approximately 3 is calculated, indicating by their own standards an ‘average’ rating. (EPA’s data quality ratings are A, B, C, D and E, where, for example, A, C and E represent ‘Excellent,’ ‘Average’ and ‘Poor’ respectively. This alphabetically based system was temporarily converted into a numerical system of 1 through 5 where 1 corresponds to A and 5 corresponds to E to calculate the required averages.) Second, the bulk of the AP-42 data was dated January 1995; updates were included several times since then (two in 1996 and one in 1998), however, each update included only small changes to the whole AP-42 emission factor data set.

The cooling water use (for all fuels) and the solid waste and water release data for coal were assigned a data quality rating of ‘Unknown’ due to a lack of information on the original data source.

Table 11. Data Sources and Quality Information for the U.S. Electric Grid Inventories

I/O Type [a]	Data	Data Source/ Reference	Data Source Comments	Data Quality [b]	Data Quality Explanation
NONFUEL SPECIFIC					
AR	Criteria pollutants	EPA 1998b	Although the EPA uses measured data wherever feasible in calculating the emissions included in this report, much data required estimating to effectively model the national totals for certain pollutant categories.	Average	Although the bulk of the data used in this analysis were measured, some estimates were required to obtain emissions information from particular industries before aggregating to obtain the U.S.-wide totals.
COAL					
PM	Coal	EIA 1998c	Measured; required for regulatory recording purposes.	Excellent	Measurements provide the highest quality data.
AM	Limestone and lime	EIA 1997	The primary data used in calculating the limestone and lime usage were measured, however approximately six sources of information were accessed to obtain the necessary information to derive final factors.	Average	Of the sources referenced for this calculation, three utilized measured data, while the remaining utilized average or poor quality data. Thus, the overall rating is 'Average.'
AM	Cooling water	CEC 1979	Only source located in which cooling water requirements were detailed for the main electricity generation categories.	Unknown	CEC did not list its data sources.
SW & WR	All	ORNL 1994	Original source of data in the ORNL 1994 report was Meridian Corporation 1989, however, could not be located.	Unknown	Original data document could not be found.
AR	All noncriteria pollutants	EPA 1996	AP-42 factors have a self-assigned 'Average' to 'Poor' quality rating.	Poor	Given 'Poor' rating for several reasons, including primarily that 1) overall AP-42 self-assigned ratings are 'Average' and 2) data applies to 1995.
AR	Methane from coal mining	EPA 1998c	Measured; reported for regulatory recording purposes.	Excellent	Measurements provide the highest quality data.
GAS & PETROLEUM					
PM	Gas and petroleum	EIA 1998c	Measured; required for regulatory recording purposes.	Excellent	Measurements provide the highest quality data.
AM	Cooling water	CEC 1979	Only source located in which cooling water requirements were detailed for the main electricity generation categories.	Unknown	CEC did not list its data sources.
AR	All noncriteria pollutants	EPA 1996	AP-42 factors have a self-assigned 'Poor' quality rating for gas and 'Average' to 'Poor' quality rating for petroleum.	Poor	Given 'Poor' rating for several reasons, including primarily that 1) overall AP-42 self-assigned ratings are 'Average' and 2) data applies to 1995.
URANIUM					
PM	Uranium	EIA 1998b	Measured data, yet had to scale using an unproven scaling mechanism.	Average	Measurements provide the highest quality data, yet the scaling mechanism utilized introduces potential error.
AM	Cooling water	CEC 1979	Only source located in which cooling water requirements were detailed for the main electricity generation categories.	Unknown	CEC did not list its data sources.
SW	Spent fuel	EIA 1996	Estimates the quantity of spent fuel that will be generated in the US in 1997, using measured historical records and knowledge of what facilities will be changing operating patterns in future years (from 1996 perspective).	Excellent	Although not directly measured, use of recently measured data along with in-depth knowledge of future industry changes to project value earns an 'Excellent' rating.
SW	LLRW	Loiselle 1998	Estimated by an industry expert.	Average	Lack of any measured data gives way to an 'Average' rating.
RR	Airborne radionuclides	ORNL 1995	Averaged measured data from nuclear generation facilities.	Excellent	Measurements provide the highest quality data.
RR	Waterborne radionuclides	ORNL 1995	Averaged measured data from nuclear generation facilities.	Excellent	Measurements provide the highest quality data.

[a] Input/Output (I/O) types: PM = primary material, AM = ancillary material, SW = solid waste, AR = airborne release, WR = water release, RR = radioactive release.

[b] The data quality ratings given were assigned to one of the following four data quality categories: Excellent, Average, Poor and Unknown.

5.3 Gas & Petroleum

Each of these data sets utilize the EIA's *Electric Power Annual* for the primary fuel consumption estimates and AP-42 data for the air emissions. The EIA data were given 'Excellent' data quality marks as these data are reported as direct measurements and applicable to 1997. The air emissions were given a quality rating of 'Poor' for the same two reasons the coal inventory data AP-42 estimates were given that rating.

5.4 Uranium

For the nuclear-related inputs and outputs, the largest category of input or output type information was radionuclide emissions. The radionuclide emission information contained in the report was obtained by averaging radionuclide emissions data from 36 different pressurized water reactors (PWRs) across the U.S. (out of just over 110 nuclear reactors total in the U.S.). As discussed previously, the emissions were not found to directly correlate to electricity generation (kWh) or generating capacity (kW), but "were more likely affected by random events within the reactor, such as fuel pin cladding failures, leaks in the primary coolant loop and steam-generator tube leaks" (ORNL 1995). Thus, all factors considered, the overall data quality rating for these emissions was deemed 'Average.' The mass of uranium consumed annually was given the 'Excellent' rating as this information is measured through reporting supplied to the EIA and applicable to 1997.

Of the remaining inputs and outputs, most received higher quality ratings except for the cooling water values which received the 'Unknown' rating due to a lack of information on the original data source.

6. DATA LIMITATIONS

Several limitations of the U.S. electrical energy grid inventory data relate to the exclusion of either entire generation categories (e.g., hydro) or life-cycle substages (see Table 2). For example, no data are readily available for the life-cycle substages of ore and fuel transportation and preliminary ore or fuel processing. Examples of ore and fuel transportation and processing burdens for which insufficient data are available include the emissions generated during the processing of crude oil to produce fuel oils Nos. 6 and 2, and the energy use and wastes generated during the processing of uranium ore into fuel pellets.

With regard to the exclusion of entire generation categories, the renewable and hydroelectric generating categories have not been included in this U.S.-wide inventory. Renewables accounted for only about 0.24% of the total electricity generated in the U.S. in 1997, and are expected to have greatly reduced impacts when compared to the other fuel types. Hydropower was omitted, as stated previously, due to the scarcity of data on hydroelectric inputs and outputs, and also that the CDP LCIA methodology does not account directly for the effects of habitat destruction (expected to be one of the largest impacts from hydroelectric generation once quantified).

Other limitations of the data are related to the use of AP-42 emissions factors, primarily due to the fact that EPA's own ratings of their factors are, at best, 'Average' (see discussion in Section 5.2). Other data limitations include the small number of sources from which much of the data have been obtained. Not necessarily as much a limitation of the data as a limitation in the sources of the data, this is still an area for quality improvement. Also, as noted previously, nonutility electricity generation in the U.S. is excluded from this inventory, and accounts for about 11% of the total electricity generated annually.

There are some implications that can be derived from the limitations mentioned here on the U.S.-wide electric grid inventory data. These implications include the following:

- Since there are currently no other sources of detailed air emission information like AP-42, there is no way of knowing just how accurate their estimates are (possibly predicting a bias in one direction or the other). It appears that the reason that the EPA's quality ratings of their AP-42 data tend toward 'Average' is that in quite a few cases, emissions test were run on only a small number of boilers. Without a larger body of data on which to base the emission factors, it is not known how the use of these factors biases the results.
- The exclusion of the inputs and outputs from materials extraction, the initial and secondary materials processing stages, and the associated transportation for several fuel types (see Table 2) will underestimate the total inventory from electricity generation. Especially when considering the massive amount of processing that is required to develop the uranium fuel pellets that are used in nuclear generation, this may be the largest influence of all the biases for this inventory. (It should also be noted that these processing steps for developing uranium pellets are extremely energy intensive, thus decreasing the efficiency of not only the nuclear electricity generation process, but also the whole grid's overall efficiency as well.)
- The exclusion of the hydropower and renewable generation types should have little effect on the U.S.-wide electric grid inventory data because the renewables are a minimal percentage of the total generation, and hydropower involves no combustion and thus would have minimal impacts.
- The exclusion of the nonutility-type generation brings two major issues forward. First, nonutilities use cogeneration the majority of the time to produce electricity (EIA 1997). Cogeneration utilizes two cycles to produce electrical energy and another form of usable energy (typically steam) thereby increasing the overall efficiency of the energy conversion process. Second, renewables (including hydropower) and gas make up 76% of the energy generation type for nonutilities, two of the lesser polluting types of electricity generation. These two factors should combine to, for the average kWh, decrease not only the quantity of raw materials needed as inputs but also the amount of air emissions generated as outputs for the inventory.

Finally, the Japanese inventory is limited by having been derived from the U.S. fuel-specific inventories and may not accurately represent electricity production operations in Japan.

Overall, with some implications inferring an underestimate in the inventory and some inferring an overestimate, it is uncertain which way the inventory may be biased. To a certain extent, the lessened impacts from the exclusion of nonutility electricity production data seem to offset the exclusion of the processing and transportation life-cycles substages data. However, the exclusion of this relevant data hampers the effort to build a completely accurate and representative electric grid inventory.

7. CONCLUSIONS

The U.S. electric grid inventory data presented in this TM will be used to determine the environmental burdens that result from energy consumption in the U.S. using the CDP LCIA methodology. To summarize the work done in this analysis and its use within the CDP, the following is presented:

- The fuel-specific inventories for each of the four primary generation categories used in the average electric grid were compiled from a variety of sources, and then the fuel-specific inventories were combined using a generation-based weighted average to develop the U.S.-wide and Japanese electrical energy grid inventories of material inputs and pollutant outputs in units of grams of input or output per kWh consumed (except for radioactive materials which were placed in units of Becquerels/kWh).
- The U.S.-wide electrical energy grid inventory data are used in the CDP to calculate material inputs and pollutant outputs from electricity consumed during some manufacturing, use, and final disposal of computer displays.
- The Japanese electrical energy grid inventory data are used in the CDP to calculate material inputs and pollutant outputs from electricity consumed during the manufacturing of monitors in Asia.
- The electrical energy grid data are not used for upstream life-cycle stages (i.e., extraction of materials, materials processing) as these are being obtained from secondary sources which already have included the inputs and outputs from energy consumption.

Once the data have been gathered for all of the CDP processes of interest and the inputs and outputs for each of these processes have been analyzed from a life-cycle perspective, the results will help identify how important the impacts of energy consumption are throughout a monitor’s life-cycle.

ACRONYMS/ABBREVIATIONS

CCPCT	Center for Clean Products and Clean Technologies
CEC	California Energy Commission
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
DOE	Department of Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FGD	Flue Gas Desulfurization
GWh	Gigawatthour
HCl	Hydrogen chloride
HF	Hydrogen fluoride
kWh	kilowatthour
LCA	Life-cycle assessment
LCI	Life-cycle inventory
LLRW	Low-level radioactive waste
MW	Megawatt
Mwh	Megawatthour
N_2O	Nitrous oxide
NO_X	Oxides of nitrogen
ORNL	Oak Ridge National Laboratory
PAH	Polycyclic aromatic hydrocarbons
Pb	Lead
PM-10	Particulate matter 10 microns or less in diameter
PWR	Pressurized Water Reactor
SO_2	Sulfur dioxide
TNMOC	Total nonmethane organic carbon
TOC	Total organic carbon
TRI	Toxic Release Inventory
U_3O_8	Uranium oxide
UT	University of Tennessee

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ATTACHMENT A. COAL INFORMATION WORKSPACE

Table A1. Mining Related Outputs - Methane Air Emissions

Pollutant	Quantity [a]	Units	Converted Quantity [b]	Units
Outputs				
Methane	169,906	million ft 3/yr	1.52E+05	million ft 3/yr

[a] Value pertains to methane emissions related to all coal mined nation-wide in U.S. (EPA 1998a).
[b] This value represents methane emissions from coal mined exclusively for electricity generation. It is calculated based on the knowledge that 89.6% of the coal mined in the U.S. in 1997 was for electricity generation, thus the toal methane emissions are multiplied by 89.6% to obtain the emissions from electricity generation alone.
(EIA web page: http://www.eia.doe.gov/cneaf/coal/cia/summary/cia_sum.html, 1997).

Table A2. Generation Related Inputs and Outputs - Excluding Air Emissions

Material/Pollutant	Quantity	Units	Converted Quantity	Units
Inputs				
Ancillary Materials				
Water [a]	0.49	gallons/kWh	---	---
Limestone [b]	12,091,817	tons/yr	---	---
Lime [b]	5,310,548	tons/yr	---	---
Outputs				
SOLID WASTES [c]				
Dust/sludge	55.143	tons/GWh	1.10E+02	lbs/MWh
Coal waste	142.857	tons/GWh	2.86E+02	lbs/MWh
Fly/bottom ash	35.714	tons/GWh	7.14E+01	lbs/MWh
WASTEWATER EMISSIONS [c]				
Dissolver	0.278	tons/GWh	5.56E-01	lbs/MWh
Suspended solids	0.005	tons/GWh	1.00E-02	lbs/MWh
Sulfate	0.192	tons/GWh	3.84E-01	lbs/MWh

[a] CEC (1979).
[b] Primary data used to calculate these values from EIA (1997); however, data were modified to derive nationwide average.
[c] ORNL (1994).

Table A3. Generation Related Outputs - Air Emissions [a]

Pollutant	Quantity (lbs/ton of coal)	EPA's Factor Raging [b]
Outputs		
Miscellaneous Compounds [c]		
Methane	0.04	B
Nitrous oxide	0.03	B
Hydrogen chloride	1.2	B
Hydrogen fluoride	0.15	B
Total organic compounds	0.3	E
Total nonmethane organic compounds	0.06	B
Speciated Organic Compounds [d], [e]		
Acetaldehyde	5.70E-04	C
Acetophenone	1.50E-05	D
Acrolein	2.90E-04	D
Benzene	1.30E-03	A
Benzyl chloride	7.00E-04	D
Bis(2-ethyhexyl)pththalate (DEHP)	7.30E-05	D
Bromoform	3.90E-05	E
Carbon disulfide	1.30E-04	D
2-Chloroacetophenone	7.00E-06	E
Chlorobenzene	2.20E-05	D
Chloroform	5.90E-05	E
Cumene	5.30E-06	E
Cyanide	2.50E-03	D
2,4-Dinitrotoluene	2.80E-07	D
Dimethyl sulfate	4.80E-05	E
Ethyl benzene	9.40E-05	D
Ethyl chloride	4.20E-05	D
Ethylene dichloride	4.00E-05	E
Ethylene dibromide	1.20E-06	E
Formaldehyde	2.40E-04	A
Hexane	6.70E-05	D
Isophorone	5.80E-04	D
Methyl bromide	1.60E-04	D
Methyl chloride	5.30E-04	D
Methyl ethyl ketone	3.90E-04	D
Methyl hydrazine	1.70E-04	E
Methyl methacrylate	2.00E-05	E
Methyl tert butyl ether	3.50E-05	E
Methylene chloride	2.90E-04	D

Table A3. Generation Related Outputs - Air Emissions [a]

Pollutant	Quantity (lbs/ton of coal)	EPA's Factor Raging [b]
Phenol	1.60E-05	D
Propionaldehyde	3.80E-04	D
Tetrachloroethylene	4.30E-05	D
Toluene	2.40E-04	A
1,1,1-Trichloroethane	2.00E-05	E
Styrene	2.50E-05	D
Xylenes	3.70E-05	C
Vinyl acetate	7.60E-06	E
Trace Metals [d], [e]		
Antimony	1.80E-05	A
Arsenic	4.10E-04	A
Beryllium	2.10E-05	A
Cadmium	5.10E-05	A
Chromium	2.60E-04	A
Chromium (VI)	7.90E-05	D
Cobalt	1.00E-04	A
Magnesium	1.10E-02	A
Manganese	4.90E-04	A
Mercury	8.30E-05	A
Nickel	2.80E-04	A
Selenium	1.30E-03	A
Polycyclic Aromatic Hydrocarbons [d], [e]		
Biphenyl	1.70E-06	D
Acenaphthene	5.10E-07	B
Acenaphthylene	2.50E-07	B
Anthracene	2.10E-07	B
Benmzo(a)anthracne	8.00E-08	B
Benzo(a)pyrene	3.80E-08	D
Benzo(b,j,k)fluoranthene	1.10E-07	D
Benzo(g,h,i)perylene	2.70E-08	D
Chrysene	1.00E-07	C
Fluoranthene	7.10E-07	B
Fluorene	9.10E-07	B
Indeno(1,2,3-cd)pyrene	6.10E-08	C
Naphthalene	1.30E-05	C
Phenanthrene	2.70E-06	B
Pyrene	3.30E-07	B
5-Methyl chrysens	2.20E-08	D
Dioxins & Furans [d], [f]		

Table A3. Generation Related Outputs - Air Emissions [a]

Pollutant	Quantity (lbs/ton of coal)	EPA's Factor Raging [b]
2,3,7,8-TCDD	1.43E-11	E
Total TCDD	9.28E-11	D
Total PeCDD	4.47E-11	D
Total HxCDD	2.87E-11	D
Total HpCDD	8.34E-11	D
Total OCDD	4.16E-10	D
Total PCDDd	6.66E-10	D
2,3,7,8-TCDF	5.10E-11	D
Total TCDF	4.04E-10	D
Total PeCDF	3.53E-10	D
Total HxCDF	1.92E-10	D
Total HpCDF	7.68E-11	D
Total OCDF	6.63E-11	D
Total PCDFd	1.09E-09	D
TOTAL PCDD/PCDF	1.76E-09	D

[a] All the air emissions presented here are from EPA's AP-42 factors (EPA 1996).

[b] "EPA's AP-42 emissions factor rating is an overall assessment of how good a factor is, based on both the quality of the test(s) or information that is the source of the factor and on how well the factor represents the emission source." (EPA 1996) EPA's factor ratings are as follows:
A = Excellent; B = Above Average; C = Average; D = Below Average; and E = Poor.

[c] Due to a lack of data on firing configurations for all U.S. boilers, the pulverized coal (PC), dry, wall-fired boiler firing configuration (the most common configuration in the U.S.) was chosen as the representative configuration. Additionally, the factors for methane, nitrous oxide,, total organic compounds and total nonmethane organic compounds are for uncontrolled emissions, while the values for hydrogen chloride and hydrogen fluoride are for controlled and uncontrolled emissions (measurements were taken from different facilities were some had control equipment and others did not).

[d] These are all controlled factors.

[e] Apply to bituminous, subbituminous and ignite coal types. Even though these factors apply only to these three coal types, the emission factors are applied to all coal types. This was done for two reasons: 1) because no factors were given for the remaining coal types; and 2) those remaining coal types do generate some of these emissions, and it would have been erroneous to consider then 'pollutant-free."

[f] Apply to bituminous and subbituminous coal types. Even though these factors apply only to these two coal types, the emission factors are applied to all coal types. This was done for two reasons: 1) because no factors were given for the remaining coal types; and 2) those remaining coal types do generate some of these emissions, and it would have been erroneous to consider them 'pollutant-free.'

ATTACHMENT B. GAS INFORMATION WORKSPACE

Table B1. Generation Related Inputs

Material	Quantity	Units
Inputs		
Ancillary Materials		
Water [a]	0.25	gallons/kWh

[a] CEC (1979). The value listed under 'Combined Cycle' in the reference was used for gas-fired generation since the majority of combined cycle units's top cycle is fired by gas.

Table B2. Generation Related Outputs

Pollutant	Quantity (lbs/million ft3 of gas)	EPA's factor rating [b]
Outputs		
AIR EMISSIONS [a]		
Miscellaneous Compounds [c]		
Nitrous oxide	2.2	C
Total organic compounds	1.7	C
Speciated Organic Compounds [d]		
Fluoranthene	3.10E-06	E
Formaldehyde	1.55E-01	C
2-Methylnaphthalene	9.02E-06	E
Naphthalene	2.40E-04	E
Phenanthrene	1.00E-05	E
Pyrene	5.10E-06	E
Toluene	2.20E-03	E
Trace Metals [e]		
Arsenic	2.30E-04	E
Barium	2.40E-03	E
Chromium	1.10E-03	E
Cobalt	1.20E-04	E
Copper	2.51E-04	E
Manganese	3.81E-04	E
Molybdenum	5.81E-04	E
Nickel	3.61E-03	E
Vanadium	3.21E-03	E

[a] All outputs for gas-fired generation are air emissions and are from the EPA's AP-42 emission factors (EPA 1996).

[b] "EPA's AP-42 emissions factor rating is an overall assessment of how good a factor is, based on both the quality of the test(s) or information that is the source of the factor and how well the factor represents the emission source (EPA 1996). EPA's factor ratings are as follows: A = Excellent; B = Above Average; C = Average; D = Below Average; and E = Poor.

[c] Factors are for uncontrolled combustion.

[d] Each of the seven factors provided are for controlled and uncontrolled combustion.

[e] Factors are for controlled combustion.

ATTACHMENT C. PETROLEUM INFORMATION WORKSPACE

Table C1. Generation Related Inputs

Material	Quantity	Units
Inputs		
ANCILLARY MATERIALS		
Water [a]	0.43	gallons/kWh

[a] CEC (1979).

Table C2. Generation Related Outputs

Pollutant	Quantity (lbs/thousand gallons of oil)	EPA's factor rating [b]	Quantity (lbs/thousand gallons of oil)	EPA's factor rating [b]	Quantity (lbs/thousand gallons of oil)	EPA's factor rating [b]
	Fuel Oil #6		**Fuel Oil #2**		**Average Factors**	
Outputs						
AIR EMISSIONS [a]						
Miscellaneous Compounds [c]						
Methane	0.28	A	0.052	A	2.66E-01	A
Nitrous oxide	0.11	B	0.11	B	1.10E-01	B
Total organic compounds	1.04	A	0.252	A	9.93E-01	A
Total nonmethane organic compounds	0.76	A	0.2	A	7.26E-01	A
Speciated Organic Compounds [d]						
Acenaphthene	2.11E-05	C			2.11E-05	C
Acenaphthylene	2.53E-07	D			2.53E-07	D
Anthracene	1.22E-06	C			1.22E-06	C
Benzene	2.14E-04	C			2.14E-04	C
Benz(a)anthracene	4.01E-06	C			4.01E-06	C
Benzo(b,k)fluoranthene	1.48E-06	C			1.48E-06	C
Benzo(g,h,i)perylene	2.26E-06	C			2.26E-06	C
Chrysene	2.38E-06	C			2.38E-06	C
Dibenzo(a,h)anthracene	1.67E-06	D			1.67E-06	D
Ethylbenzene	6.36E-05	E			6.36E-05	E
Fluoranthene	4.84E-06	C			4.84E-06	C
Fluorene	4.47E-06	C			4.47E-06	C
Formaldehyde	3.30E-02	C			3.30E-02	C
Indo(1,2,3-cd)pyrene	2.14E-06	C			2.14E-06	C
Naphthalene	1.13E-03	C			1.13E-03	C
OCDD	3.10E-09	E			3.10E-09	E
Phenanthrene	1.05E-05	C			1.05E-05	C
Pyrene	4.25E-06	C			4.25E-06	C
Toluene	6.20E-03	D			6.20E-03	D

Table C2. Generation Related Outputs

Pollutant	Quantity (lbs/thousand gallons of oil)	EPA's factor rating [b]	Quantity (lbs/thousand gallons of oil)	EPA's factor rating [b]	Quantity (lbs/thousand gallons of oil)	EPA's factor rating [b]
	Fuel Oil #6		**Fuel Oil #2**		**Average Factors**	
1,1,1-Trichloroethane	2.36E-04	E			2.36E-04	E
o-xylene	1.09E-04	E			1.09E-04	E
Trace Metals [e]						
Antimony	5.25E-03	E			5.25E-03	E
Arsenic	1.32E-03	C	5.88E-04	E	1.28E-03	C
Barium	2.57E-03	D			2.57E-03	D
Beryllium	2.78E-05	C	3.50E-04	E	4.71E-05	C
Cadmium	3.98E-04	C	1.54E-03	E	4.67E-04	C
Chloride	3.47E-01	D			3.47E-01	D
Chromium	8.45E-04	C	8.05E-03	E	1.28E-03	C
Chromium (VI)	2.48E-04	C			2.48E-04	C
Cobalt	6.02E-03	D			6.02E-03	D
Copper	1.76E-03	C			1.76E-03	C
Fluoride	3.73E-02	D			3.73E-02	D
Manganese	3.00E-03	C	1.96E-03	E	2.94E-03	C
Mercury	1.13E-04	C	4.20E-04	E	1.31E-04	C
Molybdenum	7.87E-04	D			7.87E-04	D
Nickel	8.45E-02	C	2.38E-02	E	8.09E-02	C
Phosphorous	9.46E-03	D			9.46E-03	D
Selenium	6.83E-04	C			6.83E-04	C
Vanadium	3.18E-02	D			3.18E-02	D
Zinc	2.91E-02	D			2.91E-02	D

[a] All outputs for oil-fired generation are air emissions and are from the EPA's AP-42 emission factors (EPA 1996).

[b] "EPA's AP-42 emissions factor rating is an overall assessment of how good a factor is, based on both the quality of the test(s) or information that is the source of the factor and on how well the factor represents the emission source" (EPA 1996). EPA's factor ratings are as follows: A = Excellent; B = Above Average; C = Average; D = Below Average; and E = Poor.

[c] Factors are for uncontrolled combustion of all pollutants, except for N2O. No information was provided as to the control of N2O emissions.

[d] No information was provided as to the control of these pollutants. No emission factors were presented for fuel oil #2, thus, the factors for #6 were considered the same for #2. Even though one could assume that fuel oil #2 should have smaller quantities of pollutants to contribute per equivalent volume than fuel oil #6 (due to #6 being a residual oil and # 2 being a distillate), some of the results from the trace metals table contradict that assumption, thus substantiating this action.

[e] No information was provided as to the control of these pollutants. Where no fuel oil #2 emission factor was given, the factor for fuel oil #6 was used for both fuel oils. Even though one could assume that fuel oil #2 should have smaller quantities of pollutants to contribute per equivalent volume than fuel oil #6, some of the results from this table (where factors were reported for both fuel oils) contradict that assumption, thus substantiating this action.

Table C3. Miscellaneous Calculation Information

	Quantity	Unit	Quantity	Unit
	Fuel Oil #6		Fuel Oil #2	
Type of petroleum used at utilities [a]	94	%	6	%
AP-42 heat values for fuel oils [f]	152,000	btu/gal	140,000	but/gal

[a] Source: EIA's "Cost & Quality of Fuels for Electric Utility Plants 1997."
[b] EPA (1996).

ATTACHMENT D. NUCLEAR INFORMATION WORKSPACE

Table D1. Generation Related Inputs and Outputs - Excluding Radionuclide Emissions

Material/Pollutant	Quantity	Units	Converted Quantity	Units
Inputs				
PRIMARY MATERIALS				
Uranium oxide [a]	48,700,000	lbs/yr	---	---
ANCILLARY MATERIALS				
Water [b]	0.62	gallons/kWh	---	---
Outputs				
SOLID/HAZARDOUS WASTES				
Uranium (spent fuel generated) [c]	2,400	metric tons/yr	5.29E+06	lbs/yr
Low-level radioactive waste [d]	220,500	cubic feet/yr	---	---

[a] Known as ‘yellowcake,’ this post-milling uranium product is sent to conversion facilities (EIA 1998b).
[b] CEC (1979).
[c] EIA (1996); Table 18.
[d] Loisell (1998).

Table D2. Generation Related Outputs - Radionuclide Emissions

Isotope	**Quantity**	**Units**	**Converted Quantity**	**Units [d]**
Outputs [a], [b], [c]				
AIRBORNE RADIONUCLIDE EMISSIONS				
T-3	5.98E+01	Curies/yr	7.33E-06	Curies/MWh
Ar-41	2.55E+01	Curies/yr	3.13E-06	Curies/MWh
Cr-51	1.60E-03	Curies/yr	1.96E-10	Curies/MWh
Mn-54	2.27E-05	Curies/yr	2.78E-12	Curies/MWh
Co-57	4.30E-06	Curies/yr	5.27E-13	Curies/MWh
Co-58	5.49E-05	Curies/yr	6.73E-12	Curies/MWh
Co-60	4.13E-04	Curies/yr	5.06E-11	Curies/MWh
Kr-85	4.23E+01	Curies/yr	5.18E-06	Curies/MWh
Kr-85M	2.05E+00	Curies/yr	2.51E-07	Curies/MWh
Kr-87	7.63E-01	Curies/yr	9.35E-08	Curies/MWh
Rb-88	8.38E-03	Curies/yr	1.03E-09	Curies/MWh
Kr-88	3.58E+00	Curies/yr	4.39E-07	Curies/MWh
Br-89	2.95E-06	Curies/yr	3.62E-13	Curies/MWh
Br-90	1.20E-06	Curies/yr	1.47E-13	Curies/MWh
Nb-95	9.02E-07	Curies/yr	1.11E-13	Curies/MWh
Zr-95	2.33E-06	Curies/yr	2.86E-13	Curies/MWh
Tc-99M	1.21E-07	Curies/yr	1.48E-14	Curies/MWh
Ag-110M	2.69E-08	Curies/yr	3.30E-15	Curies/MWh
I-131	1.93E-03	Curies/yr	2.37E-10	Curies/MWh

Table D2. Generation Related Outputs - Radionuclide Emissions

Isotope	Quantity	Units	Converted Quantity	Units [d]
Xe-131M	3.45E+00	Curies/yr	4.23E-07	Curies/MWh
I-132	3.92E-04	Curies/yr	4.80E-11	Curies/MWh
Xe-133	4.98E+02	Curies/yr	6.10E-05	Curies/MWh
I-133	1.79E+00	Curies/yr	2.19E-07	Curies/MWh
Xe-133M	3.31E+01	Curies/yr	4.06E-06	Curies/MWh
Cs-134	8.10E-05	Curies/yr	9.93E-12	Curies/MWh
I-134	2.03E-03	Curies/yr	2.49E-10	Curies/MWh
Xe-135	1.88E+01	Curies/yr	2.30E-06	Curies/MWh
I-135	1.02E-04	Curies/yr	1.25E-11	Curies/MWh
Xe-135M	3.59E-01	Curies/yr	4.40E-08	Curies/MWh
Cs-137	6.11E-04	Curies/yr	7.49E-11	Curies/MWh
Xe-138	1.19E+00	Curies/yr	1.46E-07	Curies/MWh
T-3	4.47E+02	Curies/yr	5.48E-05	Curies/MWh
Na-24	2.24E-03	Curies/yr	2.75E-10	Curies/MWh
Cr-51	6.07E-02	Curies/yr	7.44E-09	Curies/MWh
Mn-54	4.00E-02	Curies/yr	4.90E-09	Curies/MWh
Fe-55	1.43E-01	Curies/yr	1.75E-08	Curies/MWh
Co-57	1.47E-03	Curies/yr	1.80E-10	Curies/MWh
Co-58	5.98E-01	Curies/yr	7.33E-08	Curies/MWh
Fe-59	7.34E-03	Curies/yr	9.00E-10	Curies/MWh
Co-80	1.57E-01	Curies/yr	1.92E-08	Curies/MWh
Zn-85	6.75E-04	Curies/yr	8.27E-11	Curies/MWh
Kr-85M	3.78E-02	Curies/yr	4.63E-09	Curies/MWh
Sr-89	2.42E-03	Curies/yr	2.97E-10	Curies/MWh
Sr-90	5.69E-04	Curies/yr	6.97E-11	Curies/MWh
Nb-95	1.03E-02	Curies/yr	1.26E-09	Curies/MWh
Sr-95	6.27E-03	Curies/yr	7.68E-10	Curies/MWh
Mo-99	7.55E+04	Curies/yr	9.25E-03	Curies/MWh
Tc-99M	8.78E-04	Curies/yr	1.08E-10	Curies/MWh
Ru-103	1.26E-03	Curies/yr	1.54E-10	Curies/MWh
Ag-110M	1.47E-02	Curies/yr	1.80E-09	Curies/MWh
Sn-113	1.39E-03	Curies/yr	1.70E-10	Curies/MWh
Sb-124	1.26E-02	Curies/yr	1.54E-09	Curies/MWh
Sb-125	5.02E-02	Curies/yr	6.15E-09	Curies/MWh
I-131	2.80E-02	Curies/yr	3.43E-09	Curies/MWh
Xe-131M	4.60E-01	Curies/yr	5.64E-08	Curies/MWh
I-132	1.06E-02	Curies/yr	1.30E-09	Curies/MWh
Xe-133	7.07E+01	Curies/yr	8.66E-06	Curies/MWh
I-133	1.20E-02	Curies/yr	1.47E-09	Curies/MWh

Table D2. Generation Related Outputs - Radionuclide Emissions

Isotope	Quantity	Units	Converted Quantity	Units [d]
Xe-133M	5.79E-01	Curies/yr	7.10E-08	Curies/MWh
Cs-134	3.37E-02	Curies/yr	4.13E-09	Curies/MWh
I-135	8.61E-03	Curies/yr	1.06E-09	Curies/MWh
Xe-135	5.27E-01	Curies/yr	6.46E-08	Curies/MWh
s-136	1.35E-03	Curies/yr	1.65E-10	Curies/MWh
Cs-137	5.06E-02	Curies/yr	6.20E-09	Curies/MWh
Ba-140	9.34E-04	Curies/yr	1.14E-10	Curies/MWh
La-140	1.00E-03	Curies/yr	1.23E-10	Curies/MWh

[a] ORNL (1995).

[b] There were 111 operating commercial nuclear power stations in the U.S. in 1995, of which 75 were PWRs (presssurized-water reactors) and 36 were BWRs (boiling-water reactors). Of the PWRs, 52 were designed by Westinghouse; the remaining 23 were designed by either ABB or Babcock & Wilcox. From the available data, the authors chose to use data from all Westinghouse PWRs with greater than 800 MWS capacity (36 facilities) in attempts to gather consistent data for their calculations on transport and dose-effects for their reference PWR.

[c] "These emissions are characterisitc of normal (nonaccident) emissions, and did not appear to readily correlate to MWhs produced or reactor capacity. Amounts produced are more likely affected by random events within reactor, such as fuel pin cladding failures, leaks in the primary coolant loop, steam-generator tube leaks, etc." (ORNL 1995, pp. 6-35 & 6-36).

[d] The units of Curies/MWh were derived by dividing the Curies/yr values by the number of MWhs produced annually in the virtual facility discussed in the source for this information (8,160,000 MWh/yr).

ATTACHMENT E. SUMMARY INFORMATION WORKSPACE

Notes:
- In the tables in this Appendix, "US kWh" is utilized to identify values that are representative of an average U.S. kWh in 1997.
- Unless stated otherwise, the sources for the data presented here are detailed in Attachments A through D.

Table E1. Generation Related Inputs and Outputs - Excluding Air Emissions

Material/Pollutant	Quantity	Units	Converted Quantity	Units
Inputs				
PRIMARY MATERIALS				
Coal	900,361,000	tons/yr	2.83E+02	grams/US kWh
Gas	2,968,453,000,000	ft3/yr	2.20E+01	grams/US kWh
Petroleum	5,256,132,000	agal/yr	5.99E+00	grams/US kWh
Uranium (yellow cake)	48,700,000	lbs/yr	7.64E-03	grams/US kWh
ANCILLARY MATERIALS				
Limestone	12,091,817	tons/yr	3.79E+00	grams/US kWh
Lime	5,310,548	tons/yr	1.67E+00	grams/US kWh
Water	11,426,836,328,400	lbs/yr	1.79E+03	grams/US kWh
Outputs				
SOLID WASTES				
Dust/sludge	197,169,972,516	lbs/yr	3.09E+01	grams/US kWh
Coal waste	510,801,203,484	lbs/yr	8.01E+01	grams/US kWh
Fly/bottom ash	127,699,406,968	lbs/yr	2.00E+01	grams/US kWh
Uranium (spent fuel generated)	1.83E-06	lbs/kWh	8.30E-04	grams/US kWh
LLRW	6.10E-06	lbs/kWh	2.77E-03	grams/US kWh
WATER RELEASES				
Dissolver	994,020,136	lbs/yr	1.56E-01	grams/US kWh
Suspended solids	17,878,060	lbs/yr	2.80E-03	grams/US kWh
Sulfate	686,517,504	lbs/yr	1.08E-01	grams/US kWh

Table E2. Generation Related Outputs - Air Emissions

Pollutant	Quantity	Units	Converted Quantity	Units
Outputs				
Criteria Pollutants [a]				
Carbon dioxide	2,231,433,058	tons/yr	6.48E+02	grams/US kWh
Nitrogen oxides	6,178,000	tons/yr	1.79E+00	grams/US kWh
Sulfur dioxide	13,082,000	tons/yr	3.80E+00	grams/US kWh
Carbon monoxide	406,000	tons/yr	1.18E-01	grams/US kWh
Lead	64	tons/yr	1.86E-05	grams/US kWh
Particulate matter (10 microns or less)	290,000	tons/yr	8.43E-02	grams/US kWh
Uncategorized Pollutants				
Methane (includes coal mining releases)	6,473,160,931	lbs/yr	1.02E+00	grams/US kWh
Nitrous oxide	34,119,601	lbs/yr	5.35E-03	grams/US kWh
Hydrogen chloride	1,080,433,200	lbs/yr	1.70E-01	grams/US kWh
Hydrogen fluoride	135,054,150	lbs/yr	2.12E-02	grams/US kWh
Total organic compounds	280,372,537	lbs/yr	4.40E-02	grams/US kWh
Total nonmethane organic compounds	57,839,714	lbs/yr	9.07E-03	grams/US kWh
Speciated Organic Compounds				
Acetaldehyde	513,206	lbs/yr	8.05E-05	grams/US kWh
Acetophenone	13,505	lbs/yr	2.12E-06	grams/US kWh
Acrolein	261,105	lbs/yr	4.10E-05	grams/US kWh
Benzene	1,171,594	lbs/yr	1.84E-04	grams/US kWh
Benzo(b,k)fluoranthene	8	lbs/yr	1.22E-09	grams/US kWh
Benzyl chloride	630,253	lbs/yr	9.89E-05	grams/US kWh
Bis(2-ethylhexyl)phthalate (DEHP)	65,726	lbs/yr	1.03E-05	grams/US kWh
Bromoform	35114.079	lbs/yr	5.51E-06	grams/US kWh
2-Chloroacetophenone	6302.527	lbs/yr	9.89E-07	grams/US kWh
Carbon disulfide	117046.93	lbs/yr	1.84E-05	grams/US kWh
Chlorobenzene	19807.942	lbs/yr	3.11E-06	grams/US kWh
Chloroform	53121.299	lbs/yr	8.33E-06	grams/US kWh
Cumene	4771.9133	lbs/yr	7.49E-07	grams/US kWh
Cyanide	2250902.5	lbs/yr	3.53E-04	grams/US kWh
2,4-Dinitrotoluene	252.10108	lbs/yr	3.96E-08	grams/US kWh
Dibenzo(a,h)anthracene	8.77774044	lbs/yr	1.38E-09	grams/US kWh
Dimethyl sulfate	43217.328	lbs/yr	6.78E-06	grams/US kWh
Ethyl benzene	84968.224	lbs/yr	1.33E-05	grams/US kWh
Ethyl chloride	37815.162	lbs/yr	5.93E-06	grams/US kWh
Ethylene dichloride	36014.44	lbs/yr	5.65E-06	grams/US kWh
Ethylene dibromide	1080.4332	lbs/yr	1.70E-07	grams/US kWh

Table E2. Generation Related Outputs - Air Emissions

Pollutant	Quantity	Units	Converted Quantity	Units
Formaldehyde	849649.211	lbs/yr	1.33E-04	grams/US kWh
Hexane	60324.187	lbs/yr	9.46E-06	grams/US kWh
Indo(1,2,3-cd)pyrene	11.24812248	lbs/yr	1.76E-09	grams/US kWh
Isophorone	522209.38	lbs/yr	8.19E-05	grams/US kWh
2-Methylnaphthalene	26.77544606	lbs/yr	4.20E-09	grams/US kWh
Methyl bromide	144057.76	lbs/yr	2.26E-05	grams/US kWh
Methyl chloride	477191.33	lbs/yr	7.49E-05	grams/US kWh
Methyl ethyl ketone	351140.79	lbs/yr	5.51E-05	grams/US kWh
Methyl hydrazine	153061.37	lbs/yr	2.40E-05	grams/US kWh
Methyl methacrylate	18007.22	lbs/yr	2.83E-06	grams/US kWh
Methyl tert butyl ether	31512.635	lbs/yr	4.94E-06	grams/US kWh
Methylene chloride	261104.69	lbs/yr	4.10E-05	grams/US kWh
OCDD	0.016294009	lbs/yr	2.56E-12	grams/US kWh
Phenol	14405.776	lbs/yr	2.26E-06	grams/US kWh
Propionaldehyde	342137.18	lbs/yr	5.37E-05	grams/US kWh
Tetrachloroethylene	38715.523	lbs/yr	6.07E-06	grams/US kWh
Toluene	255205.255	lbs/yr	4.00E-05	grams/US kWh
1,1,1-Trichloroethane	19247.66715	lbs/yr	3.02E-06	grams/US kWh
Styrene	22509.025	lbs/yr	3.53E-06	grams/US kWh
Xylenes	33313.357	lbs/yr	5.23E-06	grams/US kWh
o-xylene	572.918388	lbs/yr	8.99E-08	grams/US kWh
Vinyl acetate	6842.7436	lbs/yr	1.07E-06	grams/US kWh
Trace Metals				
Antimony	43,801	lbs/yr	6.87E-06	grams/US kWh
Arsenic	376,538	lbs/yr	5.91E-05	grams/US kWh
Barium	20,633	lbs/yr	3.24E-06	grams/US kWh
Beryllium	19,155	lbs/yr	3.01E-06	grams/US kWh
Cadmium	48,371	lbs/yr	7.59E-06	grams/US kWh
Chloride	1,823,878	lbs/yr	2.86E-04	grams/US kWh
Chromium	244,073	lbs/yr	3.83E-05	grams/US kWh
Chromium (VI)	72,432	lbs/yr	1.14E-05	grams/US kWh
Cobalt	122,034	lbs/yr	1.91E-05	grams/US kWh
Copper	9,996	lbs/yr	1.57E-06	grams/US kWh
Fluoride	196,054	lbs/yr	3.08E-05	grams/US kWh
Magnesium	9,903,971	lbs/yr	1.55E-03	grams/US kWh
Manganese	457,748	lbs/yr	7.18E-05	grams/US kWh
Mercury	75,421	lbs/yr	1.18E-05	grams/US kWh
Molybdenum	5,861	lbs/yr	9.20E-07	grams/US kWh
Nickel	687,818	lbs/yr	1.08E-04	grams/US kWh
Phosphorous	49,723	lbs/yr	7.80E-06	grams/US kWh

Table E2. Generation Related Outputs - Air Emissions

Pollutant	Quantity	Units	Converted Quantity	Units
Selenium	1,174,059	lbs/yr	1.84E-04	grams/US kWh
Vanadium	176,674	lbs/yr	2.77E-05	grams/US kWh
Zinc	152,953	lbs/yr	2.40E-05	grams/US kWh
Polynuclear Aromatic Hydrocarbons (PAHs)				
Biphenyl	1,531	lbs/yr	2.40E-07	grams/US kWh
Acenaphthene	459	lbs/yr	8.94E-08	grams/US kWh
Acenaphthylene	225	lbs/yr	3.55E-08	grams/US kWh
Anthracene	189	lbs/yr	3.07E-08	grams/US kWh
Benzo(a)anthracene	72	lbs/yr	1.46E-08	grams/US kWh
Benzo(a)pyrene	34	lbs/yr	5.37E-09	grams/US kWh
Benzo(b,j,k)fluoranthene	99	lbs/yr	1.55E-08	grams/US kWh
Benzo(g,h,i)perylene	24	lbs/yr	5.68E-09	grams/US kWh
Chrysene	90	lbs/yr	1.61E-08	grams/US kWh
Fluoranthene	639	lbs/yr	1.06E-07	grams/US kWh
Fluorene	819	lbs/yr	1.32E-07	grams/US kWh
Indeno(1,2,3-cd)pyrene	55	lbs/yr	8.62E-09	grams/US kWh
Naphthalene	11,705	lbs/yr	2.88E-06	grams/US kWh
Phenanthrene	2,431	lbs/yr	3.95E-07	grams/US kWh
Pyrene	297	lbs/yr	5.25E-08	grams/US kWh
5-Methyl chrysene	20	lbs/yr	3.11E-09	grams/US kWh
Dioxins & Furans				
2,3,7,8-TCDD	0.012875162	lbs/yr	2.02E-12	grams/US kWh
Total TCDD	0.083553501	lbs/yr	1.31E-11	grams/US kWh
Total PeCDD	0.040246137	lbs/yr	6.31E-12	grams/US kWh
Total HxCDD	0.025840361	lbs/yr	4.05E-12	grams/US kWh
Total HpCDD	0.075090107	lbs/yr	1.18E-11	grams/US kWh
Total OCDD	0.374550176	lbs/yr	6.13E-11	grams/US kWh
Total PCDDd	0.599640426	lbs/yr	9.41E-11	grams/US kWh
2,3,7,8-TCDF	0.045918411	lbs/yr	7.20E-12	grams/US kWh
Total TCDF	0.363745844	lbs/yr	5.71E-11	grams/US kWh
Total PeCDF	0.317827433	lbs/yr	4.99E-11	grams/US kWh
Total HxCDF	0.172869312	lbs/yr	2.71E-11	grams/US kWh
Total HpCDF	0.069147725	lbs/yr	1.08E-11	grams/US kWh
Total OCDF	0.059693934	lbs/yr	9.37E-12	grams/US kWh
Total PCDFd	0.98139349	lbs/yr	1.54E-10	grams/US kWh
TOTAL PCDD/PCDF	1.58463536	lbs/yr	2.49E-10	grams/US kWh

[a] The criteria pollutants were not multiplied by the transmission and distribution factor due to their being reported totals for the electric industry.

Table E3. Generation Related Outputs - Radionuclides

Isotope	Quantity	Units	Converted Quality	Units
Outputs				
Airborne Radionuclides				
T-3	4606.974412	Curies/yr	5.90E+01	Becquerels/US kWh
Ar-41	1964.5125	Curies/yr	2.51E+01	Becquerels/US kWh
Cr-51	0.123263529	Curies/yr	1.58E-03	Becquerels/US kWh
Mn-54	0.001748801	Curies/yr	2.24E-05	Becquerels/US kWh
Co-57	0.000331271	Curies/yr	4.24E-06	Becquerels/US kWh
Co-58	0.00422948	Curies/yr	5.41E-05	Becquerels/US kWh
Co-60	0.031817399	Curies/yr	4.07E-04	Becquerels/US kWh
Kr-85	3258.779559	Curies/yr	4.17E+01	Becquerels/US kWh
Kr-85M	157.9313971	Curies/yr	2.02E+00	Becquerels/US kWh
Kr-87	58.78129559	Curies/yr	7.52E-01	Becquerels/US kWh
Rb-88	0.645592735	Curies/yr	8.26E-03	Becquerels/US kWh
Kr-88	275.8021471	Curies/yr	3.53E+00	Becquerels/US kWh
Br-89	0.000227267	Curies/yr	2.91E-06	Becquerels/US kWh
Br-90	9.24476E-05	Curies/yr	1.18E-06	Becquerels/US kWh
Nb-95	6.94898E-05	Curies/yr	8.89E-07	Becquerels/US kWh
Zr-95	0.000179503	Curies/yr	2.30E-06	Becquerels/US kWh
Tc-99M	9.3218E-06	Curies/yr	1.19E-07	Becquerels/US kWh
Ag-110M	2.07237E-06	Curies/yr	2.65E-08	Becquerels/US kWh
I-131	0.148686632	Curies/yr	1.90E-03	Becquerels/US kWh
Xe-131M	265.7869853	Curies/yr	3.40E+00	Becquerels/US kWh
I-132	0.030199565	Curies/yr	3.86E-04	Becquerels/US kWh
Xe-133	38365.77353	Curies/yr	4.91E+02	Becquerels/US kWh
I-133	137.9010735	Curies/yr	1.76E+00	Becquerels/US kWh
Xe-133M	2550.014265	Curies/yr	3.26E+01	Becquerels/US kWh
Cs-134	0.006240216	Curies/yr	7.99E-05	Becquerels/US kWh
I-134	0.156390603	Curies/yr	2.00E-03	Becquerels/US kWh
Xe-135	1448.346471	Curies/yr	1.85E+01	Becquerels/US kWh
I-135	0.00785805	Curies/yr	1.01E-04	Becquerels/US kWh
Xe-135M	27.65725441	Curies/yr	3.54E-01	Becquerels/US kWh
Cs-137	0.04707126	Curies/yr	6.02E-04	Becquerels/US kWh
Xe-138	91.67725	Curies/yr	1.17E+00	Becquerels/US kWh
Waterborne Radionuclides				
T-3	34436.74853	Curies/yr	4.41E+02	Becquerels/US kWh
Na-24	0.172568941	Curies/yr	2.21E-03	Becquerels/US kWh
Cr-51	4.676310147	Curies/yr	5.98E-02	Becquerels/US kWh
Mn-54	3.081588235	Curies/yr	3.94E-02	Becquerels/US kWh
Fe-55	11.01667794	Curies/yr	1.41E-01	Becquerels/US kWh
Co-57	0.113248368	Curies/yr	1.45E-03	Becquerels/US kWh
Co-58	46.06974412	Curies/yr	5.90E-01	Becquerels/US kWh
Fe-59	0.565471441	Curies/yr	7.24E-03	Becquerels/US kWh

Table E3. Generation Related Outputs - Radionuclides

Isotope	Quantity	Units	Converted Quality	Units
Co-80	12.09523382	Curies/yr	1.55E-01	Becquerels/US kWh
Zn-85	0.052001801	Curies/yr	6.65E-04	Becquerels/US kWh
Kr-85M	2.912100882	Curies/yr	3.73E-02	Becquerels/US kWh
Sr-89	0.186436088	Curies/yr	2.39E-03	Becquerels/US kWh
Sr-90	0.043835593	Curies/yr	5.61E-04	Becquerels/US kWh
Nb-95	0.793508971	Curies/yr	1.02E-02	Becquerels/US kWh
Sr-95	0.483038956	Curies/yr	6.18E-03	Becquerels/US kWh
Mo-99	5816497.794	Curies/yr	7.44E+04	Becquerels/US kWh
Tc-99M	0.067640862	Curies/yr	8.66E-04	Becquerels/US kWh
Ru-103	0.097070029	Curies/yr	1.24E-03	Becquerels/US kWh
Ag-110M	1.132483676	Curies/yr	1.45E-02	Becquerels/US kWh
Sn-113	0.107085191	Curies/yr	1.37E-03	Becquerels/US kWh
Sb-124	0.970700294	Curies/yr	1.24E-02	Becquerels/US kWh
Sb-125	3.867393235	Curies/yr	4.95E-02	Becquerels/US kWh
I-131	2.157111765	Curies/yr	2.76E-02	Becquerels/US kWh
Xe-131M	35.43826471	Curies/yr	4.54E-01	Becquerels/US kWh
I-132	0.816620882	Curies/yr	1.05E-02	Becquerels/US kWh
Xe-133	5446.707206	Curies/yr	6.97E+01	Becquerels/US kWh
I-133	0.924476471	Curies/yr	1.18E-02	Becquerels/US kWh
Xe-133M	44.60598971	Curies/yr	5.71E-01	Becquerels/US kWh
Cs-134	2.596238088	Curies/yr	3.32E-02	Becquerels/US kWh
I-135	0.663311868	Curies/yr	8.49E-03	Becquerels/US kWh
Xe-135	40.599925	Curies/yr	5.20E-01	Becquerels/US kWh
s-136	0.104003603	Curies/yr	1.33E-03	Becquerels/US kWh
Cs-137	3.898209118	Curies/yr	4.99E-02	Becquerels/US kWh
Ba-140	0.071955085	Curies/yr	9.21E-04	Becquerels/US kWh
La-140	0.077039706	Curies/yr	9.86E-04	Becquerels/US kWh

Table E4. Net Generation Information

Generation type [a]	Net Generation	
	(MWh/yr)	%
Coal	1,787,806,000	57.255%
Gas	283,625,000	9.083%
Petroleum	77,753,000	2.490%
Nuclear	628,644,000	20.133%
Hydro [b]	337,233,000	10.800%
Renewables [b]	7,462,000	0.239%
Total	3,122,522,000	100.000%

[a] This breakdown excludes nonutility electricity generation (Non and Independent Power Producers (NPPs or IPPs)), which typically contribute about 11% of the U.S. total (EIA 1999).

[b] Hydro and renewables were excluded from the calculation of inputs and outputs.

Table E5. Conversion Factors

Universal factor	1 pound =	453.59	grams
Water	1 gallon =	8.34	pounds
Coal [a]	1 pound =	10,275	btu
Gas [b]	a cubic foot =	0.0473	pounds
Petroleum	1 gallon =	7.26	pounds
Nuclear	1 Curie =	3.70E+10	Becquerals
Nuclear (LLRW)	1 cubic foot =	80	pounds
Transmission & distribution [c]	1 kWh out requires =	1.08	kWhs in

[a] Source: EIA's "Cost & Quality of Fuels for Electric Utility Plants 1997," Table ES-4.

[b] Calculated by the CCPCT with reference information from "Perry's Chemical Engineer's Handbook, 6th Edition."

[c] Source: EIA's Short-Term Energy Outlook," Table A8.

APPENDIX F

MANUFACTURING DATA COLLECTION QUESTIONNAIRE

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Design for the Environment
U.S. EPA

DESIGN FOR THE ENVIRONMENT COMPUTER DISPLAY PROJECT
Life-Cycle Inventory (LCI) Data Collection Questionnaire

Introduction

The Design for the Environment (DfE) Program in the U.S. Environmental Protection Agency's (EPA) Office of Pollution Prevention and Toxics has begun a voluntary, cooperative project with the electronics industry to assess the life-cycle environmental impacts of cathode ray tube (CRT) and liquid crystal display (LCD) desktop monitors. The DfE Program conducts comparative analyses of alternative products or processes to provide businesses with data to make environmentally informed choices about product or process improvements. The DfE Program has no regulatory or enforcement agenda and was established to act as a partner with industry to promote pollution prevention. This environmental life-cycle assessment will address human and ecological risk, energy and natural resource use, performance, and cost of various display technologies. The University of Tennessee (UT) Center for Clean Products and Clean Technologies is conducting the life-cycle inventory (LCI), which is the data collection phase of a life-cycle assessment, with technical assistance from the Asian Technology Information Program, Microelectronics and Computer Technology Corporation, the Electronics Industry Alliance, and other partners.

Boundaries

A *life-cycle* assessment considers impacts from materials acquisition, material manufacturing, product manufacturing, use, and final disposition of a product. The LCI data are intended to be used to evaluate relative environmental impacts over the entire life-cycle of a product, including transport between life-cycle stages. In this project, the product is either a color CRT or LCD monitor. Therefore, data associated with the materials and processes used directly in the manufacturing, use, and disposition of the product are relevant to the LCI and requested in this questionnaire. You will not need to include materials or energy *not directly* used in the production of the monitor or its components (e.g., general building heating and air conditioning).

Product focus

This project will evaluate CRT and LCD (twisted nematic and in-plane switching) technologies, based on 1998 production for a 17" CRT and a 15" LCD desktop monitor, with the following approximate specifications:

- 1024×768 resolution
- 100:1 contrast ratio
- 200 cd/m² brightness
- 262,000 colors

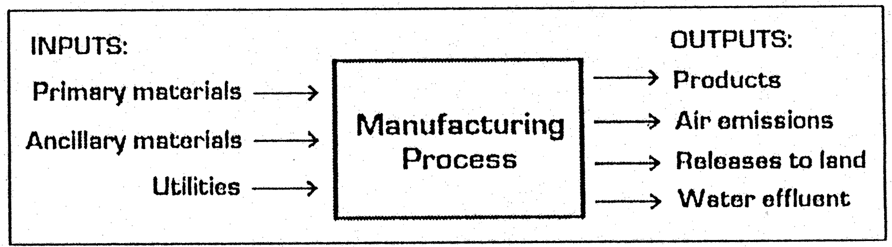

Fig. 1. Manufacturing process inventory conceptual template

Inventory data

We are asking you for data on a particular "product of interest" that you manufacture, which is defined as a material, component, or subassembly that is part of the product focus defined above. The inputs and outputs data (Fig. 1) that you provide will be aggregated in the LCI to quantify the overall inputs and outputs of a CRT and LCD. Additionally, transportation information is requested in the inventory.

Data sources
Much of the requested information can be drawn from existing sources, including, but not limited to the following:

1. Purchase and production records
2. Bills and invoices
3. Material Safety Data Sheets (MSDS)
4. Toxic Release Inventory (TRI) forms
5. Audit and analysis results (e.g., wastewater discharge analyses)
6. Local, state, and federal reporting forms (e.g., hazardous waste manifests)
7. Local, state, and federal permits
8. Monthly utility billing records

How the data will be used
UT will aggregate the inventory data and tally the average inputs and outputs for the different monitors. Information gathered by this questionnaire will be used to develop environmental profiles based on inputs and outputs for each stage in the manufacture of displays. The profiles will be used to evaluate environmental impacts from each product. Cost data will also be collected and presented along with environmental results. The environmental profiles can be used to encourage product design changes for product improvement. UT will aggregate data and ensure that data associated with particular companies remain anonymous to the EPA. UT can enter into confidentiality agreements where proprietary data are concerned. Please understand that accurate and representative information from you is critical for the success of this project.

Results of project
The results are intended to provide industry with an analysis of the life-cycle environmental impacts, cost, and performance of CRT and LCD computer monitors. Results will help identify areas for product and process improvement as related to risk and environmental impact (e.g., identifying material use inefficiencies) and will identify impacts from various life-cycle stages of the product systems. Use of the results will also help meet growing global demands of extended product responsibility.

Benefits of involvement
Your input will allow for your interests to be considered in the project development and data collection. By supplying data, the results will partially reflect your operations and, therefore, the results will be directly relevant to your interests. The project will allow you to directly apply results to your manufacturing process and identify areas for improvement. You will also be recognized as working voluntarily and cooperatively with the U.S. EPA.

Deadline
We are attempting to obtain all completed questionnaires before *October 29, 1999*.

Your cooperation and assistance are greatly appreciated.

*For any questions, please contact **Maria Leet Socolof** at 423-974-9526, <socolofml@utk.edu> or **Jonathan G. Overly** at 423-974-3625, <jgoverly@utk.edu> at the University of Tennessee, 311 Conference Center Bldg., Knoxville, TN 37996-4134. Fax: 423-974-1838.*
For more project details, see the Project Fact Sheet, DfE Website <www.epa.gov/dfe>, or the Draft Final Goal Definition and Scoping Document.

INSTRUCTIONS

1. Please be sure to read the introductory text on each page before filling out the questionnaire.
2. The data you supply in the tables should represent inputs and outputs associated only with the **"product of interest" (i.e., materials, components or subassemblies you manufacture that are either part of, or that are itself, the desktop monitor as defined on p. 1 under Product focus). If** quantities provided are not specific to the "product of interest," please explain how they differ in the comments section at the bottom of the appropriate table.
3. Where supporting information is available as independent documents, reports or calculations, please provide them as attachments with reference to the associated page(s) or table(s) in this questionnaire.
4. If you have more than one product of interest to this project, please duplicate this questionnaire and fill out one questionnaire for each product.
5. If there is not adequate room on a page to supply your data (including comments), please copy the appropriate page and attach it to this packet.
6. The ensuing pages refer to the four indices shown below to detail specific information about the data. Additional information is provided below as required.
   Data Quality Indicators Index: These indicators will be used to assess the level of data quality in this questionnaire. Please report a DQI for the numerical value requested in each table on the following pages. The first category, Measured, pertains to a value that is a directly measured quantity. The second category, Calculated, refers to a value that required one or more calculations to obtain. The third category, Estimated, refers to a value that required a knowledgable employee's professional judgement to estimate. Lastly, the fourth category, Assumed, should be used only when a number had to be guessed.
   Hazardous and Nonhazardous Waste Management Methods Index: These methods are applicable to both hazardous and nonhazardous wastes (Tables 7a and 7b). Please give the appropriate abbreviation in the Management Method column on p. 7 where requested. Depending on whether the management method is on or offsite, please indicate by specifying "on" or "off" in the appropriate column on p. 7.

For Tables 2, 3a, 3b, 4, 7a, and 7b:

Transportation Modes Index	
A	- Large truck (18-wheeler), diesel
B	- Small truck, diesel
C	- Small truck, gasoline
D	- Rail, diesel
E	- Barge, diesel
F	- Ocean freighter, diesel
G	- Other (please specify in comments section)

For Table 6b:

Wastewater Treatment/Disposal Methods Index	
A	- Direct discharge to surface water
B	- Discharge to offsite wastewater treatment facility
C	- Underground injection
D	- Surface impoundment (e.g., settling pond)
E	- Direct discharge to land
F	- Other (please specify in comments section)

For Tables 3a, 3b, 4, 5, 6a, 7a, and 7b:

Data Quality Indicators Index	
M	- Measured
C	- Calculated
E	- Estimated
A	- Assumed

For Tables 7a and 7b:

Hazardous and Nonhazardous Waste Management Methods Index	
RU	- Reused
R	- Recycled
L	- Landfilled
Iv	- Incinerated - volume reduction
Ic	- Incinerated - energy conversion
S	- Solidified/stabilized
D	- Deep well injected
O	- Other (please specify in comments section)

IF YOU HAVE QUESTIONS, PLEASE CONTACT EITHER:

Maria L. Socolof (Project Manager):
Phone: 423-974-9526
Fax: 423-974-1838
Email: socolofml@utk.edu

OR

Jonathan G. Overly (Project Engineer):
Phone: 423-974-3625
Fax: 423-974-1838
Email: jgoverly@utk.edu

OFFICE OF MANAGEMENT AND BUDGET STATEMENT

The public reporting and recordkeeping burden for this collection of information is estimated to average 8 hours per response. Burden means the total time, effort, or financial resources expended by persons to generate, maintain, retain, or disclose or provide information to or for a Federal agency. The burden for this collection includes the time needed to review instructions; search data sources; complete and review the collection of information; and transmit or otherwise disclose the information. An agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a currently valid OMB control number. The OMB control number for this collection is 2070-0152.

Send comments on the Agency's need for this information, the accuracy of the provided burden estimates, and any suggested methods for minimizing respondent burden, including through the use of automated collection techniques to the Director, OPPE Regulatory Information Division, U.S. Environmental Protection Agency (2136), 401 M Street, S.W., Washington, DC 20460. Include the OMB control number in any correspondence.

1. FACILITY & CONTACT INFORMATION

Table 1.

Facility Information

1. Company name: ____________________
2. Facility name: ____________________
3. Facility address (location): ____________________

____

____

____

____

4. Products manufactured onsite: ____________________

____

____

Contact Information

5a. Prepared by: ____________________ Date: __________

5b. Title: ____________________

5c. Phone number: ____________________ Ext.: __________

5d. Fax number: ____________________

5e. Email address: ____________________

2. PRODUCT OF INTEREST INFORMATION

Table 2.

NOTE: If the product of interest is an assembled monitor, please send an Owner's Manual to us at the address shown at the bottom of page ii.

1. Product of interest: ____________________
2. 1998 annual production (e.g., units, kg, lbs): ____________________
3. Facility's percent global market share for product of interest: ____________________
4. Product of interest unit weight: ____________________
5. 1998 product of interest retail unit price: ____________________
6. Energy consumption information (fill out only if the product of interest is an assembled monitor):
   - Active use: ____________________ watts
   - Standby: ____________________ watts
   - Suspend: ____________________ watts
   - Active off: ____________________ watts
7. Performance specifications (fill out only if the product of interest is an assembled monitor):
   - Maximum resolution: ____________________
   - Colors (at max. reso.): ____________________
   - Contrast ratio: ____________________
   - Brightness: ____________________ cd/m²
8. Brief description of the main operations/subprocesses required to manufacture the product of interest: ____________________

____

____

9. Product transport information. In this table, please list the top five locations (by quantity) to which you send the product of interest. You may supply one-way distances in lieu of locations. See Transportation Modes Index on p. iii for modes abbreviations. Percent capacity represents what percent of the transport vehicle's total load was carrying the products of interest.

	Location (City, State, Country)	Distance	Percent of production	Mode	Number of trips annually	Percent capacity
1)						
2)						
3)						
4)						
5)						

10. Does your facility receive any returned products from your customers? If so, is the product recycled in some way or disposed? Please explain: ____________________

____

3. PRIMARY & ANCILLARY INPUTS

1. Primary & Ancillary Materials: Primary materials, are defined as those materials that become part of the final product. Ancillary materials are those material inputs that assist production, yet do not become part of the final product. Please include the trade name and the generic name of each material where applicable.
2. CAS # or MSDS: Please either supply the chemical CAS (Chemical Abstract Service) number or attach a material "MSDS" to this document.
3. Annual quantity/units & Density/units: Please specify the amount of material consumed in 1998. Please use the units of mass-per-year (e.g., kg/yr, lb/yr). If you specify units of volume in lieu of mass, please provide the density.
4. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please supply the DQI for the *annual quantity* value given.
5. Recycled content: Please specify the recycled content of each material identified. For example, 60/40/0 would represent a material that has 60% virgin material, 40% pre-consumer recycled and 0% post-consumer recycled content. Enter N/A (not applicable) for all components that are assemblies.
6. Transportation information: See the Transportation Modes Index on p. iii for mode abbreviations. Please specify the one-way transportation distance, or the location from where the material is shipped, and the number of trips made to your facility on an annual basis. % capacity represents what percent of the transport vehicle's total ***load*** was carrying the materials of interest.

Table 3a. Primary Materials[1]	CAS # or MSDS[2]	Annual Quantity[3]	Units	Density[3]	Units	DQI[4]	Recycled Content[5]	Transportation Information (Receiving)[6]			
								Dist. or Location	Mode	# trips	% cap.
EXAMPLE: 'GRTX resin (polypropylene resin)	*MSDS*	*450,000*	*kg/yr*	*-----*	*---*	*M*	*60/40/0*	*450 km*	*A*	*24*	*40*
1.											
2.											
3.											
4.											
5.											
6.											
7.											

Primary material comments:

Table 3b. Ancillary Materials[1]	CAS # or MSDS[2]	Annual Quantity[3]	Units	Density[3]	Units	DQI[4]	Recycled Content[5]	Transportation Information (Receiving)[6]			
								Dist. or Location	Mode	# trips	% cap.
EXAMPLE: Petroleum naphtha (cleaning solvent)	*8032-32-4*	*920*	*liters/yr*	*0.96*	*kg/liter*	*C*	*100/0/0*	*St. Louis, MO*	*C*	*2*	*100*
1.											
2.											
3.											
4.											
5.											
6.											
7.											

Ancillary material comments:

4. UTILITY INPUTS

1. Annual quantity/units: Please specify the amount of each utility consumed in 1998. If possible, please exclude nonprocess-related consumption. If not possible, please include a comment that nonprocess-related consumption is included.
2. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please supply the DQI for the *annual quantity* value given.
3. Transportation information: See the Transportation Modes Index on p. iii for mode abbreviations. Please specify the one-way transportation distance, or the location from where the fuel is shipped, and the number of trips made to your facility on an annual basis. % capacity represents what percent of the transport vehicle's total *load* was carrying the materials of interest.
4. Individual Utility Notes:

Electricity:
The quantity of electricity should reflect only that used toward manufacturing the product of interest (identified on p. 2). One approach would be to start with your facility's total annual electrical energy consumption, estimate and remove nonprocess-related consumption, then estimate what portion of the remaining consumption is related to the specific operations of interest (if you manufacture more than one product). Please include consumption in all systems that use electricity for process-related purposes. Some examples include compressed air, chilled water, water deionization and HVAC consumption where clean or controlled environments are utilized.

Natural gas and LNG:
Please exclude all use for space heating or other nonprocess-related uses. If you choose to use units other than MCF (thousand cubic feet), please utilize only units of energy content or volume (e.g., mmBTU, therm, CCF).

Fuel oils:
Please use units of either volume or energy content (e.g., liters, cubic meters, mmBTU, MJ). Additionally, if the fuel oil is delivered by pipeline, enter "pipeline" in the Transportation Information space; if not delivered by pipeline, please include the associated transportation information.

All waters (e.g., deionized, city):
Please include all waters received onsite. Please indicate consumption in units of mass or volume.

Table 4.		**Annual**	**Units**	**DQI**[2]	**Transportation Information (Receiving)**[3]			
	Utilities[4]	**Quantity**[1]			**Dist. or Location**	**Mode**	**# trips**	**% cap.**
1.	Electricity		MJ		▨	▨	▨	▨
2.	Natural gas		MCF		▨	▨	▨	▨
3.	Liquified natural gas (LNG)		MCF					
4.	Fuel oil - type #2 (includes distillate and diesel)		liters					
5.	Fuel oil - type #4		liters					
6.	Fuel oil - type #6 (includes residual)		liters					
7.	Propane		liters					
8.	Water		liters		▨	▨	▨	▨
9.								
10.								
11.								
12.								
13.								

Utility comments:

5. AIR EMISSIONS

1. Air emissions: The emissions listed in the table below are some of the more common ones found in air release inventories; if you have information on other specific emissions, please include that information in the space provided. If you have any reporting forms or other air emission records for 1998, please attach copies to this questionnaire. Also, if you have information on stack as well as fugitive emissions, please copy this page and place each set of emissions on a different page. The energy consumed in any equipment used onsite to treat air emissions should be included in the utilities values on p. 4.
2. Annual quantity/units: Please specify the amount of air emissions generated in 1998. If you do not have 1998 emissions data, use the next closest year's data you have and specify what year's data you are supplying in the comment section below. Please use units of mass-per-year (e.g., kg/yr, lb/yr).
3. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please supply the DQI for the *annual quantity* value given.

Table 5. Air Emissions[1]	CAS number	Annual Quantity[2]	Units	DQI[3]
Total particulates	-----			
Particulates < 10 microns (PM-10)	-----			
Sulfur oxides (SOx)	-----			
Nitrogen oxides (NOx)	-----			
Carbon monoxide	630-08-0			
Carbon dioxide	124-38-9			
Methane	74-82-8			
Benzene	71-43-2			
Toluene	108-88-3			
Xylenes	1330-20-7			
Naphthalene	91-20-3			
Total nonmethane VOCs	-----			
Other speciated hydrocarbon emissions:	▨	▨	▨	▨
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				

Table 5 (continued). Air Emissions[1]	CAS number	Annual Quantity[2]	Units	DQI[3]
Ammonia	7664-41-7			
Arsenic	7440-38-2			
Chromium	7440-47-3			
Copper	7440-50-8			
Lead	7439-92-1			
Manganese	7439-96-5			
Mercury	7439-98-7			
Nickel	7440-02-0			
Other emissions:	▨	▨	▨	▨
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Air emission comments:

6. WASTEWATER RELEASES & CONSTITUENTS

1. Annual quantity/units: Please specify the amount of wastewater(s) generated in 1998. Please use units of mass-per-year (e.g., kg/yr, lb/yr). If multiple streams exist, please copy this page and fill it out for each stream.
2. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please include one DQI for the annual wastewater stream quantity value supplied, and one DQI for the wastewater constituents information supplied. If more than one DQI is applicable to the wastewater constituents data, please clarify this in the comment section.
3. Wastewater constituents: Please let us know what type of values you are supplying (e.g., daily maximums, monthly averages, annual averages). Additionally, if you have any reporting forms of other wastewater constituent records for the 1998, please attach them to this questionnaire. The energy consumed in any equipment used onsite to treat wastewater releases should be included in the utilities values on p. 4.
4. Concentration/units: Please specify the concentration of wastewater constituents generated in 1998. Please utilize the units of mass-per-volume (e.g., mg/liter, lb/gal).
5. Wastewater treatment/disposal (WW T/D) method: See the Wastewater Treatment/Disposal Methods Index on p. iii for method abbreviations.

Table 6a. Wastewater Stream	Annual Quantity[1]	Units	DQI for Wastewater Annual Quantity[2]	DQI for Wastewater Constituents[2]

Table 6b. Wastewater Constituents[3]	CAS number	Concentration[4]	Units	WW T/D Method[5]
Dissolved solids	-----			
Suspended solids	-----			
Chemical Oxygen Demand (COD)	-----			
Biological Oxygen Demand (BOD)	-----			
Oil & grease	-----			
Hydrochloric acid	7647-01-0			
Sulfuric acid	7664-93-9			
Other acids (please specify):	▨	▨	▨	▨
1.				
2.				
Phosphorus	7723-14-0			
Phosphates	-----			
Sulfates	-----			
Fluorides	-----			
Cyanide	-----			
Chloride	-----			
Chromium	7440-47-3			
Iron	7439-89-6			
Aluminum	7429-90-5			
Nickel	7440-02-0			

Table 6b (continued). Wastewater Constituents[3]	CAS number	Concentration[4]	Units	WW T/D Method[5]
Mercury	7439-98-7			
Lead	7439-92-1			
Nitrogen	7727-37-9			
Zinc	7440-66-6			
Tin	7440-31-5			
Ferrous sulfate	7720-78-7			
Ammonia	7664-41-7			
Nitrates	-----			
Pesticides	-----			
Other constituents:	▨	▨	▨	▨
1.				
2.				
3.				
4.				
5.				
6.				

Wastewater comments:

7. HAZARDOUS & NONHAZARDOUS WASTES

1. Hazardous wastes and EPA hazardous waste numbers: Please list your waste streams that are considered hazardous by the U.S. EPA. Include the hazardous waste codes for any hazardous waste you include.
2. Annual quantity/units & Density/units: Please specify the amount of waste generated in 1998. Use units of mass-per-year (e.g., kg/yr, lb/yr). Please also provide the density for each waste.
3. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please supply the DQI for the *annual quantity* value given.
4. Management method: See the Management Methods Index on p. iii for abbreviations. If none are applicable, please indicate other and use the comments section to expound.
5. Transportation information: See the Transportation Modes Index on p. iii for mode abbreviations. Please specify the one-way transportation distance, or the location to where the waste is shipped, and the number of trips made from your facility on an annual basis. % capacity represents what percent of the transport vehicle's total ***load*** was carrying the wastes of interest.

Table 7a. **Hazardous Wastes**[1]	**EPA Haz. Waste #**[1]	**Annual Quantity**[2]	**Units**	**Density**[2]	**Units**	**DQI**[3]	**Mgmt. method**[4]	**On or offsite?**	**Transportation Information (Shipping)**[5] **Dist. or Location**	**Mode**	**# trips**	**% cap.**
EXAMPLE: Spent solvent (toluene)	*F005*	*20,000*	*kg/yr*	*0.9*	*kg/liter*	*M*	*Ie*	*off*	*Indianapolis, IN*	*A*	*24*	*40*
1.												
2.												
3.												
4.												
5.												
6.												
7.												
8.												

Hazardous waste comments:

Table 7b. **Nonhazardous Wastes**	**Annual Quantity**[2]	**Units**	**Density**[2]	**Units**	**DQI**[3]	**Mgmt. method**[4]	**On or offsite?**	**Transportation Information (Shipping)**[5] **Dist. or Location**	**Mode**	**# trips**	**% cap.**
EXAMPLE: Waste metal chips	*22,000*	*kg/yr*	*1,000*	*kg/m3*	*C*	*R*	*off*	*225 km*	*A*	*2*	*100*
1.											
2.											
3.											
4.											
5.											
6.											
7.											

Nonhazardous waste comments:

APPENDIX G

SUPPLEMENTAL MANUFACTURING DATA INFORMATION

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APPENDIX G

SUPPLEMENTAL MANUFACTURING DATA INFORMATION

G-1. Frit Manufacturing Data Collection

No manufacturers were willing to supply complete frit manufacturing data as primary data for this study. Inventory data for the frit manufacturing process were obtained from secondary sources and from communications with industry representatives. Input data were derived from personal communication with an industry representative (Peer 2000) and output data were compiled from the U.S. Environmental Protection Agency's (EPA) *AP-42* publication (*Compilation of Air Pollutant Emission Factors*) (EPA 1997). The AP-42 data are provided for one ton of feed material, and it was assumed that the material efficiency is 100%, such that for each mass quantity of raw material input, the same mass quantity of frit is produced.

Limitations to these data are that a complete inventory, with all the information asked in the questionnaire for other manufacturing processes in this study, was not obtained. Personal communications were made to provide information on the major inputs to the process, based on a conversation taken place in June, 2000. The output data are based on a 1997 EPA publication. The publication date of the output data remains within the range of dates of primary data obtained in this study. Further, the frit manufacturing process is expected to be a relatively mature technology (compared to some LCD-related technologies), and 1997 data are expected to be representative of the monitors being studied in this project.

G-2. Printed Wiring Boards (PWBs) and Electronic Component Manufacturing Data Collection

Each display technology requires electronic printed wiring boards (PWBs) and their associated components such as integrated circuit (IC) chips, resistors, capacitors to operate the displays, independent of the computer's central processing unit. Therefore, the display PWBs and components are within the bounds of the analysis.

PWB and semiconductor (IC) manufacturing are highly energy and resource intensive processes. In purely a comparative analysis, we could consider eliminating the PWBs from the analysis since both the CRT and LCD display technologies use PWBs. However, the number of PWBs (4 major ones for LCDs and 2 for CRTs) and their makeup differ between the two technologies. For example, the AMLCD controller has more active parts because its addressing system is more complicated than the CRT. Therefore, exclusion of the PWB manufacturing process was chosen to be included in the scope of this project. In addition, beyond the goal of a comparative analysis between CRT and LCD, this study is intended to provide baseline data for each individual technology such that improvement assessments can be considered when evaluating the entire life cycle of a particular monitor. This provides another reason to include PWB manufacturing in the scope. However, due to the importance of collecting primary data for the other major display components (e.g., CRT tube and LCD panel/module manufacturing), a lower priority was given to obtaining PWB data.

Given the lower priority for PWB and component data collection, questionnaires were not sent to multiple PWB and component manufacturers. Alternatively, data were obtained from an industry contact knowledgeable in PWB manufacturing (Sharp 2000). PWB component manufacturing data were not obtained; however, materials use as well as energy consumption from manufacturing PWB components are expected to be small in comparison to the overall manufacturing requirements for the CRT and LCD monitors; therefore, lack of PWB component manufacturing data is not expected to have a significant impact on the results.

REFERENCES

EPA (Environmental Protection Agency). 1997. *Compilation of Air Pollutant Emission Factors (AP-42).* Fifth Edition, Volume I. June.

Peer, J. 2000. Personal communication with J. Peer, Techneglas, and J. G. Overly, University of Tennessee, Center for Clean Products and Clean Technologies. June.

Sharp, J. 2000. Personal communication with J. Sharp, Teredyne Corp.; J. G. Overly and M. Socolof, University of Tennessee, Center for Clean Products and Clean Technologies. August.

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APPENDIX H

TECHNICAL MEMORANDUM:
Use Life-Cycle Stage Approach

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APPENDIX H

TECHNICAL MEMORANDUM:
Use Life-Cycle Stage Approach

1. INTRODUCTION

1.1 Background

As part of the Environmental Protection Agency's Design for the Environment Program (DfE) Computer Display Project (CDP), the University of Tennessee Center for Clean Products and Clean Technologies is conducting an environmental life-cycle assessment (LCA) of 17" cathode ray tube (CRT) and 15" active matrix liquid crystal display (LCD) computer monitors. Chapter 1 of this report provides further details about the scope and boundaries of this project. As typically defined in LCA, the five main life-cycle stages of any product are as follows:

- Materials Extraction;
- Materials Processing;
- Product Manufacture;
- Product Use, Maintenance and Repair; and
- End-of-Life.

This technical memorandum (TM) presents the CDP's approach to developing the inventory that will be used to assess the environmental and health impacts from the use life-cycle stage of computer monitors. Maintenance and repair are not included within the boundaries of this analysis because they are expected to be minor contributors to environmental impacts compared to use and other life-cycle stages.

The purpose of this TM is to present the approach for developing the inventory of inputs and outputs associated with the actual use of the monitors. The final use-stage inventory will consist of electricity consumption from use as well as the indirect inputs and outputs from the generation of that electricity. The focus of this TM is on identifying the amount of electricity consumed during use. The inventory from electricity generation is presented in Appendix E. The final use-stage inventory combines these two sets of data and will be presented as part of the final LCI in Section 2.7 and Appendix J of this report.

In addition to energy consumption, other environmental or health issues have been associated with the use of computer monitors, including eye strain, ergonomics, and exposure to electric and magnetic fields. However, quantitative methods for assessing these impacts within the project LCA framework are not available. Thus, these impacts will be addressed qualitatively in the final LCA report for the project.

1.2 Calculating Energy Consumption During the Use Stage

CRTs and LCDs use different mechanisms to produce images on screen, which result in different energy use rates. These energy use rates can be combined with the number of hours a desktop monitor is on during its lifespan to calculate the total quantity of electrical energy consumed during the use life-cycle stage. In this project, two lifespan scenarios are considered:

- Manufactured life - the amount of time either an entire monitor or a single component will last before reaching a point where the equipment no longer functions, independent of user choices.
- Effective life - the actual amount of time a monitor is used, by one or multiple users, before it is disposed of, recycled, or re-manufactured. Reuse of a monitor by a subsequent user is considered part of its effective life. Recycling, on the other hand, is the reuse of parts or materials that require additional processing after disassembly and it is not considered part of the use stage.

These two scenarios are considered in this project in order to account for potential differences between how consumers *currently* use the equipment and how consumers could use the equipment. Currently, consumers often replace monitors before they physically break down. This behavior results in a lifespan that is not dependent on the monitor technology itself. The manufactured life, on the other hand, is based on the technology and represents how consumers could potentially use the equipment. If the lifespans are significantly different, the difference could have a large impact on how the use stage compares to the other life-cycle stages in this study. The remainder of this TM is broken down into the following sections: Methodology, Preliminary Results, Data Sources and Quality, Limitations and Uncertainties, and Discussion and Conclusions.

2. METHODOLOGY

As discussed in the previous section, calculating electrical energy consumption during the life of an electrical component requires two main pieces of information: the component's energy use rate (typically in watts or kilowatts) and the amount of time the component can or does spend in use (in hours per life).

Once energy use rates and hours per life in each mode are known, they can be multiplied to derive the total number of kilowatthours (kWh) consumed during the lifetime of a monitor according to the following general equation where “ mode *I*” indicates the power consumption mode of a monitor (i.e., full-on or low, discussed further in Sect. 2.1). This basic equation will be used to calculate the total kWhs consumed over the manufactured and effective lives for LCDs and CRTs.

$$\sum_{i=1}^{2}\left[(kW\ \text{consumed in mode}\ i)\ x\ \left(\frac{hours}{life}\ \text{spent in mode}\ i\right)\right] = \frac{kWh}{life}$$

Section 2.1 presents information on the various energy use rates that exist for the project functional units in different power modes. Section 2.2 presents the methodology for calculating hours per life under the manufactured and effective life scenarios.

2.1 Energy Use Rate

Most desktop monitors manufactured today are built to use several different power consumption modes during normal operation. There are often up to four different power consumption modes that can be used by a monitor in going from a state of active use to a state of almost complete shut-down. These four modes, from greatest power consumption to least, are typically entitled 'full-on' or active use, 'standby,' 'suspend' and 'active-off.' For this TM, manufacturers' data on these power modes were collected from company contacts and Internet sites for 35 different 17" CRT monitors and 12 different 15" LCD monitors. The complete list of these data is presented in Attachment A, Table A1.

For the purposes of this TM, the power consumption modes have been categorized into two modes: 'full-on' and 'low.' The 'low' power mode is an average of the three low power modes typically provided by the manufacturers (i.e., standby, suspend, and active-off). These three categories were averaged to create one 'low' power consumption mode because hours per use data (needed for calculations in this TM) are only available for a 'full-on' and a reduced power mode. The low mode value for the CRT is the average of the three modal averages of standby, suspend and active-off. For the LCD, data on only two low-power modes (standby and active-off) were provided by manufacturers (see Attachment A, Table A2), and therefore, the low mode value is an average of those two modal averages. Table 1 presents the average values for full-on and low power modes that were used for subsequent calculations in this TM.

Table 1. Average Energy Use Rates [a]

Monitor Type	Full-on Power Mode		Low Power Mode [b]	
	(W)	(kW)	(W)	(kW)
17" CRT	112	0.113	13.1	0.013
15" LCD	39.7	0.040	6.44	0.006

[a] See Attachment A, Table A1 for source data.

[b] An average of company-reported values for standby, suspend and active-off (see Attachment A, Table A1).

2.2 Calculating Lifespan

As stated previously, lifespan calculations in this TM are based on two different scenarios: manufactured life and effective life. Sects. 2.2.1 and 2.2.2 present the methodology and data needed to calculate energy use under each of these two scenarios, respectively. Sect. 2.2.2 is further divided into discussions of office versus home use patterns, the amount of time a monitor is operating in each power mode, and the number of years the monitor is operating in its lifetime. These results will be combined with data from the energy use rate calculations in Sect. 2.1 to obtain the energy consumption per life for each scenario and for each monitor.

2.2.1 Scenario #1: Manufactured Life

The manufactured life is defined here as the length of time a monitor is designed to operate effectively for the user. It is the number of hours a monitor would function as manufactured, and is independent of user choices or actions. One way to estimate this manufactured life is to use the mean-time-before-failure (MTBF) specification of a monitor or its components. The CRT MTBF specification dictates the amount of time the display must operate before it reaches its brightness 'half-life,' or the ability to produce 50% of its initial, maximum brightness. The MTBF value, generally provided in total hours per life of a monitor, is what most final manufacturers or assemblers of personal computer (PC) equipment, including monitor assemblers, typically specify for a component. To meet the specification, suppliers typically calculate the MTBF (a military-based specification) based on component data. Suppliers' test results are usually called the 'calculated' MTBF. The MTBF value also depends on which combination of power modes are used during testing, which is referred to as the 'duty cycle' and each supplier may use a different duty cycle to test their component.

Additionally, monitor assemblers will often perform their own testing, typically entitled 'demonstrated' MTBF. The testing includes sequences where the monitor is 'stressed' by quickly switching back and forth from an all black picture to an all white one, or quickly switching individual pixels either on and off or through multiple colors or black and white. Manufacturers typically find that their demonstrated MTBF is on the order of twice as long as the calculated MTBF (McConnaughey 1999, Douglas 1999). However, it should be noted that the demonstrated MTBF is not a real-time testing method, as the testing data is used in a complex equation to calculate that 'demonstrated' value.

From review of the information obtained on CRT-based monitors (see Attachment A, Table A2), it appears that the CRT itself is the limiting component, or the component that 99% of the time determines whether the entire monitor has reached its end-of-life. Thus, from the limited information that was obtained on CRTs, and the limited confidence that can be instilled in that data, an average of the two ranges obtained on the estimated lifetime of CRTs (10,000 - 15,000 hours) was used as the CRT manufactured lifetime (12,500 hours) (Goldwassar 1999, Douglas 1999).

For active matrix LCDs, the components that have the greatest potential to fail first are the display panel itself (including the liquid crystals and thin-film transistors), backlights, driver integrated circuit (IC) tabs, and other smaller components. The backlights and driver IC tabs can be field-replaced, thus their failure does not necessarily represent the end of the monitor's life. However, failure of the liquid crystals or transistors, which would require replacement of the display panel itself, would most likely mean that the monitor cannot be cost-effectively repaired. The MTBFs of all these components appear to have a broad range. For example, different backlight manufacturers reported from as few as 15,000 hours to as many as 50,000 hours (Douglas 1999, Tsuda 1999, VP150 1999). However, it appears that those components that are not field-replaceable (e.g., the LCD panel) have MTBFs in the range of 40,000 - 50,000 hours (Tsuda 1999, Young 1999). Thus in this TM, the amount of time an LCD monitor would operate during its manufactured life is assumed to be the average of the two non field-replaceable values, or 45,000 hours. In order for a monitor to operate for 45,000 hours, any major field-replaceable parts that have MTBFs less than 45,000 hours will need to accounted for in this LCA project. For example, assuming the backlights last on average 32,500 hours (the average of the values obtained for backlights), two would be needed for every panel during its lifetime. Therefore, in the final CDP LCA, the manufacturing of these type of components would need to be included in the inventory.

Little information is available on the duty cycles that component manufacturers use to test components. Thus, it is assumed that the average duty cycle utilized in testing components is 50% of the time tested in full-on mode and 50% in a lower power mode. Table 2 shows the values that are used in this TM for the hours per manufactured life for the CRT and LCD. The LCD manufactured life (45,000 hours) is 3.6 times greater than the CRT manufactured life (12,500 hours). Therefore, based on equivalent use periods, 3.6 CRTs would need to be manufactured for every single LCD.

Table 2. Manufactured Life Values

Monitor Type	Total Hours (hours/life)	Mode	Duty Cycle (% time spent in each mode during testing)	Hours per Mode (hours/life)
17" CRT	12,500	Full-on	50%	6,250
		Low	50%	6,250
15" LCD	45,000	Full-on	50%	22,500
		Low	50%	22,500

2.2.2 Scenario #2: Effective Life

The effective life scenario attempts to model the actual quantity of hours that an average monitor spends in each of the two primary power consumption modes (full-on and a lower power state) during its lifetime. The effective life of an average monitor is based on the following information:

- The proportion of computers that are used in an office environment versus a home environment, to account for different use rates in these two basic user environments;
- The amount of time in a year a typical monitor spends in full-on power mode and in a lower power-consuming mode for both office and home environments; and
- The number of years a typical monitor is used during its lifespan for both office and home environments, not including years in storage before a monitor is replaced or discarded (as it is not consuming power during storage).

Under this lifespan scenario, we assume there is no difference in the amount of time a CRT or LCD monitor is operating. That is, the hours per life for the effective life calculation is not technology-dependent. Therefore, the same set of hours-per-life values are used to calculate the kWhs used per effective lifetime for a CRT and an LCD. The remainder of this section discusses the data and methods used to calculate the final hours-per-life values used in the effective life scenario. In order to obtain these final values, we need to determine the percentage of office versus home environment users, the annual use operating patterns in the office and home environments (hours/year) within each power mode, and the number of years a monitor is in operation during life. The following three subsections address these data needs.

2.2.2.1 Percentages of Office- and Home-Environment Users

Home and office users of computer equipment do not follow the same use patterns. Thus, data are needed on the percent of users in each environment to determine the use pattern of an "average" computer monitor. The most recent data available for both home and office users are for 1997. The Computer Industry Almanac for 1997 reports an estimated 117 million total computers were in use in the United States in 1997 (CIA 1997). In addition, the 1997 Residential Energy Consumption Survey (RECS) reports that 43 million PCS were used in homes in 1997 (EIA 1999). Therefore, assuming the remaining non-household computer monitors are all in office environments, there would be approximately 74 million computers being used in office environments.

Note that an 'office' environment may be a school, hospital, or other commercial environment, and the computers they use may follow widely varying degrees of use. For example, computers (and thus monitors) in a school may only be used a few hours in a day, while hospitals might operate theirs nearly constantly. For this TM, it is assumed that on average, typical office use patterns (to be presented in Sect. 2.2.2.2) are representative of all non-home environment users.

The 1997 RECS also reported that 6% of the 43 million household computers were used to telecommute (EIA 1999), which equals approximately 2.6 million computers. The use pattern of a telecommuter is assumed to resemble more closely an office environment than a home environment; therefore, the number of office environment monitors is assumed to total 76.6 million. Therefore, for purposes of calculations in this TM, the percentage breakdown of office and home environment monitors in the United States is as follows:

- Office: (74 million + 2.6 million) / 117 million = 65%
- Home: (43 million - 2.6 million) / 117 million = 35%.

2.2.2.2 Operating Pattern (Average Hours in Use Per Year)

In order to determine the amount of electricity consumed during a monitor's effective life, we need to know the use operating patterns for both the office and home environments. The 'operating pattern' is defined here as the number of hours per year spent in each power mode. The average number of hours per mode per year will be the weighted average of the two user environments (i.e., 65% office, 35% home).

A literature search for computer monitor operating patterns was conducted for both office and home environments and a summary of literature reviewed is presented in Attachment A, Table A3. For data on office environment operating patterns, the most relevant and complete information found was from work performed by Lawrence Berkeley National Laboratory (LBNL) presented in a report entitled "Measured Energy Savings and Performance of Power-Managed Personal Computers and Monitors" (Nordman et al. 1996). Their definition of the standard operating pattern was based on earlier work performed by LBNL that studied electricity use by office equipment in commercial buildings, and referenced multiple studies on the use of office equipment, some having sample sizes as large as several hundred systems. Table 3 presents the standard office operating pattern for three different types of days (workday, weekend day and absence day), based on Nordman et al. (1996). Note that Nordman et al. "...first distinguish between weekdays and weekend days, with the latter including only Saturdays and Sundays. Then, any weekday which has less than half an hour of on-time (full-on or low power) is considered an absence day; the rest of the weekdays are workdays." Therefore, absence days may include some hours in operation. Also, some individuals may leave their computers on while out of the office, also resulting in hours in operation while the user is out of the office.

Table 3. Standard Office Operating Pattern[a]

Type of Day	Standard Office Operating Pattern			
	On			Off
	Full-on	Low	Total	
Workday (hr/day)	4.1	8.4	12.5	11.5
Weekend Day (hr/day)	0.0	4.8	4.8	19.2
Absence Day (hr/day)	0.0	4.8	4.8	19.2
Average Day[b] (hr/day)	2.3	6.9	9.2	14.8

Source: Adapted from Nordman et al. 1996, based on percentage of time in each mode.

[a] Based on the assumption that all monitors take advantage of low power modes.

[b] To calculate the average day, an average week is assumed to consist of 4 workdays, 2 weekend days, and 1 absence day per week. Average monitor usage per day weighs each average day by the number of each day type in a week.

Using the hours per day for the three basic day types, we created an average annual day for the purposes of eventually obtaining an annual average. To calculate the average day, we assumed that a typical week of computer use in the year contains 4 workdays, 2 weekend days, and 1 absence day. By including 1 absence day in the typical week, the calculation results in 52 days annually that are days of no active computer system use, and are intended to include the following: holidays, sick days, vacations, work travel and days when computers are not needed for work or are not in use in the office.

LBNL's operating patterns do not appear to take into account whether or not a monitor is actually taking advantage of the various power savings modes. In their 1996 study, Nordman et al. found that only one-third of the monitors were set up to recognize time-based indicators that power down a part of the monitor or part of the PC that sends information to the monitor. More recently, a representative of the EPA Energy Star Program estimated that approximately 90 - 95% of those monitors manufactured and sold in tandem with a PC in 1998 were pre-set up to take advantage of the multiple power consumption modes of the monitor, without any setup by the user (Fanara 1999). However, monitors are also sold individually, and no statistics were found on how many are sold that way and what percent of those are able to work with a PC's energy savings systems without assistance from the user. For the purposes of this TM, we assume that 90% of the monitors manufactured in 1998 and in use today are set up to recognize the power management signaling either from the monitor itself or from the PC to which they are connected. The lower end of the 90 - 95% range was chosen to recognize that monitors sold separately were not accounted for, and also, from an environmental impact perspective, it is conservative to assume a lower percent, which means less use of power saving features and greater energy consumption.

It should also be noted that this 90/10 split takes several assumptions into account, including but not limited to the percentage of users who alter or change their PC's and/or monitor's energy-saving settings, the percentage of users who know how to alter or change their PC's and/or monitor's energy-savings settings and the number of small-sized companies that build PC systems and whether or not they configure their systems to be able to take advantage of energy-savings settings 'out-of-the-box.' Because our confidence in this percentage split is not high, we will perform a sensitivity analysis of different percentage breakdowns of using low power modes versus not using them (50/50, 75/25, and 100/0; presented in Sect. 3.3).

This 90/10 split of using versus not using the power saving modes is implemented in the calculations by adjusting the average amount of hours per day a monitor spends in each mode for the effective life calculations (see Table 3). Thus, 10% of the value of each number in the 'Low' column of Table 3 was removed and added to the 'Full-on' value in that same row, to account for those that cannot go into a lower power-saving mode. Table 4 presents the adjusted figures for hours per day and presents the annual average values by multiplying the average day values by 365 days. The average day is calculated in Table 4 the same way it was calculated in Table 3.

Table 4. Adjusted Office Operating Pattern[a]

Type of Day	Adjusted Office Operating Pattern			
	On			Off
	Full-on	Low	Total	
Workday (hr/day)	4.9	7.6	12.5	11.5
Weekend Day (hr/day)	0.48	4.3	4.8	19.2
Absence Day (hr/day)	0.48	4.3	4.8	19.2
Average Day[b] (hr/day)	3.0	6.2	9.2	14.8
Annual Average (hr/yr)	**1,095**	**2,263**	**3,358**	**5,402**
Percent on time spent in each mode	33%	67%	100%	-----

[a] Values in Table 3 have been adjusted based on the assumption that 90% of monitors can take advantage of low power modes. Therefore, 10% of the hours in low mode in Table 4 were added to the full-on column and subtracted from the low column in this table.

[b] To calculate the average day, an average week is assumed to consist of 4 workdays, 2 weekend days, and 1 absence day per week. Average monitor usage per day weighs each average day by the number of each day type in a week.

For the home environment operating patterns, the most relevant and complete information was found in the RECS report (EIA 1999). The survey contained data on the use of computers in the home and how many hours per week the users have their computer on, without distinguishing power mode. Table 5 reveals the information obtained from the RECS report and breaks that data down to calculate a daily average and then an annual average operating pattern (i.e., the total number of hours of on time in one year).

Table 5. RECS Home Operating Pattern Breakdown

Use Frequency Category	U.S. Households with Computers (EIA 1999)		Average Hours in Use for Each Category	Average Household Use[a]
	(millions of households)	(% of households)	(hours/week)	(hours/week)
Less than 2 hours per week	8.2	23.0%	1	0.2
2 to 15 hours per week	17.4	48.9%	8.5	4.2
16 to 40 hours per week	6.7	18.8%	28	5.3
On all the time	3.3	9.3%	168	15.6
Totals	35.6	100.0%	-----	25.2
Daily Average (hours per day)				3.6
Annual Average (hours per year)				**1,315**

Note: Totals may not be additive due to independent rounding.

[a] These values are the product of the fraction of households in each category and the average hours per week in each category.

Data on the amount of time a home-environment monitor is in full-on versus a lower power mode was not provided in the RECS, nor was such data found elsewhere. Thus, lacking any other information, we have chosen to use the percentage breakdown found in the office-environment data for the home-environment data in this TM (see the bottom row of Table 4). These percentages are applied to the total 1,315 hours/year for home-environment use to estimate the amount of time in each mode. In addition, the 90/10 split of equipment that can/cannot go into lower power saving modes was applied to these values to determine the actual expected number of hours per year per mode for the home environment. In Table 6, the hours per year values for each power mode are shown. In order to determine these hours spent in each mode, the total number of hours spent on annually (1,315 hours/year) was first split by the 90/10 factor into equipment that can and cannot save energy categories. Then, the resulting 1,183 hours/year was split by the office-environment data on the percent of time spent in each mode, resulting in 390 hours annually in full-on mode and 793 hours annually in a lower power mode. The remaining 132 hours/year that cannot go into an energy saving mode, was included in the 'Full-on' row. The two values for each row are then added to obtain the total hours annually in a home environment that a monitor would spend in each power mode.

Lastly, Table 7 shows the final values obtained for the effective life calculations, as presented in this section, for hours per year per mode for office- and home-environment users.

Table 6. Splitting the Home Operating Pattern Data into the Two Power Modes

Power Mode	Percent of Time in Each Mode (from office- environment data)	Time Operating in Each Mode (hours/year)		
		90% That Can Save Energy	10% That Cannot Save Energy	Total
Full-on	33%	390	132	**522**
Low	67%	793	0	**793**
Total	100%	1,183	132	1,315

Table 7. Summary of Operating Patterns for Effective Life Calculations

User Environment	Time Operating in Each Environment (hours/year)		
	Full-On Power Mode	Low Power Mode	Total
Office	1,095	2,263	3,358
Home	522	793	1,315

2.2.2.3 Average Years Per Life

The third set of values required for the calculation of hours per effective life is the number of years of use in the life of a monitor. The number of years per effective life, multiplied by the operating patterns in hours per year (presented in Table 7), will result in the hours per effective life.

A monitor may be reused in multiple 'lives' before reaching its end-of-life. The end-of-life is defined as the point at which the monitor is no longer used for its intended purpose in the physical form in which it was originally manufactured. End-of-life options include indefinite storage (in which case it is not reused after storage), de-manufacturing, recycling, or disposal. A monitor may be stored before being reused; however, this storage time will not affect our use calculations since no electricity is required to operate the monitor during this storage. After its first life as used by the original owner, a monitor might be used by different people and with different PC systems in subsequent lives.

For data on the number of years of use that are in a monitor's lifetime, several sources of information were reviewed. Two particular studies provided relevant data on the number of years per life (Matthews et al. 1997, NSC 1999). A study by Matthews et al. (1997), which was an update to a study originally performed in 1991, concluded that after a first life of 5 years, approximately 45% of all PC systems are reused, while the remaining 55% either go directly to recycling or landfilling (10%) or are stored and then recycled or landfilled (45%). Their study only addressed PC systems as a whole and did not break down the lifetimes of individual components. Additionally, they concluded that the period over which the systems are reused is 3 years.

In a recently completed study for the National Safety Council (NSC 1999), researchers interviewed more than 30 major manufacturers and resellers of CRT computer monitors and other computer components. NSC found that a CRT monitor's first life lasts approximately 4 years, while the total lifespan is on the order of 6 - 7 years. Since the NSC study contains results that pertain specifically to monitors, and provides the most recent data, its results are used in this TM. The values that are used for calculations in this section are 4 years for the first life of use, and 2.5 years for the second and subsequent lives of use. The operating pattern for monitors in all the years over its effective life (6.5 years) are assumed to be the same as presented in Sect. 2.2.2.2 (Table 7). However, in the lives subsequent to the first life, the hours per year values are reduced by the fraction of monitors assumed to be reused. Matthews et al. (1997) estimated that 45% of PCS are reused after a first life; thus, the effective life operating pattern values in years of life after the first life are 45% of the values in the first life (which were presented in Table 7).

While the NSC data singled out CRT monitors in their lifespan estimates, they did not single out desktop LCD monitors. Their data did contain estimates of a 'Notebook PC,' which were 2 - 3 years for the first life and 1 - 2 years for the remaining lives, however, we expect that desktop LCD monitors will more closely mirror the lifetime estimates of a desktop CRT monitor than that of a notebook PC. Consequently, it was assumed that LCD desktop monitors also spend 4 years in their first life and 2.5 years in their subsequent lives. Additionally, the NSC document did not attempt to separate those computer systems or monitors that are used in an office versus a home environment. Thus, it was assumed that the same years per life are realized for office and home environments.

2.2.2.4 Summary of Effective Life Values (Hours per Life)

Data presented throughout Sect. 2.2.2 that are needed to estimate the hours per effective life, are shown in Table 8. The values for hours per year per power mode, calculated in Sect. 2.2.2.2 and presented in Table 7 are assumed to be the operating pattern throughout the first life (first four years). In the remaining lives, the annual operating hours decreases to 45% of the hours in operation during each year in the first life, with the remaining lives lasting a total of 2.5 years (see Sect. 2.2.2.3). Table 8 also presents the total hours per effective life per mode, based on percentage in office and home environments. These values are in bold in Table 8 (4,586 and 8,961 hrs per effective life) and will be used with the energy use rates per mode (presented in Sect. 2.1, Table 1), to calculate the total energy consumption per effective life for each monitor type.

Table 8. Effective Life Values

User Environment	Power Mode	First Life (4 years)		Remaining Lives (2.5 years)		Model Totals[b] (hr/effective life)
		Operating Pattern (hr/yr)	Total (hr/4 yrs)	Operating Pattern (hr/yr)[a]	Total (hrs/2.5 yrs)	
OFFICE (65%)	Full-on	1,095	4,380	493	1,233	5,613
	Low	2,263	9,052	1,018	2,545	11,597
HOME (35%)	Full-on	522	2,088	235	588	2,676
	Low	793	3,172	357	893	4,065
WEIGHTED AVERAGE[c]	Full-on	---	---	---	---	**4,585**
	Low	---	---	---	---	**8,961**

[a] The remaining lives operating pattern is 45% of first life operating pattern, based on 45% of monitors that are reused (Matthews et al. 1997).

[b] Modal totals calculated as [(Total for first 4 years) + (Total for remaining 2.5 years)].

[c] The weighted averages shown for full-on and low power modes are based on the assumption that 65% of users operate in an office environment and 35% operate in a home environment.

3. PRELIMINARY RESULTS

In order to calculate the total kWhs consumed per manufactured life and effective life, values from Sects. 2.1 and 2.2 were combined as shown in Tables 9A and 9B. First, the energy use rates (kW) were multiplied by the lifespans (hours per life) for each mode and each monitor type. They were then summed for the two power modes to obtain a total kWh/life for each monitor type. In an LCA, comparisons are made based on functional equivalency. Therefore, if one monitor will operate for a longer period of time than another, as in the manufactured life scenario, overall life-cycle impacts should be based on an equivalent use. Thus, because the manufactured life of an LCD is 3.6 times greater than a CRT (see Sect. 2.2.1), in the final analysis, the CRT manufacturing process inventories must be multiplied by 3.6 to retain a functionally equivalent basis for the CRT and LCD monitor comparison. Since the effective life calculation is not technology-dependent, both monitor types operate for the same number of hours in the effective life (see Table 8) and thus they are considered functionally equivalent and no modification to the overall life-cycle analysis is necessary.

Table 9A. Manufactured Life (ML) Electricity Consumption

Monitor Type	Power Mode	Energy Use Rate (kW)	ML Calculated Lifespan (hours/life)	ML Energy Consumption (kWh/life)
17" CRT	Full-on	0.113	6,250	706
	Low	0.013	6,250	81
	Total	----	12,500	787
15"LCD	Full-on	0.040	22,500	900
	Low	0.006	22,500	135
	Total	----	45,000	1,035

Table 9B. Effective Life (EL) Electricity Consumption

Monitor Type	Power Mode	Energy Use Rate (kW)	EL Calculated Lifespan (hours/life)	EL Energy Consumption (kWh/life)
17" CRT	Full-on	0.113	4,585	518
	Low	0.013	8,961	116
	Total	----	13,547	634
15"LCD	Full-on	0.040	4,585	183
	Low	0.006	8,961	54
	Total	----	13,547	237

3.1 Comparing Lifespans: Manufactured Life to Effective Life

Since the energy use rates are the same across both lifespan scenarios for CRTs and LCDs, we can compare the calculated lifespans of the manufactured and effective lives (hours per life). For the CRT monitor, the manufactured life total hours are 12,500 versus the effective life total of 13,547. While this does seem to suggest that a CRT can be used longer than is physically possible, what this brings out is the lower confidence we have in these numbers and some of their supporting values, with less confidence in the manufactured life data. Assumptions were required several times that could bias these numbers in either direction, however it is thought that most likely the manufactured life estimate is low based on the other estimates for the overall CRT monitor (see Attachment A, Table A2). However, there was no sound basis for assuming a lower value and thus the above hours per life values were used. It should also be stated that while these numbers are different, they are within an 8% error range of one another, and can be taken to be a near 1:1 ratio, indicating a similar potential lifespan.

For LCDs, the comparison across lifespan scenarios looks more like what one would expect, with the manufactured life value of 45,000 hours per life being much greater than the effective life value of 13,547 hours per life. The effective life value reflects the assumption that a user's use habits are not technology-dependent, and would seem to reveal that LCDs are not being used as long as they can physically be (less than a third as long).

The difference between the manufactured and effective lives are important when evaluating all the life-cycle stages for a particular monitor type. If the manufactured life is significantly greater than the effective life, the use stage will have greater impacts, as compared to other life-cycle stages. Therefore, it is important to focus on the lifetime scenario that is most realistic, while still recognizing the potential impacts from another feasible lifespan scenario.

In the final LCA for this project, we will use the effective life as the primary basis for the use stage inventory due to the fact that the effective life data are attempting to obtain a more realistic value for kWhs consumed per lifetime, and that we currently have greater confidence in those data versus the manufactured life data. The manufactured life data will be used to discuss potential differences in the use stage impacts based on this alternative lifetime scenario.

3.2 Sensitivity Analysis

Finally, in an effort to provide some sensitivity analysis to the final values, the assumption used in the effective life calculation that 10% of the computers manufactured in 1998 and currently in use are not able to take advantage of lower power-saving modes (a 90/10 split) was adjusted to three different splits, with all the other assumptions and calculations kept unchanged (50/50, 75/25 and 100/0, respectively in each case those that are able to go into power saving modes and those that are not). Table 10 presents the results of the sensitivity analysis for each of the four power-saving functionality scenarios.

Table 10. Sensitivity Analysis of Effective Life Results

Monitor Type	**Power Mode**		**% that Can / % that Cannot Take Advantage of Power-Saving Features**			
			50/50	75/25	**90/10**	100/0
17" CRT	Full-on	(kWh/life)	969	689	**518**	408
	Low		64	97	**116**	129
	Total		1,033	786	**634**	537
15" LCD	Full-on	(kWh/life)	343	244	**183**	145
	Low		30	45	**54**	60
	Total		373	289	**237**	205

The data in Table 10 reveal that the final electrical energy consumption values for the CRT would increase by 63% with a 50/50 split and decrease by 15% with a 100/0 split (from the 90/10 split assumption). Similarly for the LCD, the results would increase by 57% or decrease by 14%. Varying the use of power-saving features results in variations in the total amount of energy consumed for LCDs and CRTs, but does not vary the ratio of LCD to CRT energy use. Therefore, these variations will affect the magnitude of the use stage impacts for effective life scenarios when compared to other life-cycle stages, but will not affect the comparison of LCD to CRT. Additional sensitivity analyses are available in Socolof et al. (2000).

4. DATA SOURCES AND QUALITY

Source and quality information for the data utilized in this TM are detailed in Table 11. Four categories of data quality ratings were assigned: excellent, average, poor, and unknown. In general, data assigned higher quality ratings were directly measured and represent 1998 data. As data required more calculation or estimation, or were found from a previous year, the data quality rating was reduced.

In general, the overall level of data quality is between average and excellent. However, a distinct difference can be seen in the average data quality ratings given to manufactured life data (average) and the effective life data (excellent). This infers that greater confidence can be placed in the effective life data than in the manufactured life data. Additionally, the energy use rate data appears to be of average.

Table 11. Data Sources and Quality Information for the Use Life-Span Stage TM

Data	Data Source/References	Data Source Comments	Data Quality [a]	Data Quality Explanation
ENERGY USE RATE				
Various monitor manufacturer's energy use rate data	Web sites in most cases; E-mail from manufacturer in remaining cases.	It was assumed that the data provided by manufacturers on the Web sites were high-quality data in that the data should be measured and directly applicable to the equipment for which the information is provided. However, the search for information did not separate information obtained by performance level of the monitors.	Average	It was not possible to determine in what year each individual monitor was manufactured; however, it is assumed that each monitor is on the order of several months to 2 years old when promoted for sale. Thus it is estimated that the average date of the information obtained is probably relative to approximately 1997. Adding that the data was not sorted by performance level, this data was given a data quality rating of Average.
MANUFACTURED LIFE (Only those sources utilized to derive values are discussed here.)				
Discussion of CRT lifespan	McConnaughey 1999	Professional opinion provides good insights into potential ranges for certain components, however is still an opinion and not scientific data.	Average	As a computer manufacturing company employee, it is expected that they are a quality source of information on this topic; however, information is still an opinion and not scientific data, thus an Average data quality rating was assigned.
Discussion of CRT and LCD lifespans	Douglas 1999	See above comment.	Average	See above comment.
Discussion of LCD lifespan	Ritsko 1999	See above comment.	Average	See above comment.
Discussion of LCD lifespan	Tsuda 1999	See above comment.	Average	See above comment.
Discussion of CRT and LCD lifespans	Young 1999	See above comment.	Average	As the leader of a group that closely follows the trends in the LCD market and produces monthly reports on technology and market trends, it is expected that they are a quality source of information on this topic, however, information is still an opinion and not scientific data, thus an Average data quality rating was used.
17" CRT monitor specifications sheet	VP150 1998	As technical data on one specific CRT monitor the information is expected to be at least testing quality data or better.	Excellent	As direct manufacturer information applicable to 1998, this data is given an Excellent data quality rating.

Table 11. Data Sources and Quality Information for the Use Life-Span Stage TM

Data	Data Source/References	Data Source Comments	Data Quality [a]	Data Quality Explanation
EFFECTIVE LIFE				
Number of PCS in use in the U.S.	CIA 1997	Authors have much experience in obtaining and collecting computer statistics in U.S. and other countries; have been publishing this book since 1986.	Excellent	From review of the available information on the authors and data sources for the data that go into the Computer Industry Almanac, the data quality rating of Excellent is given. Even though data is from 1996, the authors used that data and recent trends information to predict 1997 values, and it is expected that the 1997 values are not significantly different than the 1998 values.
Percent of PCS in the home that are used in an office-like environment	RECS 1999	"The Residential Energy Consumption Survey provides national...information about U.S. households and their energy usage. The 1997 survey collected data from a statistically selected sample of 5,902 households that were interviewed in their homes."	Excellent	While these data are 1997 data, it is assumed that the energy usage patterns of home dwellers has not changed significantly between 1997 and 1998.
Number of PCs in use in the home	RECS 1999	See previous comment on RECS.	Excellent	See previous comment on RECS.
Office PC use pattern	Nordman 1996	Used multiple sources of previous data covering many samples of PCs, as well as their own research, to derive their equipment usage pattern.	Average	Their data was manipulated slightly to account for a greater number of affectors on typical usage patterns. By manipulating their data the data quality is slightly reduced, thus data quality rating of Average was assigned.
Home PC use pattern	RECS 1999	See previous comment on RECS.	Excellent	See previous comment on RECS.
Number of years PCS are used in 1st life and 2nd and subsequent lives	NSC 1999	"This study presents the results of the first large-scale survey (which covered the years 1997 and 1998) and analysis of end-of-life electronic product recycling and reuse in the U.S. Data were collected from 123 firms."	Excellent	Due to the applicable time frame and the body of companies who participated, these data were given data quality rating of Excellent.
Number of PCS that are used in their 2nd and subsequent lives	Matthews 1997	Performed a study in 1991, watched as the computer market changed over l6 years, then reviewed the original study finding the weak spots there. Reperformed study in 1997 making learned changes to the analysis format and using newer data (1997).	Average	While changes were made to the second study as weaker parts of previous study were uncovered, still extrapolated individual recycling firm data to obtain some base data for their estimates. While data is primarily relative to the 1997 time frame, which is very close to our year of interest of 1998, still chose data quality rating of Average due to amount of data manipulation that was required to obtain values.

[a] The data were assigned to one of the following four data quality categories: Excellent, Average, Poor, and Unknown.

5. LIMITATIONS & UNCERTAINTIES

This section is subdivided into three subsections, with each addressing the limitations and uncertainties of the energy use rate, manufactured life and effective life calculations.

5.1 Energy Use Rate

The energy use rates utilized in this TM were not from a systematic study of the energy use rates of all applicable monitors, only those for which information was located on the World Wide Web. Also, it was difficult to pinpoint the exact date from which much of the data came (see the data quality explanation of those data in Table 11). To successfully and effectively take advantage of the data on each of the three lower power modes, it would have been necessary to have hours per life data for each of the three power modes as well as for manufactured and effective lives. No sources of data, for either lifespan, separated hours per life estimates into three distinct low power modes. While this does induce error, it is expected that averaging those categories to estimate the total amount of time that a monitor spends in all the lower power modes would only have a minor effect on the final energy use rate values. The effect of averaging these categories probably overestimates the total amount of electrical energy that is consumed during lower-power mode use. This is so because those that are left on for significant periods of time (overnight, over a two-day weekend, or over an extended stay) most likely are reaching their lowest power mode within the first 1 - 2 hours and staying there for the duration of the away time.

When this information was obtained from the World Wide Web, the data were simply separated into one of the two large categories of 17" CRT and 15" LCD desktop monitors. Thus, since it is fairly common that one type of monitor manufacturer will make several different models with varying performance characteristics with one size range, a limitation of this data is that it is not sorted by performance characteristics. Additionally, the data obtained from these Web sites are most likely maximums, and were stated as such in several cases. However, if some manufacturers did not state that the reported values were maximums, then our averages are slightly high.

5.2 Manufactured Life

Only a very limited amount of information was obtained with which to make the assumptions made in this TM about manufactured life. The primary uncertainties relate not only to the assumption of the MTBF lifespan of the monitors, but also to the testing duty cycle which was completely estimated. With the lack of any high quality data, the confidence in the manufactured life calculations is low.

5.3 Effective Life

Several assumptions were made to calculate the effective life data set. They include the following:

- 90% of monitors are able to go into lower power consumption modes;
- Atypical workplace computers (e.g., those used in hospitals and schools) balance to fit the office-like use environment established in this TM;
- Atypical (average) office use environment week consists of 4 'weekdays,' 1 'absence day' and 2 'weekend days,' where the absence day accounts for holidays, sick days, work-related travel days, vacations and days of no use of the work computer;
- The percent of time a monitor spends in full-on versus lower power modes in a home environment is the same as in an office environment;
- Used the office environment split of the total on time that equipment spends in full-on versus a lower power mode for the home environment split of total on time;
- LCD desktop monitor lifetimes are more similar to desktop CRT monitors than notebook PC displays; and
- The same number of years of use per life exist for office and home environments.

While the above assumptions do introduce error, the magnitude of the error is unknown. Some assumptions may have a greater effect on the final values than others. For example, it may be concluded that the assumption that the average office PC system usage pattern is fairly accurate, while the assumption about atypical workplace computers could potentially contain significant error in either direction of the assumed value. Table 10 showed the effects on the results from varying the use of energy saving features. If several of these assumptions are biased in the same direction (either all underestimating or overestimating the results), then the effective life results have the potential to be significantly under or overestimated.

6. DISCUSSION AND CONCLUSIONS

The information presented in this TM are used to calculate the environmental burdens generated during the use life-cycle stage of the monitors. That information is then compared to those burdens that occur in the other four life-cycle stages of materials extraction, materials processing, manufacturing and end-of-life. To calculate the environmental burdens from the use life-cycle stage, the results of this TM -- the values for each monitor's electrical energy consumption over its lifetime in kWhs -- are multiplied by each of the inputs and outputs from the electricity generation process.

ACRONYMS & ABBREVIATIONS

CDP	Computer Display Project
CRT	Cathode ray tube
DfE	Design for the Environment
DOE	Department of Energy
DPMS	Display Power Management Signaling
EIA	Energy Information Administration
IC	Integrated circuit
kW	Kilowatt
kWh	Kilowatthour
LBNL	Lawrence Berkeley National Laboratory
LCA	Life-cycle assessment
LCD	Liquid crystal display
LCI	Life-cycle inventory
MTBF	Mean-time-before-failure
PC	Personal computer
RECS	Residential Energy Consumption Survey
TM	Technical memorandum
W	Watt

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Attachment A to Appendix H
Supporting Tables

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Table A-1. CRT & LCD Monitor Energy Consumption Values

CRTs	Company	Model	Size (inches)	VIS [a] (inches)	Energy Consumption (watts)								Comments/Assumptions
						Full-on		Standby [b]		Suspend		Act. Off	
	Apple	Color Sync	17.0	16.1	<	125	<	60			<	5	
		Multiple Scan 720	17.0	16.0	<	120					<	5	
	Compaq (& Digital)	V75	17.0	16.0	<	115							
		P75	17.0	16.0	<	115							
		71C	17.0	15.7	<	110	<	15	<	15	<	8	
		71P	17.0	16.0	<	120	<	15	<	15	<	8	
	EIZO	FlexScan TX-C7	17.0	15.8		140	<	12			<	5	
		FlexScan FX-C5	17.0	15.6		95	<	10			<	5	
	Hitachi	SuperScan Elite 641	17.0	15.9	<	135	<	15			<	8	
		SuperScan Pro 620	17.0	15.9	<	115	<	15			<	8	
	LG	Studioworks 74i	17.0	16.0		100		15				8	
		77M	17.0	15.9	<	130						5	
	MAG	XJ707	17.0		<	120	<	15	<	15	<	8	
		XJ717	17.0		<	120	<	10	<	10	<	5	
		XJ700T	17.0		<	120	<	15	<	15	<	5	
		DJ707 AV	17.0		<	120	<	15	<	15	<	8	
	Mitsubishi	Diamond 87TXM	17.0	16.0		120	<	100	<	15	<	8	Due to the significant difference in the Mitsubishi "Standby" power mode category values and those supplied by other manufacturers, these values were omitted from the average "Standby" power mode calculation.
		Diamond Pro 700	17.0	16.0		110	<	95	<	15			
		Diamond Plus 72	17.0	16.0		105	<	90	<	15			
		Diamond Plus 70	17.0	16.0		95	<	80	<	15			
	NEC	Multisyne A700	17.0	15.6		85					<	8	NEC representative contacted through support phone number stated that the energy saver mode power consumption is usually rated at 8 watts or less for all monitors. Due to range similarities, assumed that this rating falls into the 'Active Off' power mode consumption category.
		Multisync E700	17.0	15.6		95					<	8	
		Multisync M700	17.0	15.6		120					<	8	
		Multisync P750	17.0	15.6		125					<	8	
	Panasonic	PanaSync S17	17.0	16.0		110	<	15	<	15	<	8	The company Web site stated "typical" or "nominal" for the associated power consumption values.
		PanaMedia PM17	17.0	16.0		130	<	20	<	20	<	8	
	Philips	107S	17.0	15.9		80					<	5	
		107MB	17.0	15.9		85					<	5	
		107B	17.0	16.0		85					<	5	
	Sony	CPD-200ES	17.0	16.0	<	120	<	15			<	8	
		CPD-200GS	17.0	16.0	<	120	<	15			<	8	
	Toshiba	TekBright 700P	17.0	15.8		100							Web site indicated 110 watts maximum, 100 watts nominal.
	Viewsonic	PT775	17.0	16.0		130							The company Web site stated "typical" or "nominal" for the associated power consumption values.
		EA771B	17.0	16.0		130							
		G773	17.0	16.0	<	110							
				CRT Averages:		113.00		17.31		15.00		6.85	
				Standard deviations:		15.35		11.61		2.13		1.49	
						CRT Standby, Suspend and Active Off average:				13.05			
						Standard deviation:				5.08			

Table A1. CRT & LCD Monitor Energy Consumption Values (continued)

LCDs	Company	Model	Size/VIS [a] (inches)	Energy Consumption (watts)								Comments/Assumptions
					Full-on		Standby [b]		Suspend		Act. Off	
	Apple	Studio Display	15.1	<	35		10				8	
	Batron	FM-17TX11	15.0		35							
	Compaq	TFT500	15.0	<	50							
	Digital	51P	15.0		40		8				8	Received data through phone support (800.354.9000).
	EIZO	FlexScan L34	15.0		30	<	15			<	5	
	LG	500LC	15.1		40		5				5	
	Mitsubishi	LCD50	15.0		45		8				8	
	NEC	LCD1510	15.0		50		8					
	Samsung	500TFT	15.0	<	45					<	5	Received data via E-mail. The Samsung E-mail received stated that in full power on mode, the power consumption was a maximum of 45 watts and a nominal of 36 watts.
	Sharp	Super-V	15.0		36						2	
	Sony	CDP-L150	15.0	<	35	<	4			<	4	
	Viewsonic	VP150	15.0		35		2.6				2.6	Received data via E-mail. Full-on category value noted as “typical.”
LCD Averages:					39.67		7.58				5.29	
Standard deviations:					6.50		3.89				2.29	
LCD Standby, Suspend and Active Off average:							6.44					
Standard deviation:							3.09					

[a] VIS = Viewable Image Size.
[b] The ‘Standby’ energy consumption category includes listings noted as “Power Save Mode 1.”

Notes: The energy consumption data shown in this table were taken from the Web sites of the retailers during 1998 unless otherwise noted. The energy consumption ratings for these monitors showed various information. Sometimes the less than (<) symbol preceeded some or all values, sometimes the addendum note ‘maximum’ was included and sometimes only the values themselves were reported.

Table A2. CRT and LCD Monitor MTBF Values & Manufactured Life Comments

MTBF Values for the:			Source	Comments from Sources
CRT Monitor	CRT Only	LCD Monitor		
(thousand hours)				
30-60	10-15		Goldwasser 1999	- "Most manufacturers will quote an MTBF of somewhere in the 30,000 to 60,000 hour range, EXCLUSIVE of the CRT. The typical CRT, without an extended-life cathode, is usually good for 10,000 to 15,000 hours before it reaches half its initial brightness." - "CRT Life: The life of a monitor is determined by the life of the CRT. The CRT is by far the most expensive single part and it is usually not worth repairing a monitor in which the CRT requires replacement. The brightness half-life of a CRT is usually about 10-15k hours of on time independent of what is being displayed on the screen." - "In a CRT monitor, the shortest-lived component BY FAR is the CRT itself, and it ages (more properly, the cathode is aging) as long as the heater is on and the tube is under bias (i.e., receiving voltage). Most monitors don't get around to turning the heater down or off until they enter the Display Power Management Signaling (DPMS) "suspend" or "off" modes. (And no, screen-savers do NOT help here - the tube is still on and the cathode is aging.) - "In a CRT display, the CRT itself is usually the limiting factor in this (life), and in THAT specific case we usually speak of "mean time to half-bright" instead, since it's rare for a CRT to simply die once it's past its early operating life. Mean-time-to-half-bright is just what it says: how long, on average, can you operate the tube before the brightness drops to half its initial level for a given set of operating conditions. (Brightness is ALWAYS slow(ly) decreasing throughout the tube's life, due to the aging of the cathode and the phosphor.) For most tubes with standard cathodes, this will be in the neighborhood of 10,000-15,000 hours."
50-100			McConnaughey 1999	Mr. McConnaughey stated that each of the subsystems of a monitor has different components that must meet different MTBF (Mean Time Before Failure) testing. Before testing, manufacturers typically calculate what the expected MTBF should be, and then test it to obtain the demonstrated MTBF. A rule of thumb is 50,000 hours calculated and over 100,000 hours demonstrated.
75			Philips 1998	"MTBF: >75,000 h (according to MIL-HDBK 217E) at 25 degrees Celsius (excl. CRT)"
50			Maginnovision 1998	"The average MTBF (Mean Time Before Failure) for MAG InnoVision monitors is 50,000 hours, excluding the CRT."
86			PlanetMac 1999	Mean Time Before Failure = 86,000 hours.
80	10-15	(50-backlights)	Douglas 1999	Phone conversation with David Douglas at Dell in Texas. David took plenty of time to discuss MTBF, and relayed that while Dell requires suppliers of CRT components (EXCLUDING THE CRT) to meet a MTBF specification of 80,000 hours, Dell performs testing (a type of 'demonstrated' MTBF - is a torture test) that typically yields at least twice the specification value in total time the equipment can operate. With that said, David then agreed that the CRT is the component that determines a CRT-based monitor's lifetime and that it is rare that a CRT lasts anywhere near that long, with most failing in the 10,000-15,000 hours/life range. David noted that CRT semiconductors are the next component that can fail. In LCDs, components containing silicon are most likely to fail first, with most manufacturers quoting backlights that will last 50,000 hours.
			Koch 1996	Didn't supply any other data other than that they assumed 10,000 hours as the lifespan of the LCD monitor.

Table A2. CRT and LCD Monitor MTBF Values & Manufactured Life Comments

MTBF Values for the:			Source	Comments from Sources
CRT Monitor	CRT Only	LCD Monitor		
(thousand hours)				
		50: 15 for backlights	Tsuda 1999	Mr. Tsuda (Apple Computers) stated that the specs don't typically change for different size LCD monitors for specific components. MTBFs for flat panel displays are about 50,000 hours, except for the backlights which have MTBFs of about 15,000 hours. Most components can be fixed or replaced easily by trained technicians. Testing they perform is with maximum brightness, full white pattern; worst pattern for LCD is 1 pixel On/1 pixel Off.
		40	Young 1999	Through a conversation with Ross Young, Ross spoke of a note a gentlemen had sent him wherein they assumed a useful life for an LCD of 84 months and a CRT of 36 months. Additionally, it was noted that an LCD panel was assumed to have a life of around 40,000 hours, and this could increase if DPMS screen savers were implemented.
		(50- backlights)	VP150 1998	Light Source: long life, 50,000 hrs. (typ)
		(10-40 - silicon driver chips)	Ritsko 1999	Liquid crystals and thin-film transistors (TFTs) don't typically wear out, yet the amorphous silicon transistors are less reliable than the single transistors. Also, the driver (silicon) chips could be an item that might show wear, however, the chips that go in FPDs are fairly typical, use low voltages and should run between 10,000 and 40,000 hours.

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Table A3. Use Stage Data Information, Estimates and Assumptions from Reviewed Sources

Author	Operating Circumstances/Lifetime Data			Power Consumption rate/Power Management
Jung 1999	"The estimated useful life for a PC in a business environment is only two to three years, while home computers users typically use their equipment for three to five years."			
Matthews 1997	First research group to attempt to model the time effort factor of storage of computer equipment during the Use life-cycle stage. In doing so, came up with a breakdown of options (shown below). Additionally, after calculating the destinations and percent averages from their numbers, 26% of end-of-life equipment is landfilled after 8.06 years in use and storage (and possible reuse), and 74% is recycled after 8.49 years in use, storage and possible reuse.			
	Initial lifetime of PCs: 5 years	% at end of 1st life reused:	45%	
		% at end of 1st life recycled:	5%	
		% at end of 1st life stockpiled:	45%	
		% at end of 1st life landfilled:	5%	
	Lifetime of reused PC: 3 years	% reused recycled:	40%	
		% reused stockpiled:	50%	
		% reused landfilled:	10%	
	Lifetime of stockpiled PC: 3 years	% stored recycled:	75%	
		% stored landfilled:	25%	
	Calculating through the above numbers for 100 computers reveals the following breakdown:	(# out of 100)	(time)	
	Landfilled after 5 years	5	25	
	Landfilled after 8 years	15.5	124	
	Landfilled after 11 years	5.5	60.5	
	Landfilled totals	26	209.5	
	Average numbers of years to landfilling of PC:		8.06	
	Recycled after 5 years	5	25	
	Recycled after 8 years	52	416	
	Recycled after 11 years	17	187	
	Recycled totals	74	628	
	Average number of years to recycling of PC:		8.49	
NSC 1999	"The lifespan estimates used in this study were developed through interviews with more than 30 major manufacturers and resellers. Major computer manufacturers were consulted to determine the lifespan of electronic equipment. Because manufacturers know when their products were fabricated and many also have recycling facilities, these firms are qualified to make an educated lifespan estimate. Resellers and nonprofit organizations were asked to estimate the reusable life or 'second life' by product and processor type. These inputs were used to develop estimates of the first life (the amount of time a product is useful to its original owner) and the total lifespan (period from manufacturers to disposal) for each electronic product."			
		First life	Total life	
	CRT computer	4	6-7	
	Notebook PC	2-3	4	

Table A3. Use Stage Data Information, Estimates and Assumptions from Reviewed Sources

Author	Operating Circumstances/Lifetime Data			Power Consumption rate/Power Management
Chan 1997	This class report from a University of Toronto group of 4 people contains several worthwhile pieces of information. The data presented comprise responses from 180 people (130 administrative, teaching and research staff and 50 residents). Class covered 1996/1997; data were gathered during the class.			
	Hours of computer use by staff	< 4 hrs/dy	7%	
		5-8 hrs/dy	52%	
		9 or > hrs/dy	41%	
	Percentage of computers with energy-saving features installed or activated	have features	52%	
		no knowledge of features	35%	
		don't have features installed or	13%	
	Respondents who update their knowledge of computer energy-saving features	do not	75%	
		do	19%	
		no response	6%	
	Idling time of office and residential computers that are turned on	less than 2 hrs	66%	
		3-5 hrs.	22%	
		6 hrs or more	12%	
	Respondents who turn off their computer when they are away for a period (period is 45 min. or longer)	never do	70%	
		sometimes do	21%	
		always do	7%	
		no control	25%	
	Staff who shut down their computers at the end of the day	always	70%	
		sometimes	9%	
		never	19%	
		no control	2%	
	Percent of office computers left on during weekends	always	22%	
		sometimes	8%	
		never	67%	
		no control/no response	3%	
EIA 1997	The EIA's results from the Residential Energy Consumption Survey (RECS) provides some good data on			
	Hours PC turned on each week	less than 2 hrs	8.2	
		2 to 15 hrs	17.4	
		16 to 40 hrs	6.7	
		On all the time	3.3	
	How PC is used	15 hrs a week or less	26.5	
		16 hrs a week or more	10.0	
		Personal use only	4.8	

Table A3. Use Stage Data Information, Estimates and Assumptions from Reviewed Sources

Author	Operating Circumstances/Lifetime Data			Power Consumption rate/Power Management
		Business use only	2.1	
		Used for both	3.1	
	Additionally, RECS calculated that lion computers were in use in U.S. households in 1997. Other data from the RECS included "6% of the households that used PCs used that computer to tele-commute."			
CIA 1998	Estimate that 117 million computers were in use in the U.S. in 1997.			
EPA 1999	Have the EnergyStar compliance monitor specifications.			
		First low-power mode	Second	
	Low-power state:	< = 15 watts	< =8W	
	Default times:	15-30 minutes	< 70 min.	
Koch 1997	Assumed 10,000 hours/lifetime for the LCDs in the study.			
Goldberg 1998	Article reported that Walt Rosenberg, Compaq's director of environmental affairs, stated that today's machines have a useful life of two-to-three years.			
Miseli 1999	Did not separate office from home user. Assumed units operate 50% of the time (annually) around the clock. Stated that "True life of a CRT or LCD is defined for the case when it runs continually at full intensity," adding that true life for CRT is about 1.25 years and for LCD is about 2.9 years. Doubled each of those true life values for his calculations.			Assumed 90W for a CRT and 30W for an LCD.
Tekawa 1997	Assumed personal users time frame of 2 hr/dy, 365 dy/yr for 5 years, and office users time frame of 8 hr/dy, 247 dy/yr for 7 years. Assumed a ratio of personal to office user of 4.6.			Don't state the actual numbers they used, but do say they took the mean of the minimum and maximum power consumption ratings.
Atlantic 1998	They estimated that a PC's lifetime is 3 years. Then they stated that they were modeling only the first lifetime of a PC; they acknowledged other lifetimes but decided not to attempt to model them. They also estimated that the PC is turned on 8 hrs per day, 230 days per yr, altogether running for 5,520 hrs during its lifetime.			They assumed that the monitor consumes power at a rate of 100W, and that the "base case PC has no energy savings facilities."
Philips 1998	MTBF of 75,000 hrs for a 19" C1995 Typhoon high resolution CRT monitor excluding the CRT.			Power consumption: 120W typ. (140 W max)
Nordman 1996	In this document, Lawrence Berkley National Laboratory (LBNL) details results from several audits they performed determining the state of power consumption and power management in certain computers and monitors			The LBNL document provided results from a audit of 70 monitors and their setup and use of energy saving power modes. Their primary conclusions were that only approximately one-third of all monitors were "accomplishing power management." The following is a breakdown of some of what they found:
	Standard % of time in each mode by day type, by operating pattern	Full-on	Low	- 34 apparently meet Energy Star requirements
	Workday	17%	35%	- 30 were 'universal,' (able to initiate power mgmt two ways)
	Weekend day	0%	20%	- 30 were left on at time of audit (12 in suspend mode)
	Absence day	0%	20%	
	Weekdays average	13%	45%	
	All days average	10%	35%	
				This document also contained data on the actual power consumed by 3-17" monitors over a 4-6 week period, broken down by power consumption mode, and the results are shown below:
				Monitor #1: Full-on = 91 watts; Low = 7 watts
				Monitor #2: Full-on = 84 watts; Low = 3 watts
				Monitor #3: Full-on= 85 watts; Low = 4 watts

Table A3. Use Stage Data Information, Estimates and Assumptions from Reviewed Sources

Author	Operating Circumstances/Lifetime Data	Power Consumption rate/Power Management		
CCPCT 1998		The University of Tennessee CCPCT reviewed the available CRT and LCD energy consumption information (mostly via the WWW) and produced the energy consumption breakdown shown at left by energy consuming state. The units are all watts.		
		CRT	Full-on:	113.29
			Standby:	17.18
			Active off:	6.85
		LCD	Full-on:	40.00
			Standby:	7.58
			Active-off:	5.70

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APPENDIX I

TECHNICAL MEMORANDUM:
End-of-Life Approach for the DfE Computer Display Project

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APPENDIX I

TECHNICAL MEMORANDUM:
End-of-Life Approach for the DfE Computer Display Project

I. INTRODUCTION

The Computer Display Project, sponsored by the U.S. Environmental Protection Agency (EPA) as part of its Design for the Environment (DfE) program, is investigating the life-cycle impacts of cathode ray tube (CRT) displays and liquid crystal displays (LCDs) for use in desktop computers.

A meaningful comparison of the two technologies from the environmental perspective can be made only if the life-cycle impacts associated with various stages, namely, raw material extraction, materials processing, manufacture, use, and end-of-life (EOL), are evaluated. The functional units being compared are the 17-inch CRT display monitor and the 15-inch active matrix liquid crystal display (AMLCD) monitor. The two are considered to be functionally equivalent with respect to the viewing area available to the user. EOL issues are of growing interest to manufacturers nowadays due to Extended Producer Responsibility (EPR) concerns (Fishbein 1998) and the consequent higher expectations from manufacturers for influencing the ultimate fate of their products.

The purpose of this memorandum is to describe the approach for evaluating the EOL life-cycle stages of CRTs and AMLCDs for the Computer Display Project. This approach includes:

(1) developing scenarios to represent reasonable EOL alternatives; and
(2) collecting life-cycle inventory (LCI) data for the EOL alternatives.

1.1 Background

Estimates from 1998 revealed that more than 20 million personal computer central processing units (CPU) became obsolete in that year (NSC 1999). Earlier estimates indicated that approximately 10 million television sets and 12 million computer monitors reach the end of their useful lives each year (MCC 1996). Assuming that one monitor became obsolete for every CPU in 1998, and since LCDs have not been in existence long enough to have attained "end-of-life" (EOL) status in sufficiently large numbers, it is expected that approximately 20 million CRTs are retired annually. There is not much information available on the disposition options for LCDs.

The major existing EOL environmental concern associated with CRTs is disposal of leaded glass. LCDs, on the other hand, do not contain any leaded glass and are much lighter in weight, but contain other materials of concern, such as mercury used in the backlights.

1.1.1 CRT EOL Issues

According to practices followed by leading CRT recyclers such as Envirocycle (Envirocycle 1999), the material of greatest value recovered from CRTs is leaded glass (which is also the major component by weight), followed by small quantities of metals. Also, whenever the incoming EOL product is a complete computer monitor, some plastics and metals can be recovered from its outer casing and other parts.

The closed loop recycling of leaded glass involves recovering and processing the material for use as cullet in the manufacture of new CRTs. CRT manufacturers will use the cullet if it meets quality standards and is of the same chemistry and type as required by them in their manufacturing operations. Thus, effective recycling of post-consumer CRT glass requires very careful sorting and separation into various types, followed by decontamination (removal of coatings). Resmelting (for lead recovery) and downcycling (into other glass applications) are some of the other "open loop recycling" alternatives. In 1997 and 1998, CRT computer monitor recycling was done for 1.3 million units (46 million pounds) and 1.5 million units (51 million pounds), respectively (NSC, 1999).

1.1.2 Regulations Regarding CRT Disposal

Color CRTs may fail the EPA Toxicity Characteristic Leachate Procedure (TCLP) test, and therefore may be classified as hazardous waste under current EPA regulations. Some experts believe that this classification poses barriers to the effective recycling of CRTs, on account of special permits and transportation requirements for handling hazardous waste (EPA-CSI 1999). However, EPA has implemented a glass-to-glass recycling exception.

In order to landfill CRTs in accordance with EPA regulations, they must be dismantled, and the glass crushed and stabilized by micro-encapsulation in cement. However, this method has some drawbacks. Crushing increases surface area and, consequently, the potential to leach lead. Though cement encapsulation is the required method, it has been found that cement disintegrates faster than glass (MCC 1994).

To encourage recycling, some states have developed new initiatives that will ease some of the regulatory barriers. Massachusetts, for example, has proposed to specifically exempt "intact" CRTs from being classified as hazardous waste and simultaneously banned them from disposal in municipal landfills and combustion facilities (MDEP 1999). These measures could promote the recycling of CRTs by making the process of handling and transportation much easier, and the paperwork less cumbersome.

1.1.3 LCD EOL Issues

Currently, no infrastructure or established process exists for recycling LCDs specifically. Of the small numbers of LCDs that have reached the EOL stage (predominantly as notebook computers), a much smaller number is likely to have reached recycling facilities. No specific details are available on the materials recovered from them as they are expected to have been processed along with other electronic products, with some valuable and/or potentially recyclable materials removed. The following components and materials of potential reuse or recycling value found in LCDs have been identified by MCC (MCC 1994):

- Thin film transistors (TFTs).
- Color filters.
- Glass.

The toxicity potential of heavy metals is of concern in the EOL stage. The heavy metals found in the LCD monitors are identified in the main body of this LCA report. This study will consider the presence of heavy metals or other materials of potential concern in the wastes and emissions generated.

1.2 EOL Disposition Options

In the past, landfilling has been the prevalent method for the disposition of post-use computer monitors (i.e., those re-used after being resold or donated). However, with increasing awareness of potentially harmful life-cycle environmental impacts, dwindling natural resources, government regulations against disposal of toxic substances in landfills, and the consequent development of markets for recycled components and materials, more options are now available for the disposition of post-use computer monitors. They are briefly described below.

1.2.1 Reuse

Reuse, often as a result of reselling, involves continued use of the monitor for the purpose for which it was built, and is considered to occur within its originally intended useful life. Reuse does not usually entail major repairs or modifications, and is a preferred EOL option because the original materials contained in it are put to use for an extended period of time, thus conserving valuable natural resources (energy and raw materials) needed to manufacture new monitors or to dispose of discarded ones. However, reuse could result in reduced energy efficiency during the use stage as monitor manufacturers continually strive to improve the energy efficiency of their products.

1.2.2 Remanufacturing

Remanufacturing is a viable option for monitors that are no longer functional but could be refurbished (upgraded or restored to working conditions) at a cost lower than that of manufacturing a new monitor, to be sold again in domestic or foreign markets.[1] Here again, energy and raw materials are conserved, though some new parts/components may be required. Another important benefit of remanufacturing is solid waste reduction, achieved by diverting the monitor materials away from the landfill. Remanufacturing processes span a wide range of activities, from as little as replacing button tops to as extensive as testing and replacing PCBs or transformers.

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[1] In addition to cost, the arrival of new technology is another factor that inhibits remanufacturing. In such cases, remanufacturers seek to find markets where products based on old technology are still in demand.

1.2.3 Recycling

Recycling involves recovering the individual materials from EOL monitors, to be used in the production of new monitors (closed-loop recycling) or in other products (open-loop recycling). Identification, sorting, cleaning, and further processing (e.g., smelting) are often required before the recovered materials can be used again. Though materials recycling involves several processing steps, it results in the conservation of energy and raw materials, and diversion of materials that would otherwise have been landfilled, through the creation of new, desirable products that are in-line with current market demand.

1.2.4 Waste-to-Energy (WTE) Incineration

A portion of municipal solid waste (MSW) is routinely sent to incinerators or municipal waste-to-energy (WTE) facilities for energy recovery. The quantity of ash (bottom ash and fly ash) left over is a small fraction, around 25% (EPA 1998) of the original waste input, and can be disposed of either as non-hazardous or hazardous waste, depending on whether it passes the TCLP test or not. The obvious benefits are reduced solid waste and the energy produced, which is often counted as a credit in life-cycle energy calculations.[2]

1.2.5 Landfilling

Landfilling solid waste in Subtitle C (for hazardous) or D (for non-hazardous) landfills is the least preferred option, since all the other options have some expected environmental benefits. The disposal of waste in Subtitle C landfills is usually the most undesirable, as it often involves treatment to immobilize the hazardous materials before they can be landfilled, thus increasing the quantity and cost of disposal. Also, hazardous waste sites have the potential to turn into high liability ("Superfund") sites. Some states have regulatory activities that might not accept monitors in Subtitle D landfills.

2. METHODOLOGY

This section outlines key assumptions, defines conceptual models proposed for determining the flow of materials through the EOL processes, and highlights some important issues pertaining to CRTs and LCDs.

The major steps are listed below:

- Assumptions about the distribution of EOL options were made.
- Data were collected for various disposition options using existing inventory reports and inventory questionnaires sent to recyclers.
- Data were normalized to the functional unit and included as the EOL inventories.

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[2] The energy used in different life-cycle stages is summed up to arrive at the total energy used in the life cycle of the product. In case of WTE incineration, where energy is recovered instead of being used up, it is treated as a negative value and subtracted from the total.

2.1 EOL Conceptual Models

A monitor is assumed to have reached EOL status when:

- It has served its useful life and/or is no longer functional.
- Technological obsolescence renders it unusable.

The EOL options for CRT and LCD monitors are graphically depicted in Figure 1. Estimates of the percent distribution of monitors going to each EOL option are presented below. As the functional unit in this study is one monitor over its lifetime, the percentages are used as probabilities for the EOL disposition of a particular monitor.

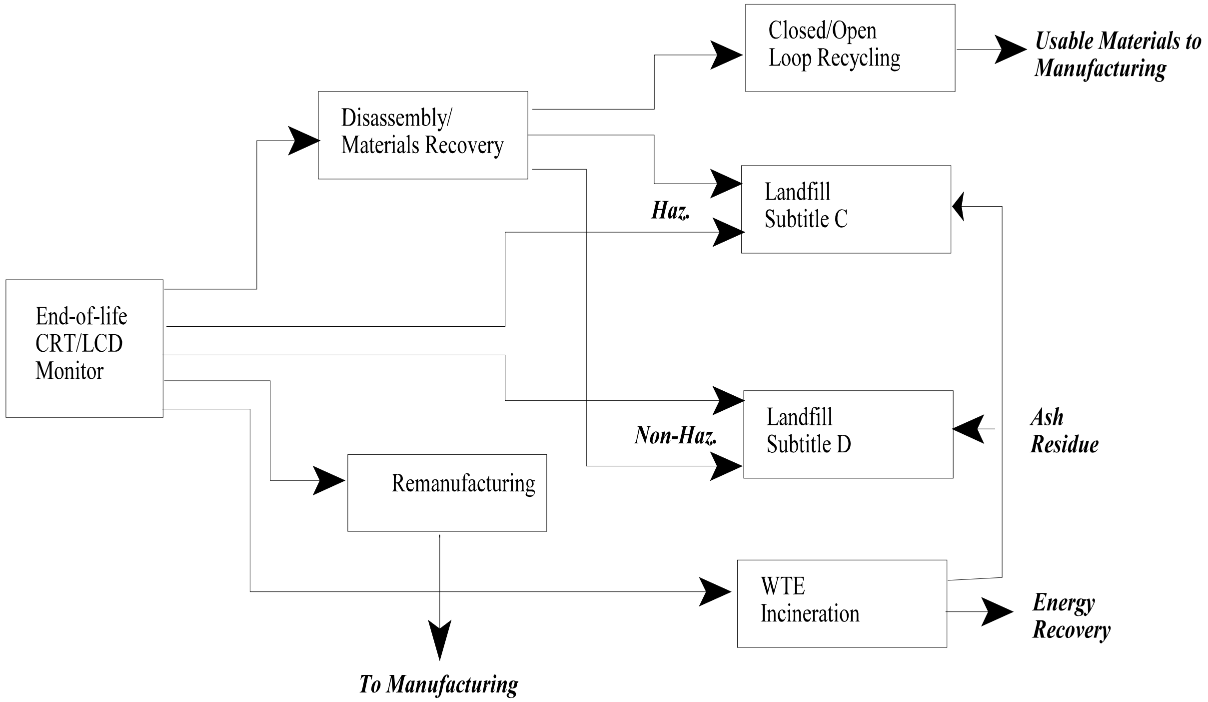

Figure 1. Conceptual Model Showing End-of-Life Disposition Options for CRT and LCD Monitors

2.2.1 CRT

The National Safety Council (NSC 1999) reported that 11% of all personal computer CPUs are recycled. Assuming one monitor is recycled with every CPU, and assuming these represent CRTs, we assume 11% of CRTs go to recycling. The NSC report also stated that 3% of personal computers are "refurbished and resold or donated." We thus used 3% as an estimate of the CRT monitors that are remanufactured, although we recognize this might be an overestimate, as we do not know if those resold and donated are also remanufactured. Given that this is a small percentage, this error is not expected to have a large effect. Further data are lacking on the percent of monitors being incinerated or going to landfills. To estimate the percent incinerated, we used the percent of all municipal solid waste in the United States being incinerated, which is estimated at 15% (EPA 1998). Summing the percents for recycling, re-manufacturing, and incineration equals 29%. This leaves 71% that is assumed to be landfilled. In the life-cycle analysis in this study, only one landfilling process is modeled, which is assumed to represent both hazardous waste and solid waste landfilling. The landfilling process is derived from Ecobalance data and is a combination of four major materials in a CRT (glass, steel, plastic, and aluminum), based on the proportion of each of those materials in the CRT. The inventories for each material are of generic materials (not necessarily the precise materials in the CRT). For example, the glass is generic glass, and not leaded glass, and the plastics are generic "plastic" and may not represent the exact plastics in the CRT.

Although the percentage of monitors that are landfilled are not separated into hazardous and non-hazardous waste landfilling processes, we have still attempted to estimate the proportion of CRTs that go to each landfill. Due to a lack of data, we assumed as a best estimate that the percent of monitors that are in households are equivalent to the percent of landfilled monitors that would be disposed of in a solid waste (Subtitle D) landfill and the percent of monitors that are in businesses would be disposed of in a hazardous waste (subtitle C) landfill. As presented in the Use Stage discussion in the main body of this report (Section 2.4.1.2), 35% of monitors are in households and 65% are in office and other environments. Therefore, of the 71% of monitors assumed to going to landfills, 25% are assumed to be sent to solid waste landfills and 46% to hazardous waste landfills. To summarize, the EOL dispositions assumed for the CRT are as follows:

• Incineration:	15%
• Recycling:	11%
• Remanufacturing:	3%
• Hazardous waste landfill:	46%
• Solid waste landfill:	25%

2.2.1 LCD

Data were even more lacking for the EOL dispositions of LCDs. The same 15% of municipal solid waste incinerated in the United States was assumed for LCD incineration as it was for the CRT. An individual in the monitor recycling business estimated that no more than 5% of LCDs are sent to hazardous waste landfills and that essentially none are currently being recycled (Vorhees 2000). Given this limited data, the remaining 80% needed to be split between solid waste landfilling and remanufacturing. Given no other data, we assumed half of the remaining 80% goes to solid waste landfills and half to remanufacturing. Assuming that 40% are remanufactured is likely an overestimate; however, no supporting data were available to modify this estimate. Therefore, in the baseline analysis of this study, the following percentages have been used:

Incineration:	15%
Recycling:	15%
Remanufacturing:	15%
Hazardous waste landfill:	5%
Solid waste landfill:	50%

Sensitivity analyses have been conducted to determine the effects of these assumptions on the results and are discussed in Chapters 2 (LCI) and 3 (LCIA) of the main report.

2.2 Assumptions

In developing the EOL model for CRT and LCD monitors, it was necessary to make several assumptions. In addition to the percent distributions presented above, the following assumptions apply to the EOL data:

- Reuse and resale are not included in the EOL scenarios modeled as these events are considered to occur within the originally intended useful life of the monitor.
- The monitors currently in storage are not considered to have reached EOL yet and have, therefore, been excluded from the EOL model. Moreover, they are assumed not to have environmental impacts while in storage, and maintenance of storage space is assumed to the beyond the scope of this study.
- Only waste-to-energy incineration is modeled because there is very limited straight incineration (without energy recovery) being done in the U.S. at present. In fact, the 1996 total U.S. WTE design capacity was 100,355 tons per day, with 110 WTE facilities in operation. In contrast, the capacity for incineration without energy recovery was only 2,451 tons per day, with a total of 19 facilities in operation. In general, WTE has become the prevalent method for MSW combustion since the 1980s (EPA 1998).

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ATTACHMENT A TO APPENDIX EOL:
EOL QUESTIONNAIRE

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DESIGN FOR THE ENVIRONMENT COMPUTER DISPLAY PROJECT
Life-Cycle Inventory (LCI) Data Collection Questionnaire for the End-of-Life Stage

Introduction

The Design for the Environment (DfE) Program in the U.S. Environmental Protection Agency's (EPA) Office of Pollution Prevention and Toxics has begun a voluntary, cooperative project with the electronics industry to assess the life-cycle environmental impacts of cathode ray tube (CRT) and liquid crystal display (LCD) desktop monitors. The DfE Program conducts comparative analyses of alternative products or processes to provide businesses with data to make environmentally informed choices about product or process improvements. The DfE Program has no regulatory or enforcement agenda and was established to act as a partner with industry to promote pollution prevention. This environmental life-cycle assessment will address human and ecological risk, energy and natural resource use, performance, and cost of various display technologies. The University of Tennessee (UT) Center for Clean Products and Clean Technologies is conducting the life-cycle inventory (LCI), which is the data collection phase of a life-cycle assessment, with technical assistance from Microelectronics and Computer Technology Corporation, the Electronics Industry Alliance, and other partners.

Boundaries

A *life-cycle* assessment considers impacts from materials acquisition, material manufacturing, product manufacturing, use, and final disposition of a product. The LCI data are intended to be used to evaluate relative environmental impacts over the entire life-cycle of a product, including transport between life-cycle stages. In this project, the product is either a color CRT or LCD monitor. Therefore, data associated with the materials and processes used directly in the manufacturing, use, and disposition of the product are relevant to the LCI and requested in this questionnaire. Please include only materials or energy *directly* used in the disassembly, remanufacturing, recycling, or disposal of the monitor or its components (e.g., *do not include* general building heating and air conditioning).

Product focus

This project focuses on 17" CRT and 15" LCD desktop monitors. We will appreciate your providing data specifically on these sizes, to the extent possible.

Inventory data

We are asking you for data on CRT and LCD desktop monitors that you either remanufacture, or disassemble and recover, reuse, or recycle components and materials from. The inputs and outputs data (Fig. 1) that you provide will be aggregated in the LCI to quantify the overall inputs and outputs of a CRT and LCD. Additionally, transportation information is requested in the inventory.

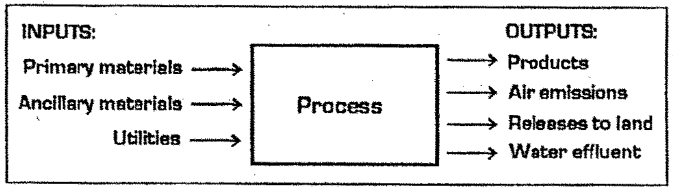

Fig. 1. End-of-Life process inventory conceptual template

Data sources
Much of the requested information can be drawn from existing sources, including, but not limited to the following:

1. Purchase and production records
2. Bills and invoices
3. Material Safety Data Sheets (MSDS)
4. Toxic Release Inventory (TRI) forms
5. Audit and analysis results (e.g., wastewater discharge analyses)
6. Local, state, and federal reporting forms (e.g., hazardous waste manifests)
7. Local, state, and federal permits
8. Monthly utility billing records

How the data will be used
UT will collect inventory data and tally the inputs and outputs for the different monitors. Information gathered by these questionnaires will be used to develop environmental profiles based on inputs and outputs for each stage in the life cycle of displays. The profiles will be used to evaluate environmental impacts from each product. Cost data will also be collected and presented along with environmental results. The environmental profiles can be used to encourage product design changes for product improvement. UT will aggregate data and ensure that data associated with particular companies remain anonymous to the EPA. UT can enter into confidentiality agreements where proprietary data are concerned. Please understand that accurate and representative information from you is critical for the success of this project.

Results of project
The results are intended to provide industry with an analysis of the life-cycle environmental impacts, cost, and performance of CRT and LCD computer monitors. Results will help identify areas for product and process improvement as related to risk and environmental impact (e.g., identifying material use inefficiencies) and will identify impacts from various life-cycle stages of the product systems. Use of the results will also help meet growing global demands of extended product responsibility.

Benefits of involvement
Your input will allow for your interests to be considered in the project development and data collection. By supplying data, the results will partially reflect your operations and, therefore, the results will be directly relevant to your interests. The project will allow you to directly apply results to your own processes and identify areas for improvement. You will also be recognized as working voluntarily and cooperatively with the U.S. EPA.

Deadline
Please complete this form and return it to us at the address below by ***September 30, 1999***. If this is not possible, please contact Maria Leet Socolof at 423-974-9526 or at the addresses below to discuss alternative dates.

Your cooperation and assistance are greatly appreciated.

*For any questions, please contact **Maria Leet Socolof at 423-974-9526**, <socolofml@utk.edu> or **Rajive Dhingra at 423-974-8752**, <rdhingra@utk.edu> at the University of Tennessee, 311 Conference Center Bldg., Knoxville, TN 37996-4134.*
For more project details, see the Project Fact Sheet, DfE Website <http://www.epa.gov/opptintr/dfe/compdisp/compdisp.html>, or the Draft Final Goal Definition and Scoping Document.

INSTRUCTIONS

1. Please be sure to read the introductory text on each page before filling out the questionnaire.
2. The data you supply in the tables should represent inputs and outputs associated only with the "product of interest" (**i.e., materials, components or subassemblies that are either part of, or that are itself, the desktop monitor as defined on p. i under Product focus**). If quantities provided are not specific to the "product of interest," please explain how they differ in the comments section at the bottom of the appropriate table.
3. Where supporting information is available as independent documents, reports or calculations, please provide them as attachments with reference to the associated page(s) or table(s) in this questionnaire.
4. If you have more than one product of interest to this project, please duplicate this questionnaire and fill out one questionnaire for each product.
5. If there is not adequate room on a page to supply your data (including comments), please copy the appropriate page and attach it to this packet.
6. The ensuing pages refer to the four indices shown below to detail specific information about the data. Additional information is provided below as required.
   <u>Data Quality Indicators Index</u>: These indicators will be used to assess the level of data quality in this questionnaire. Please report a DQI for the numerical value requested in each table on the following pages. The first category, Measured, pertains to a value that is a directly measured quantity. The second category, Calculated, refers to a value that required one or more calculations to obtain. The third category, Estimated, refers to a value that required a knowledgable employee's professional judgement to estimate. Lastly, the fourth category, Assumed, should be used only when a number had to be guessed.
   <u>Hazardous and Nonhazardous Waste Management Methods Index</u>: These methods are applicable to both hazardous and nonhazardous wastes (Tables 8a and 8b). Please give the appropriate abbreviation in the Management Method column on p. 8 where requested. Depending on whether the management method is on or offsite, please indicate by specifying "on" or "off" in the appropriate column on p. 8.

For Tables 2, 3a, 3b, 4, 5, 8a, and 8b:

Transportation Modes Index	
A	- Large truck (18-wheeler), diesel
B	- Small truck, diesel
C	- Small truck, gasoline
D	- Rail, diesel
E	- Barge, diesel
F	- Ocean freighter, diesel
G	- Other (please specify in comments section)

For Table 7b:

Wastewater Treatment/Disposal Methods Index	
A	- Direct discharge to surface water
B	- Discharge to offsite wastewater treatment facility
C	- Underground injection
D	- Surface impoundment (e.g., settling pond)
E	- Direct discharge to land
F	- Other (please specify in comments section)

For Tables 3a, 3b, 4, 5, 6, 7a, 8a and 8b:

Data Quality Indicators Index	
M	- Measured
C	- Calculated
E	- Estimated
A	- Assumed

For Tables 8a and 8b:

Hazardous and Nonhazardous Waste Management Methods Index	
RU	- Reused
R	- Recycled
L	- Landfilled
Iv	- Incinerated - volume reduction
Ie	- Incinerated - energy conversion
S	- Solidified/stabilized
D	- Deep well injected
O	- Other (please specify in comments section)

IF YOU HAVE QUESTIONS, PLEASE CONTACT EITHER:

Maria L. Socolof (Project Manager): Phone: 423-974-9526
Email: socolofml@utk.edu

OR

Rajive Dhingra (Project Engineer): Phone: 423-974-8752
Email: rdhingra@utk.edu

1. FACILITY & CONTACT INFORMATION

Table 1.

Facility Information		**Contact Information**	
1. Company name:		5a. Prepared by:	Date:
2. Facility name:		5b. Title:	
3 Facility address (location):		5c. Phone number:	Ext.:
		5d. Fax number:	
		5e. Email address:	
4. Products handled onsite:			

2. PRODUCT OF INTEREST INFORMATION

Table 2.

1. Product of interest: ______________________
E.g., End-of-Life CRT/LCD desktop monitor

2. No. of monitors processed annually (e.g., units, kg, lbs): ______________________

3. Facility's percent global market share for handling product of interest: ______________________

4. Product of interest unit weight: ______________________

5. Brief description of the main operations/subprocesses required to process the product of interest: ______________________

6. Product transport information. In this table, please list the top five locations (by quantity) from where you receive the product of interest. See Transportation Modes Index on p. iii for modes' abbreviations. Percent capacity represents what percent of the transport vehicle's total load was carrying the products of interest.

Location (City, State)	Mode	Number of trips annually	Percent capacity
1)			
2)			
3)			
4)			
5)			

3. PRIMARY & ANCILLARY INPUTS

1. Primary & Ancillary Materials: Primary materials are defined as those materials that become part of a product output. Ancillary materials are those material inputs that assist in a process, yet do not become part of the final product. Please include the trade name and the generic name of each material where applicable.
2. CAS # or MSDS: Please include either the CAS (Chemical Abstract Service) number of each material (fill in the blank with the number), or state "MSDS" and append a copy to this document.
3. Annual quantity/units & Density/units: Please specify the amount of material consumed annually. Please use the units of mass-per-year (e.g., kg/yr, lb/yr). If you specify units of volume in lieu of mass, please provide the density.
4. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please supply the DQI for the *annual quantity* value given.
5. Recycled content: Please specify the recycled content of each material identified. For example, 60/40/0 would represent a material that has 60% virgin material, 40% pre-consumer recycled and 0% post-consumer recycled content. Enter N/A (not applicable) for all components that are assemblies.
6. Transportation information: See the Transportation Modes Index on p. iii for mode abbreviations. Please specify where the material is coming from (location) and the number of trips made to your facility on an annual basis. % capacity represents what percent of the transport vehicle's total *load* was carrying the materials of interest.

Table 3a.	Primary Materials[1]	CAS # or MSDS[2]	Annual Quantity[3]	Units	Density[3]	Units	DQI[4]	Recycled Content[5]	Transportation Information (Receiving)[6]			
									Location	Mode	# trips	% cap.
1.												
2.												
3.												
4.												
5.												
6.												
7.												

Primary material comments:

Table 3b.	Ancillary Materials[1]	CAS # or MSDS[2]	Annual Quantity[3]	Units	Density[3]	Units	DQI[4]	Recycled Content[5]	Transportation Information (Receiving)[6]			
									Location	Mode	# trips	% cap.
1.												
2.												
3.												
4.												
5.												
6.												
7.												

Ancillary material comments:

4. UTILITY INPUTS

1. Annual quantity/units: Please specify the amount of each utility consumed annually. If possible, please exclude nonprocess-related consumption. If not possible, please include a comment that nonprocess-related consumption is included.
2. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please supply the DQI for the *annual quantity* value given.
3. Transportation information: See the Transportation Modes Index on p. iii for mode abbreviations. Please specify where the fuel is coming from (Location) and the number of trips made to your facility on an annual basis. Percent capacity represents what percent of the transport vehicle's total *load* was carrying the fuel of interest.
4. Individual Utility Notes:

Electricity:

The quantity of electricity should reflect only that used toward manufacturing the product of interest (identified on p. 2). One approach would be to start with your facility's total annual electrical energy consumption, estimate and remove nonprocess-related consumption, then estimate what portion of the remaining consumption is related to the specific operations of interest (if you manufacture more than one product). Please include consumption in all systems that use electricity for process-related purposes. Some examples include compressed air, chilled water, water deionization and HVAC consumption where clean or controlled environments are utilized.

Natural gas and LNG:

Please exclude all use for space heating or other nonprocess-related uses. If you choose to use units other than MCF (thousand cubic feet), please utilize only units of energy content or volume (e.g., mmBTU, therm, CCF).

Fuel oils:

Please use units of either volume or energy content (e.g., liters, cubic meters, mmBTU, MJ). Additionally, if the fuel oil is delivered by pipeline, enter "pipeline" in the Transportation Information space; if not delivered by pipeline, please include the associated transportation information.

All waters (e.g., deionized, city):

Please include all waters received onsite for process-related uses. Please indicate consumption in units of mass or volume.

Table 4.		**Annual**	**Units**	**DQI**[2]	**Transportation Information (Receiving)**[3]			
	Utilities[4]	**Quantity**[1]			**Location (City, State)**	**Mode**	**# trips**	**% cap.**
1.	Electricity		MJ					
2.	Natural gas		MCF					
3.	Liquified natural gas (LNG)		MCF					
4.	Fuel oil - type #2 (includes distillate and diesel)		liters					
5.	Fuel oil - type #4		liters					
6.	Fuel oil - type #6 (includes residual)		liters					
7.	Other petroleum-based fuel		liters					
8.	Water		liters					
9.								
10.								
11.								
12.								
13.								

Utility comments:

5. PRODUCT OUTPUTS

1. Product Outputs: Product outputs are defined as useable products, materials, components or sub-assemblies.
2. CAS # or MSDS (if applicable): Please include either the CAS (Chemical Abstract Service) number of each material (fill in the blank with the number), or state "MSDS" and append a copy to this document.
3. Annual quantity/units & Density/units: Please specify the amount of material produced annually. Please use the units of mass-per-year (e.g., kg/yr, lb/yr). If you specify units of volume in lieu of mass, please provide the density.
4. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please supply the DQI for the *annual quantity* value given.
5. Recycled content (if known): Please specify the recycled content of each material identified. For example, 60/40/0 would represent a material that has 60% virgin material, 40% pre-consumer recycled and 0% post-consumer recycled content. Enter N/A (not applicable) for all components that are assemblies.
6. Transportation information: See the Transportation Modes Index on p. iii for mode abbreviations. Please specify where the material is being sent (location) and the number of trips made on an annual basis. % capacity represents what percent of the transport vehicle's total *load* was carrying the materials of interest.

Table 5. Product Outputs[1]	CAS # or MSDS[2]	Annual Quantity[3]	Units	Density[3]	Units	DQI[4]	Recycled Content[5]	Transportation Information (Shipping)[6]			
								Location	Mode	# trips	% cap.
1.											
2.											
3.											
4.											
5.											
6.											
7.											

Product output comments:

6. AIR EMISSIONS

1. Air emissions: The emissions listed in the table below are some of the more common ones found in air release inventories; if you have information on other specific emissions, please include that information in the space provided. If you have any recent reporting forms or other air emission records, please attach copies to this questionnaire. Also, if you have information on stack* as well as fugitive* emissions, please copy this page and place each set of emissions on a different page. The energy consumed in any equipment used onsite to treat air emissions should be included in the utilities values on p. 4.
   *Stack emissions** are releases to air that occur through confined air streams, such as stacks, vents, ducts, or pipes.
   *Fugitive emissions** are all releases to air that are not released through a confined air stream. Fugitive emissions include equipment leaks, evaporative losses from surface impoundments and spills, and releases from building ventilation systems.
2. Annual quantity/units: Please specify the amount of air emissions generated annually. Please use units of mass-per-year (e.g., kg/yr, lb/yr).
3. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please supply the DQI for the *annual quantity* value given.

Table 6. Air Emissions[1]	CAS number	Annual Quantity[2]	Units	DQI[3]
Total particulates	-----			
Particulates < 10 microns (PM-10)	-----			
Sulfur oxides (SOx)	-----			
Nitrogen oxides (NOx)	-----			
Carbon monoxide	630-08-0			
Carbon dioxide	124-38-9			
Methane	74-82-8			
Benzene	71-43-2			
Toluene	108-88-3			
Xylenes	1330-20-7			
Naphthalene	91-20-3			
Total nonmethane VOCs	-----			
Other speciated hydrocarbon emissions:				
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Table 6 (continued). Air Emissions[1]	CAS number	Annual Quantity[2]	Units	DQI[3]
Ammonia	7664-41-7			
Arsenic	7440-38-2			
Chromium	7440-47-3			
Copper	7440-50-8			
Lead	7439-92-1			
Manganese	7439-96-5			
Mercury	7439-98-7			
Nickel	7440-02-0			
Other emissions:				
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

Air emission comments:

7. WASTEWATER RELEASES & CONSTITUENTS

1. Annual quantity/units: Please specify the amount of wastewater(s) generated annually. Please use units of mass-per-year (e.g., kg/yr, lb/yr). If multiple streams exist, please copy this page and fill it out for each stream.
2. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please include one DQI for the annual wastewater stream quantity value supplied, and one DQI for the wastewater constituents information supplied. If more than one DQI is applicable to the wastewater constituents data, please clarify this in the comment section.
3. Wastewater constituents: Please let us know what type of values you are supplying (e.g., daily maximums, monthly averages, annual averages). Additionally, if you have any recent reporting forms or other wastewater constituent records, please attach them to this questionnaire. The energy consumed in any equipment used onsite to treat wastewater releases should be included in the utilities values on p. 4.
4. Concentration/units: Please specify the concentration of wastewater constituents generated annually. Please utilize the units of mass-per-volume (e.g., mg/liter, lb/gal).
5. Wastewater treatment/disposal (WW T/D) method: See the Wastewater Treatment/Disposal Methods Index on p. iii for method abbreviations.

Table 7a. Wastewater Stream	**Annual Quantity[1]**	**Units**	**DQI for Wastewater Annual Quantity[2]**	**DQI for Wastewater Constituents[2]**

Table 7b. Wastewater Constituents[3]	**CAS number**	**Concentration[4]**	**Units**	**WW T/D Method[5]**
Dissolved solids	-----			
Suspended solids	-----			
Chemical Oxygen Demand (COD)	-----			
Biological Oxygen Demand (BOD)	-----			
Oil & grease	-----			
Hydrochloric acid	7647-01-0			
Sulfuric acid	7664-93-9			
Other acids (please specify):				
1.				
2.				
Phosphorus	7723-14-0			
Phosphates	-----			
Sulfates	-----			
Fluorides	-----			
Cyanide	-----			
Chloride	-----			
Chromium	7440-47-3			
Iron	7439-89-6			
Aluminum	7429-90-5			
Nickel	7440-02-0			

Table 6b (continued). Wastewater Constituents[3]	**CAS number**	**Concentration[4]**	**Units**	**WW T/D Method[5]**
Mercury	7439-98-7			
Lead	7439-92-1			
Nitrogen	7727-37-9			
Zinc	7440-66-6			
Tin	7440-31-5			
Ferrous sulfate	7720-78-7			
Ammonia	7664-41-7			
Nitrates	-----			
Pesticides	-----			
Other constituents:				
1.				
2.				
3.				
4.				
5.				
6.				

Wastewater comments:

8. HAZARDOUS & NONHAZARDOUS WASTES

1. Hazardous wastes and EPA hazardous waste numbers: Please list your waste streams that are considered hazardous by the U.S. EPA. Include the hazardous waste codes for any hazardous waste you include.
2. Annual quantity/units & Density/units: Please specify the amount of waste generated annually. Use units of mass-per-year (e.g., kg/yr, lb/yr). Please also provide the density for each waste.
3. Data quality indicators: See the Data Quality Indicators Index on p. iii for abbreviations. Please supply the DQI for the *annual quantity* value given.
4. Management method: See the Management Methods Index on p. iii for abbreviations. If none are applicable, please indicate other and use the comments section to expound.
5. Transportation information: See the Transportation Modes Index on p. iii for abbreviations. Please specify where the waste is sent (location) and the number of trips made from your facility on an annual basis. % capacity represents what percent of the transport vehicle's total *load* was carrying the waste of interest.

Table 8a. Hazardous Wastes[1]	EPA Haz. Waste #[1]	Annual Quantity[2]	Units	Density[2]	Units	DQI[3]	Mgmt. method[4]	On or offsite?	Transportation Information (Shipping)[5] Location	Mode	# trips	% cap.
EXAMPLE: Spent solvent (toluene)	*F005*	*20,000*	*kg/yr*	*0.9*	*kg/liter*	*M*	*Ie*	*off*	*Indianapolis, IN*	*A*	*24*	*40*
1.												
2.												
3.												
4.												
5.												
6.												
7.												
8.												

Hazardous waste comments:

Table 8b. Nonhazardous Wastes	Annual Quantity[2]	Units	Density[2]	Units	DQI[3]	Mgmt. method[4]	On or offsite?	Transportation Information (Shipping)[5] Location	Mode	# trips	% cap.
EXAMPLE: Waste metal chips	*22,000*	*kg/yr*	*1,000*	*kg/m3*	*C*	*R*	*off*	*Scottsdale, AZ*	*A*	*2*	*100*
1.											
2.											
3.											
4.											
5.											
6.											
7.											

Nonhazardous waste comments:

APPENDIX J

LIFE-CYCLE INVENTORY TABLES

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APPENDIX J

LIFE-CYCLE INVENTORY TABLES

Table J-1. CRT primary materials (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
ABS resin	0	4.24E-01	0	0	4.24E-01	0.0649%
Aluminum (elemental)	0	3.60E-01	0	0	3.60E-01	0.0552%
Amyl acetate (mixed isomers)	0	1.20E-03	0	0	1.20E-03	0.0002%
Aquadag	0	2.06E-02	0	0	2.06E-02	0.0032%
Assembled CRT monitor	0	0	2.20E+01	0	2.20E+01	3.3765%
Audio cable assembly	0	9.45E-02	0	0	9.45E-02	0.0145%
Barium Carbonate	0	2.97E-01	0	0	2.97E-01	0.0455%
Bauxite (Al2O3, ore)	1.37E+00	0	0	0	1.37E+00	0.2096%
Blue Phosphor (ZnS)	0	3.84E-03	0	0	3.84E-03	0.0006%
Blue Phosphor (ZnS.Ag.Al)	0	1.67E-03	0	0	1.67E-03	0.0003%
Borax	0	8.00E-03	0	0	8.00E-03	0.0012%
Cables/wires	0	3.94E-01	0	0	3.94E-01	0.0604%
Cathode ray tube (CRT)	0	1.07E+01	0	0	1.07E+01	1.6381%
Coal, average (in ground)	3.57E+00	5.15E+00	1.79E+02	1.79E-02	1.88E+02	28.8170%
Connector	0	5.67E-02	0	0	5.67E-02	0.0087%
CRT glass, unspecified	0	9.76E+00	0	0	9.76E+00	1.4950%
CRT magnet assembly	0	7.56E-02	0	0	7.56E-02	0.0116%
CRT shield assembly - ASTM A366/CC#2	0	2.42E-01	0	0	2.42E-01	0.0370%
Deflection Yoke assembly	0	1.51E-01	0	0	1.51E-01	0.0232%
Demagnetic coil - PU coated paper	0	1.26E-01	0	0	1.26E-01	0.0193%
Electron gun	0	1.01E-01	0	0	1.01E-01	0.0154%
Ferrite	0	1.70E-01	0	0	1.70E-01	0.0261%
Frit	0	6.67E-02	0	0	6.67E-02	0.0102%
Fuel oil #4	0	0	0	-9.53E-02	-9.53E-02	-0.0146%
Glass, unspecified	0	4.91E-02	0	0	4.91E-02	0.0075%
Green Phosphor (ZnS)	0	3.34E-03	0	0	3.34E-03	0.0005%
Green Phosphor (ZnS.Cu.Al)	0	1.34E-03	0	0	1.34E-03	0.0002%
Iron (Fe, ore)	6.90E+00	0	0	0	6.90E+00	1.0567%
Iron ore	2.37E-01	0	0	0	2.37E-01	0.0363%
Iron scrap	9.46E-01	0	0	0	9.46E-01	0.1449%
Lead	0	4.94E-01	0	0	4.94E-01	0.0757%
Lead (Pb, ore)	4.96E-01	0	0	0	4.96E-01	0.0759%
Natural gas	0	1.47E+00	1.40E+01	-8.88E-02	1.54E+01	2.3551%
Natural gas (in ground)	8.41E-01	3.27E+00	0	-1.64E+00	2.47E+00	0.3786%
Nickel (Ni, ore)	9.80E-02	0	0	0	9.80E-02	0.0150%
Nickel Alloy (invar)	0	2.72E-01	0	0	2.72E-01	0.0417%
Petroleum (in ground)	1.32E+00	3.72E+02	3.80E+00	-1.52E+00	3.75E+02	57.5016%
Phosphate ester	0	8.31E-03	0	0	8.31E-03	0.0013%
Polycarbonate resin	0	9.23E-01	0	0	9.23E-01	0.1415%
Polystyrene (PS, high impact)	0	1.51E-01	0	0	1.51E-01	0.0232%
Potassium Carbonate	0	3.78E-01	0	0	3.78E-01	0.0579%
Power cord assembly	0	1.13E-01	0	0	1.13E-01	0.0174%
PPE	0	7.35E-01	0	0	7.35E-01	0.1126%
Printed wiring board (PWB)	0	8.47E-01	0	0	8.47E-01	0.1298%
PWB-laminate	0	8.47E-01	0	0	8.47E-01	0.1298%

Table J-1. CRT primary materials (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Recycled CRT Glass	0	2.06E+00	0	0	2.06E+00	0.3155%
Red Phosphor (Y2O2S)	0	4.65E-03	0	0	4.65E-03	0.0007%
Red Phosphor (Y2O2S.Eu)	0	1.33E-03	0	0	1.33E-03	0.0002%
Sand	0	2.40E+00	0	0	2.40E+00	0.3678%
Sand (in ground)	2.42E-05	0	0	0	2.42E-05	3.71E-08
Silica	0	5.33E-03	0	0	5.33E-03	0.0008%
Sodium Carbonate	0	4.88E-01	0	0	4.88E-01	0.0747%
Sodium chloride (NaCl, in ground or in sea)	3.17E-04	0	0	0	3.17E-04	4.85E-07
Solder (63% tin; 37% lead)	0	5.08E-02	0	0	5.08E-02	0.0078%
Solder, unspecified	0	2.67E-02	0	0	2.67E-02	0.0041%
Steel	2.48E-06	5.16E+00	0	0	5.16E+00	0.7907%
Strontium Carbonate	0	3.31E-01	0	0	3.31E-01	0.0508%
Styrene-butadiene copolymers	0	8.27E-01	0	0	8.27E-01	0.1268%
Sulfur	1.03E-05	0	0	0	1.03E-05	1.58E-08
Tricresyl phosphate	0	2.30E-02	0	0	2.30E-02	0.0035%
Triphenyl phosphate	0	5.29E-02	0	0	5.29E-02	0.0081%
Uranium, yellowcake	0	3.81E-04	4.85E-03	4.85E-07	5.23E-03	0.0008%
Video cable assembly	0	1.13E-01	0	0	1.13E-01	0.0174%
Zircon Sand	0	5.43E-02	0	0	5.43E-02	0.0083%
Total Primary Inputs	1.58E+01	4.21E+02	2.19E+02	-3.32E+00	6.53e+02	100.00%

Table J-2. CRT ancillary materials (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
2,2,4-trimethylpentane	0	1.50e-04	0	0	1.50e-04	7.59e-06
Acetone	0	3.17e-04	0	0	3.17e-04	1.60e-05
Acrylic Polymer, unspecified	0	9.13e-03	0	0	9.13e-03	4.61e-04
Alkali cleaning agent	0	7.72e-02	0	0	7.72e-02	3.90e-03
Alkali soda (to neutralize acid waste water)	0	5.45e-02	0	0	5.45e-02	2.75e-03
Aluminum Oxide	0	3.37e-02	0	0	3.37e-02	1.70e-03
Aluminum sulfate	7.41e-04	0	0	0	7.41e-04	3.74e-05
Ammonia	0	1.19e-04	0	0	1.19e-04	6.03e-06
Ammonium bifluoride	0	2.04e-03	0	0	2.04e-03	1.03e-04
Ammonium chloride	0	7.76e-02	0	0	7.76e-02	3.92e-03
Ammonium Dichromate	0	3.50e-05	0	0	3.50e-05	1.76e-06
Ammonium fluoride	0	8.91e-04	0	0	8.91e-04	4.50e-05
Ammonium hydroxide	0	7.90e-02	0	0	7.90e-02	3.99e-03
Ammonium Oxalate	0	8.92e-05	0	0	8.92e-05	4.50e-06
Ammonium Oxalate Monohydrate	0	3.16e-04	0	0	3.16e-04	1.60e-05
Barium sulfate	2.68e-03	0	0	0	2.68e-03	1.35e-04
Barium sulfate (BaSO4, in ground)	1.10e-03	0	0	0	1.10e-03	5.55e-05
Bauxite	6.31e-04	0	0	0	6.31e-04	3.18e-05
Bauxite (Al2O3, ore)	1.10e-03	4.47e-02	0	-1.14e-04	4.57e-02	2.31e-03
Bentonite (in ground)	2.48e-03	0	0	0	2.48e-03	1.25e-04
Borax	5.20e-07	0	0	0	5.20e-07	2.62e-08
Boric acid	0	4.73e-03	0	0	4.73e-03	2.39e-04
Calcium Chloride	0	1.27e-01	0	0	1.27e-01	6.42e-03
Calcium hydroxide	0	9.54e-02	0	0	9.54e-02	4.81e-03
Calcium sulfate	6.08e-05	0	0	0	6.08e-05	3.07e-06
Calcium sulfate (CaSO4, ore)	2.30e-05	0	0	0	2.30e-05	1.16e-06
Cerium Oxide	0	3.28e-03	0	0	3.28e-03	1.65e-04
Chlorine	0	4.03e-02	0	0	4.03e-02	2.04e-03
Chromium (VI)	0	7.63e-05	0	0	7.63e-05	3.85e-06
Chromium ore	1.09e-07	0	0	0	1.09e-07	5.51e-09
Chromium Oxide	0	5.62e-05	0	0	5.62e-05	2.83e-06
Clay (in ground)	4.49e-03	0	0	8.19e+00	8.19e+00	41.35%
Coal, average (in ground)	0	0	0	3.06e-03	3.06e-03	1.55e-04
Copper (Cu, ore)	8.67e-04	0	0	0	8.67e-04	4.37e-05
Cyclohexane	0	1.88e-04	0	0	1.88e-04	9.48e-06
Deoiling agent (unspecified)	1.33e-03	0	0	0	1.33e-03	6.72e-05
Dimethyl Formamide	0	4.36e-05	0	0	4.36e-05	2.20e-06
Dioctyl Sebacate	2.32e-04	0	0	0	2.32e-04	1.17e-05
Dolomite	1.43e-10	0	0	0	1.43e-10	7.24e-12
Dolomite (in ground)	1.60e-05	0	0	0	1.60e-05	8.05e-07
Etoxy Naphtol Sulphonic Acid (ENSA)	9.96e-05	0	0	0	9.96e-05	5.03e-06
Explosive (unspecified)	3.12e-04	0	0	0	3.12e-04	1.57e-05
Ferric chloride	0	1.37e-01	0	0	1.37e-01	6.93e-03
Fluorocarbon resin	0	3.75e-05	0	0	3.75e-05	1.89e-06
Fluorspar (CaF2, ore)	1.69e-06	0	0	0	1.69e-06	8.55e-08
Formaldehyde	0	6.60e-03	0	0	6.60e-03	3.33e-04
Glycol ethers	0	2.35e-02	0	0	2.35e-02	1.19e-03
Gravel/Sand	6.82e-03	0	0	0	6.82e-03	3.44e-04

Table J-2. CRT ancillary materials (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
HV Carbon (paste)	0	1.14e-05	0	0	1.14e-05	5.75e-07
Hydrochloric acid	0	2.36e-01	0	0	2.36e-01	1.19%
Hydrofluoric acid	0	8.65e-02	0	0	8.65e-02	4.36e-03
Hydrogen peroxide	0	8.45e-02	0	0	8.45e-02	4.26e-03
Iron (Fe, ore)	7.23e-02	0	0	3.41e-03	7.57e-02	3.82e-03
Iron ore	1.27e-04	0	0	0	1.27e-04	6.41e-06
Iron sulfate (FeSO4, ore)	2.56e-05	0	0	0	2.56e-05	1.29e-06
Isopentylacetate	0	1.74e-03	0	0	1.74e-03	8.80e-05
Isopropyl alcohol	0	1.94e-02	0	0	1.94e-02	9.80e-04
Lead (Pb, ore)	6.50e-05	0	0	0	6.50e-05	3.28e-06
Lime	0	3.04e-02	1.06e+00	1.06e-04	1.09e+00	5.49%
Limestone	0	6.91e-02	2.41e+00	2.41e-04	2.48e+00	12.51%
Limestone (CaCO3, in ground)	8.60e-01	1.08e+00	0	-2.39e-01	1.70e+00	8.58%
Lubricant (unspecified)	4.11e-02	0	0	0	4.11e-02	2.07e-03
Magnesium	5.08e-04	0	0	0	5.08e-04	2.56e-05
Maize	1.14e-04	0	0	0	1.14e-04	5.74e-06
Manganese (Mn, ore)	6.35e-08	0	0	0	6.35e-08	3.21e-09
Muratic Acid (drum)	0	1.87e-03	0	0	1.87e-03	9.41e-05
Natural gas (in ground)	0	0	0	4.52e-03	4.52e-03	2.28e-04
Nickel (Ni, ore)	2.45e-08	0	0	0	2.45e-08	1.24e-09
Nitric acid	0	1.44e-01	0	0	1.44e-01	7.26e-03
Nitrogen	0	4.57e-02	0	0	4.57e-02	2.31e-03
Oil (in ground)	0	0	0	3.35e-02	3.35e-02	1.69e-03
Olivine	1.08e-10	0	0	0	1.08e-10	5.43e-12
Olivine ore	1.24e-05	0	0	0	1.24e-05	6.27e-07
Oxalic acid	0	5.35e-05	0	0	5.35e-05	2.70e-06
Oxygen (Liquid)	0	7.57e-03	0	0	7.57e-03	3.82e-04
Periodic Acid	0	2.26e-04	0	0	2.26e-04	1.14e-05
Phenolsulphonic Acid	3.12e-03	0	0	0	3.12e-03	1.57e-04
Polyethylene glycol	0	5.04e-02	0	0	5.04e-02	2.55e-03
Polyvinyl alcohol	0	8.11e-03	0	0	8.11e-03	4.09e-04
Polyvinyl Pyrrolidone (PVP)	0	2.41e-02	0	0	2.41e-02	1.22e-03
Potassium chloride (KCl, as K2O, in ground)	1.92e-03	0	0	0	1.92e-03	9.69e-05
Potassium hydroxide	0	4.27e-02	0	0	4.27e-02	2.15e-03
Potassium permanganate	0	1.16e-03	0	0	1.16e-03	5.87e-05
Potassium peroxymonosulfate	0	7.06e-02	0	0	7.06e-02	3.56e-03
Potatoes	3.06e-05	0	0	0	3.06e-05	1.54e-06
Pumice	0	7.86e-02	0	0	7.86e-02	3.97e-03
PWB-solder mask solids	0	4.37e-02	0	0	4.37e-02	2.20e-03
Pyrite (FeS2, ore)	1.94e-01	0	0	0	1.94e-01	9.77e-03
Raw materials (unspecified)	8.16e-03	0	0	0	8.16e-03	4.12e-04
Sand (in ground)	5.85e-02	2.74e-02	0	2.71e+00	2.80e+00	14.13%
Silver (Ag, ore)	2.75e-09	0	0	0	2.75e-09	1.39e-10
Sodium Carbonate	0	3.22e-02	0	0	3.22e-02	1.63e-03
Sodium chloride	0	0	0	1.55e-04	1.55e-04	7.80e-06
Sodium chloride (NaCl, in ground or in sea)	7.61e-01	1.26e-02	0	-3.07e-05	7.73e-01	3.90%
Sodium Dichromate	2.63e-04	1.05e-04	0	0	3.68e-04	1.86e-05
Sodium Dichromate Dihydrate (VI)	0	3.10e-05	0	0	3.10e-05	1.56e-06

Table J-2. CRT ancillary materials (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Sodium hydroxide	0	1.98e-01	0	0	1.98e-01	9.97e-03
Sodium Hypochlorite	0	9.25e-05	0	0	9.25e-05	4.67e-06
Sodium Metabisulfite	0	4.67e-03	0	0	4.67e-03	2.36e-04
Sodium Persulfate	0	3.54e-04	0	0	3.54e-04	1.79e-05
Sulfur	3.28e-03	0	0	0	3.28e-03	1.66e-04
Sulfur (S, in ground)	5.39e-03	0	0	0	5.39e-03	2.72e-04
Sulfuric acid	0	2.38e-01	0	0	2.38e-01	1.20%
Sulfuric acid, aluminum salt	0	6.75e-02	0	0	6.75e-02	3.41e-03
Surfactant, unspecified	0	1.42e-04	0	0	1.42e-04	7.17e-06
Synthetic resin, unspecified	0	8.53e-04	0	0	8.53e-04	4.30e-05
Talcum (ore)	8.89e-03	0	0	0	8.89e-03	4.49e-04
Tin (Sn, ore)	2.43e-02	0	0	0	2.43e-02	1.23e-03
Toluene	0	4.80e-03	0	0	4.80e-03	2.42e-04
unspecified CRT process material	0	5.77e-03	0	0	5.77e-03	2.91e-04
Uranium (U, ore)	0	0	0	4.16e-08	4.16e-08	2.10e-09
Wastepaper	1.70e-03	0	0	0	1.70e-03	8.59e-05
Xylene (mixed isomers)	0	4.80e-04	0	0	4.80e-04	2.42e-05
Zinc (Zn, ore)	3.79e-02	0	0	0	3.79e-02	1.91e-03
Total ancillary materials	2.11e+00	3.54e+00	3.47e+00	1.07e+01	1.98e+01	100.00%

Table J-3. CRT utility inputs

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Fuels (kg/functional unit):						
Fuel Oil #2 (distillate)	0	1.16e+00	0	0	1.16e+00	0.27%
Fuel oil #4 (avg. of #2 + #6)	0	1.37e-01	0	-1.38e+00	-1.24e+00	-0.29%
Fuel oil #6 (residual)	0	3.68e+00	0	0	3.68e+00	0.85%
LNG	0	3.35e-01	0	0	3.35e-01	0.08%
LPG	0	3.51e+02	0	3.03e-03	3.51e+02	81.10%
Natural gas	0	2.44e+00	0	-1.30e+00	1.14e+00	0.26%
Coal, average (in ground)	2.25e+00	1.36e+01	0	-1.16e-02	1.58e+01	3.66%
Coal, lignite (in ground)	9.73e-01	0	0	0	9.73e-01	0.22%
Natural gas (in ground)	2.76e+00	4.56e+01	0	-2.09e-01	4.82e+01	11.14%
Petroleum (in ground)	2.02e+00	9.71e+00	0	-5.77e-02	1.17e+01	2.70%
Uranium (U, ore)	1.21e-04	2.29e-04	0	-1.99e-07	3.49e-04	8.06E-07
Total fuels	8.00e+00	4.28e+02	0	-2.95e+00	4.33e+02	100.00%
Electricity (MJ/functional unit):						
Electricity	7.32e+01	1.29e+02	2.29e+03	2.29e-01	2.49e+03	
Water (kg or L/functional unit):						
Water	5.54e+02	1.14e+04	1.14e+03	-2.73e+01	1.31e+04	
Total energy (fuels and electricity, MJ/functional unit):						
Energy	3.66e+02	1.83e+04	2.29e+03	-1.28e+02	2.08e+04	

Table J-4. CRT air pollutant emissions (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
1,1,1-Trichloroethane	0	2.31e-07	1.92e-06	-3.01e-08	2.12e-06	3.19e-09
1,2-Dichloroethane		3.74e-07	3.59e-06	-5.75e-08	3.90e-06	5.88e-09
1,2-Dichlorotetrafluoroethane	3.38e-07	0	0	0	3.38e-07	5.09e-10
1,4-Dichlorobenzene	0	3.06e-07	0	-2.26e-09	3.03e-07	4.57e-10
2,3,7,8-TCDD	0	3.73e-14	1.28e-12	1.28e-16	1.32e-12	1.99e-15
2,3,7,8-TCDF	0	1.31e-13	4.57e-12	4.58e-16	4.71e-12	7.09e-15
2,4-Dinitrotoluene	0	2.62e-09	2.51e-08	-4.22e-10	2.73e-08	4.11e-11
2-Chloroacetophenone	0	6.55e-08	6.28e-07	-1.46e-10	6.93e-07	1.04e-09
2-Methylnaphthalene	0	6.39e-09	2.67e-09	-5.37e-11	9.01e-09	1.36e-11
3-Methylcholanthrene	0	4.59e-10	0	-4.04e-12	4.54e-10	6.84e-13
5-Methyl chrysene	0	2.06e-10	1.97e-09	-3.32e-11	2.15e-09	3.23e-12
Acenaphthene	0	1.05e-08	5.68e-08	-7.77e-10	6.65e-08	1.00e-10
Acenaphthylene	0	2.86e-09	2.26e-08	-3.81e-10	2.50e-08	3.77e-11
Acetaldehyde	2.16e-06	5.33e-06	5.11e-05	-8.59e-07	5.78e-05	8.70e-08
Acetic acid	1.86e-05	0	0	0	1.86e-05	2.80e-08
Acetone	2.14e-06	0	0	0	2.14e-06	3.22e-09
Acetophenone	0	1.40e-07	1.35e-06	-2.26e-08	1.46e-06	2.20e-09
Acetylene	3.64e-05	0	0	0	3.64e-05	5.48e-08
Acrolein	2.38e-11	2.71e-06	2.60e-05	-4.37e-07	2.83e-05	4.26e-08
Adsorbable organic halides	1.14e-16	0	0	0	1.14e-16	1.71e-19
Alcohols	7.89e-06	0	0	0	7.89e-06	1.19e-08
Aldehydes	1.13e-04	1.52e-03	0	-1.63e-04	1.47e-03	2.21e-06
Alkane (unspecified)	3.37e-04	0	0	0	3.37e-04	5.07e-07
Alkenes	6.21e-05	0	0	0	6.21e-05	9.35e-08
Alkyne (unspecified)	4.10e-06	0	0	0	4.10e-06	6.18e-09
Aluminum (elemental)	3.35e-04	1.98e-05	0	-8.66e-08	3.55e-04	5.34e-07
Ammonia	4.36e-04	2.35e-03	0	-1.06e-04	2.68e-03	4.04e-06
Anthracene	0	2.88e-09	1.21e-10	-3.22e-10	2.68e-09	4.04e-12
Antimony	4.36e-07	1.66e-06	3.59e-06	-6.55e-08	5.61e-06	8.45e-09
Aromatic hydrocarbons	3.73e-04	5.29e-08	0	-1.37e-10	3.73e-04	5.61e-07
Arsenic	1.53e-04	1.54e-05	3.75e-05	-2.64e-06	2.03e-04	3.06e-07
Barium	5.18e-06	8.85e-07	2.06e-06	-2.45e-08	8.10e-06	1.22e-08
Benzaldehyde	1.26e-11	0	0	0	1.26e-11	1.90e-14
Benzene	6.17e-05	1.58e-02	1.17e-04	-7.31e-04	1.52e-02	2.29e-05
Benzo[a]anthracene	0	2.21e-09	9.27e-09	-1.25e-10	1.14e-08	1.71e-11
Benzo[a]pyrene	1.35e-06	7.92e-10	3.41e-09	-6.06e-11	1.35e-06	2.03e-09
Benzo[b,j,k]fluoranthene	0	1.30e-09	1.06e-08	-1.66e-10	1.18e-08	1.77e-11
Benzo[b]fluoranthene	0	5.07e-10	0	-4.23e-12	5.03e-10	7.58e-13
Benzo[g,h,i]perylene	0	1.05e-09	3.60e-09	-4.36e-11	4.61e-09	6.94e-12
Benzo[k]fluoranthene	0	5.07e-10	0	-4.23e-12	5.03e-10	7.58e-13
Benzyl chloride	0	6.55e-06	6.28e-05	-1.06e-06	6.83e-05	1.03e-07
Beryllium	7.37e-08	1.49e-06	1.91e-06	-3.06e-07	3.16e-06	4.76e-09
Biphenyl	0	1.59e-08	1.52e-07	-2.56e-09	1.66e-07	2.50e-10
Boron	7.51e-05	0	0	0	7.51e-05	1.13e-07
Bromine	3.80e-06	0	0	0	3.80e-06	5.72e-09
Bromium (Br)	7.09e-07	0	0	0	7.09e-07	1.07e-09
Bromoform	0	3.65e-07	3.50e-06	-5.88e-08	3.80e-06	5.73e-09
Bromomethane	0	1.50e-06	1.43e-05	-2.41e-07	1.56e-05	2.35e-08

Table J-4. CRT air pollutant emissions (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Butane	4.16e-05	5.35e-04	0	-4.72e-06	5.72e-04	8.61e-07
Butene	3.56e-07	0	0	0	3.56e-07	5.37e-10
Cadmium	6.60e-06	1.04e-06	4.82e-06	-6.37e-08	1.24e-05	1.87e-08
Calcium	3.01e-04	1.72e-05	0	-7.51e-08	3.18e-04	4.80e-07
Carbon	3.64e-07	0	0	0	3.64e-07	5.49e-10
Carbon dioxide	2.92e+01	1.79e+02	4.45e+02	2.59e+00	6.55e+02	98.68%
Carbon disulfide	0	1.22e-06	1.17e-05	-1.96e-07	1.27e-05	1.91e-08
Carbon monoxide	4.18e-02	4.58e-01	8.09e-02	-4.17e-03	5.76e-01	8.68e-04
Carbon tetrachloride	0	0	0	2.84e-09	2.84e-09	4.27e-12
CFC-13	5.04e-10	0	0	0	5.04e-10	7.58e-13
Chloride ions	3.06e-04	9.83e-05	1.82e-04	-2.54e-06	5.83e-04	8.78e-07
Chlorine	1.09e-06	5.84e-09	0	-2.72e-10	1.10e-06	1.65e-09
Chloroacetophenone	0	0	0	-1.04e-08	-1.04e-08	-1.57e-11
Chlorobenzene	0	2.06e-07	1.97e-06	-3.32e-08	2.15e-06	3.23e-09
Chloroform	0	5.52e-07	5.29e-06	-8.61e-08	5.76e-06	8.67e-09
Chromium	0	1.39e-07	0	0	1.39e-07	2.09e-10
Chromium (III)	7.72e-07	2.22e-05	2.45e-09	-2.14e-06	2.09e-05	3.14e-08
Chromium (VI)	7.72e-07	2.15e-05	7.21e-06	-2.14e-06	2.74e-05	4.12e-08
Chrysene	0	1.91e-09	1.02e-08	-1.55e-10	1.20e-08	1.80e-11
Cobalt	1.01e-06	3.92e-06	1.22e-05	-2.01e-07	1.69e-05	2.54e-08
Copper	4.71e-05	1.91e-06	9.96e-07	-2.54e-08	5.00e-05	7.52e-08
Cumene	0	4.35e-08	4.75e-07	-7.99e-09	5.11e-07	7.69e-10
Cumene hydroperoxide	0	6.06e-09	0	0	6.06e-09	9.12e-12
Cyanide (-1)	1.34e-07	2.34e-05	2.24e-04	-3.77e-06	2.44e-04	3.67e-07
Di(2-ethylhexyl)phthalate	0	6.83e-07	6.55e-06	-1.10e-07	7.12e-06	1.07e-08
Dibenzo[a,h]anthracene	0	6.71e-10	8.74e-10	-2.82e-12	1.54e-09	2.32e-12
Dichlorobenzene (mixed isomers)	0	0	0	-4.36e-10	-4.36e-10	-6.56e-13
Dichlorodifluoromethane	8.02e-10	0	0	0	8.02e-10	1.21e-12
Dichloromethane	0	2.71e-06	2.60e-05	-4.33e-07	2.83e-05	4.26e-08
Dimethyl Formamide	0	3.49e-05	0	0	3.49e-05	5.25e-08
Dimethyl sulfate	0	4.49e-07	4.30e-06	-7.24e-08	4.68e-06	7.05e-09
Dimethylbenzanthracene	0	3.82e-09	0	-3.39e-11	3.79e-09	5.70e-12
Dioxins, remaining unspeciated	2.79e-13	1.11e-10	5.84e-11	2.11e-10	3.81e-10	5.73e-13
Ethane	5.59e-04	7.90e-04		-6.97e-06	1.34e-03	2.02e-06
Ethanethiol	6.74e-07	0	0	0	6.74e-07	1.01e-09
Ethanol	9.49e-06	0	0	0	9.49e-06	1.43e-08
Ethyl Chloride	0	3.93e-07	3.77e-06	-6.33e-08	4.10e-06	6.17e-09
Ethylbenzene	2.25e-06	8.97e-07	8.46e-06	-1.32e-07	1.15e-05	1.73e-08
Ethylene	4.48e-04	0	0	0	4.48e-04	6.75e-07
Ethylene dibromide	0	1.12e-08	1.08e-07	-1.81e-09	1.17e-07	1.76e-10
Fluoranthene	0	8.56e-09	6.71e-08	-1.08e-09	7.46e-08	1.12e-10
Fluorene	0	1.02e-08	8.39e-08	-1.38e-09	9.28e-08	1.40e-10
Fluoride	2.12e-07	3.12e-07	1.95e-05	1.95e-09	2.01e-05	3.02e-08
Fluorides (F-)	6.70e-07	3.98e-05	0	-3.15e-07	4.01e-05	6.04e-08
Fluorine	8.94e-10	0	0	0	8.94e-10	1.35e-12
Formaldehyde	2.04e-05	1.24e-03	8.46e-05	-8.83e-06	1.33e-03	2.01e-06
Furans, remaining unspeciated	0	5.13e-10	9.32e-11	-1.14e-10	4.92e-10	7.41e-13
Halogenated hydrocarbons (unspecified)	2.27e-06	2.94e-13	0	-7.58e-16	2.27e-06	3.41e-09

Table J-4. CRT air pollutant emissions (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Halogenated matter (unspecified)	1.86e-11	0	0	0	1.86e-11	2.79e-14
HALON-1301	5.81e-07	5.11e-10	0	-1.33e-12	5.82e-07	8.76e-10
HCFC-22	2.66e-09	0	0	0	2.66e-09	4.01e-12
Heptane	1.54e-05	0	0	0	1.54e-05	2.33e-08
Hexane	6.97e-06	4.59e-04	6.01e-06	-4.15e-06	4.68e-04	7.05e-07
HFC-125	4.54e-09	0	0	0	4.54e-09	6.84e-12
Hydrocarbons, remaining unspeciated	1.28e-02	1.58e-01	0	-6.12e-04	1.70e-01	2.57e-04
Hydrochloric acid	2.39e-03	1.12e-02	1.08e-01	-1.04e-03	1.20e-01	1.81e-04
Hydrofluoric acid	5.54e-04	1.40e-03	1.35e-02	-2.26e-04	1.52e-02	2.29e-05
Hydrogen	2.96e-04	0	0	0	2.96e-04	4.46e-07
Hydrogen cyanide	1.54e-10	0	0	0	1.54e-10	2.32e-13
Hydrogen sulfide	4.49e-05	3.11e-03	0	-1.31e-05	3.14e-03	4.73e-06
Indeno(1,2,3-cd)pyrene	0	1.50e-09	6.59e-09	-9.62e-11	7.99e-09	1.20e-11
Iodine	9.41e-07	0	0	0	9.41e-07	1.42e-09
Iron	2.36e-04	3.83e-05	0	-1.67e-07	2.74e-04	4.13e-07
Isophorone	0	5.43e-06	5.20e-05	-8.74e-07	5.66e-05	8.52e-08
Isopropylpropionate	4.01e-10	0	0	0	4.01e-10	6.04e-13
Lanthanum	8.40e-08	0	0	0	8.40e-08	1.27e-10
Lead	1.66e-03	1.30e-05	1.27e-05	1.42e-05	1.70e-03	2.55e-06
Lead (Pb, ore)	0	4.41e-07	0	0	4.41e-07	6.64e-10
Magnesium	1.57e-04	1.03e-04	9.86e-04	-1.66e-05	1.23e-03	1.85e-06
Manganese	1.96e-06	2.33e-05	4.56e-05	-4.99e-06	6.59e-05	9.93e-08
Manganese (Mn, ore)	0	1.09e-06	0	0	1.09e-06	1.64e-09
Mercaptans	2.07e-07	0	0	0	2.07e-07	3.12e-10
Mercury	3.00e-06	1.12e-06	7.51e-06	-1.15e-07	1.15e-05	1.73e-08
Metals, remaining unspeciated	1.21e-04	3.16e-07	0	-1.08e-09	1.22e-04	1.83e-07
Methane	6.40e-02	9.08e-01	6.45e-01	-4.30e-02	1.57e+00	2.37e-03
Methanol	6.73e-06	0	0	0	6.73e-06	1.01e-08
Methyl chloride	0	4.96e-06	4.75e-05	-7.99e-07	5.17e-05	7.78e-08
Methyl ethyl ketone	0	3.65e-06	3.50e-05	-5.88e-07	3.80e-05	5.73e-08
Methyl hydrazine	0	1.59e-06	1.52e-05	-2.56e-07	1.66e-05	2.50e-08
Methyl methacrylate	0	1.87e-07	1.79e-06	-3.02e-08	1.95e-06	2.94e-09
Methyl tert-butyl ether	0	3.27e-07	3.14e-06	-5.28e-08	3.41e-06	5.14e-09
Molybdenum	4.61e-07	2.13e-06	5.84e-07	-2.06e-08	3.15e-06	4.75e-09
Naphthalene	1.49e-08	6.04e-07	1.83e-06	-2.92e-08	2.42e-06	3.64e-09
Nickel	4.13e-05	1.39e-04	6.85e-05	-4.59e-06	2.45e-04	3.68e-07
Nitrogen dioxide	5.76e-02	0	0	1.85e-03	5.95e-02	8.96e-05
Nitrogen oxides	6.99e-03	6.95e-01	1.18e+00	-1.90e-02	1.86e+00	2.80e-03
Nitrous oxide	9.47e-04	1.66e-02	3.40e-03	-1.11e-03	1.98e-02	2.99e-05
Nonmethane hydrocarbons, remaining unspeciated	9.97e-02	1.10e-01	0	-1.91e-03	2.08e-01	3.13e-04
n-Propane	1.50e-04	1.69e-06	0	-3.70e-07	1.51e-04	2.27e-07
Other organics	5.60e-04	7.83e-02	0	-3.65e-03	7.52e-02	1.13e-04
o-xylene	0	1.13e-06	5.71e-08	-3.79e-08	1.15e-06	1.73e-09
Pentachlorobenzene	1.93e-15	0	0	0	1.93e-15	2.91e-18
Pentachlorophenol	3.12e-16	0	0	0	3.12e-16	4.71e-19
Pentane	3.47e-05	6.62e-04	0	-5.84e-06	6.91e-04	1.04e-06
Perfluoroethane	1.44e-05	0	0	0	1.44e-05	2.17e-08
Perfluoromethane	1.30e-04	0	0	0	1.30e-04	1.95e-07

Table J-4. CRT air pollutant emissions (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Phenanthrene	0	3.22e-08	2.51e-07	-4.11e-09	2.79e-07	4.20e-10
Phenol	2.93e-06	1.50e-07	1.43e-06	-2.41e-08	4.49e-06	6.77e-09
Phosphorus (yellow or white)	1.91e-06	1.26e-05	4.95e-06	-1.20e-07	1.94e-05	2.92e-08
Phosphorus pentoxide	8.18e-10	0	0	0	8.18e-10	1.23e-12
PM	1.28e-01	1.31e-01	0	-1.88e-02	2.40e-01	3.62e-04
PM-10	0	3.15e-03	5.78e-02	4.78e-06	6.09e-02	9.17e-05
Polycyclic aromatic hydrocarbons	1.87e-05	5.87e-11	0	-1.52e-13	1.87e-05	2.82e-08
Potassium	4.90e-05	0	0	0	4.90e-05	7.37e-08
Propionaldehyde	4.61e-13	3.55e-06	3.41e-05	-5.73e-07	3.71e-05	5.58e-08
Propionic acid	2.03e-10	0	0	0	2.03e-10	3.06e-13
Propylene	3.77e-05	0	0	0	3.77e-05	5.68e-08
Pyrene	0	5.44e-09	3.33e-08	-5.09e-10	3.82e-08	5.76e-11
Scandium	2.04e-08	0	0	0	2.04e-08	3.08e-11
Selenium	4.69e-07	1.29e-05	1.17e-04	-1.96e-06	1.28e-04	1.93e-07
Silicon	1.06e-03	1.72e-05	0	-7.51e-08	1.08e-03	1.62e-06
Sodium	2.88e-05	1.02e-04	0	-4.45e-07	1.30e-04	1.96e-07
Strontium	5.83e-06	0	0	0	5.83e-06	8.78e-09
Styrene	0	2.34e-07	2.24e-06	-3.77e-08	2.44e-06	3.67e-09
Sulfur dioxide	3.37e-01	1.26e-01	2.49e+00	8.30e-04	2.96e+00	4.45e-03
Sulfur oxides	5.71e-03	8.20e-01	0	-2.97e-02	7.96e-01	1.20e-03
Sulfuric acid	8.81e-07	0	0	0	8.81e-07	1.33e-09
Tars (unspecified)	9.87e-13	0	0	0	9.87e-13	1.49e-15
Tetrachloroethylene	0	4.02e-07	3.86e-06	-6.20e-08	4.20e-06	6.32e-09
Thallium	1.39e-08	0	0	0	1.39e-08	2.10e-11
Thorium	4.51e-08	0	0	0	4.51e-08	6.79e-11
Tin	2.62e-08	0	0	0	2.62e-08	3.94e-11
Titanium	1.00e-05	0	0	0	1.00e-05	1.51e-08
TOCs, remaining unspeciated	0	2.89e-04	5.76e-03	5.76e-07	6.05e-03	9.11e-06
Toluene	2.17e-05	3.84e-03	2.54e-05	-3.87e-07	3.89e-03	5.86e-06
Trichloroethylene	0	0	0	2.84e-09	2.84e-09	4.27e-12
Trichlorofluoromethane	8.27e-09	0	0	0	8.27e-09	1.25e-11
Uranium	4.43e-08	0	0	0	4.43e-08	6.67e-11
Vanadium	6.77e-05	2.74e-04	1.76e-05	-1.39e-06	3.57e-04	5.38e-07
Vinyl acetate	0	7.11e-08	6.82e-07	-1.15e-08	7.41e-07	1.12e-09
Vinyl chloride	0	0	0	5.67e-09	5.67e-09	8.54e-12
VOCs, remaining unspeciated	1.10e-03	0	0	0	1.10e-03	1.65e-06
Waste metals, unspecified	1.45e-05	0	0	0	1.45e-05	2.18e-08
Xylene (mixed isomers)	3.65e-05	3.84e-04	3.32e-06	-6.94e-09	4.24e-04	6.38e-07
Zinc (elemental)	5.84e-04	1.56e-05	1.52e-05	-2.78e-07	6.15e-04	9.26e-07
Zirconium	2.14e-08	0	0	0	2.14e-08	3.23e-11
Total air pollutants	3.00e+01	1.83e+02	4.49e+02	2.47e+00	6.64e+02	100.00%

Table J-5. CRT water outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
WASTEWATER STREAMS							
Wastewater stream	surface water	1.70e+01	1.41e+03	0	-3.65e+00	1.42e+03	93.76%
Wastewater stream	treatment	0	9.48e+01	0	0	9.48e+01	6.24%
Total wastewater streams		1.70e+01	1.51e+03	0.00e+00	-3.65e+00	1.52e+03	100.00%
WATER POLLUTANTS							
1,1,1-Trichloroethane	surface water	1.70e-13	0	0	0	1.70e-13	8.15e-15
1,2-Dichloroethane	surface water	0	0	0	8.41e-11	8.41e-11	4.03e-12
Acetic acid	surface water	1.49e-09	0	0	0	1.49e-09	7.16e-11
Acids (H+)	surface water	1.52e-04	1.03e-07	0	-4.78e-09	1.53e-04	7.30e-06
Adsorbable organic halides	surface water	1.04e-05	3.76e-10	0	-9.75e-13	1.04e-05	4.97e-07
Alcohols	surface water	1.19e-07	0	0	0	1.19e-07	5.71e-09
Aldehydes	surface water	3.10e-09	0	0	0	3.10e-09	1.48e-10
Alkane (unspecified)	surface water	6.77e-06	0	0	0	6.77e-06	3.24e-07
Alkenes	surface water	5.27e-07	0	0	0	5.27e-07	2.52e-08
Aluminum (+3)	surface water	2.74e-03	1.43e-04	0	-3.70e-07	2.89e-03	1.38e-04
Aluminum hydroxide	surface water	1.39e-09	0	0	0	1.39e-09	6.65e-11
Ammonia	surface water	1.86e-04	0	0	-4.05e-06	1.81e-04	8.69e-06
Ammonia ions	surface water	3.54e-06	2.76e-02	0	-6.63e-05	2.75e-02	1.32e-03
Aromatic hydrocarbons	surface water	3.00e-05	8.81e-08	0	-2.28e-10	3.01e-05	1.44e-06
Arsenic cmpds	surface water	5.47e-06	0	0	1.35e-08	5.48e-06	2.63e-07
Barium cmpds	surface water	3.53e-04	2.82e-07	0	4.03e-07	3.53e-04	1.69e-05
Barium sulfate	surface water	6.71e-04	0	0	0	6.71e-04	3.21e-05
Benzene	surface water	7.40e-06	0	0	8.41e-11	7.40e-06	3.54e-07
BOD	surface water	3.93e-04	1.95e-01	0	-4.65e-04	1.95e-01	9.34e-03
Boric acid	surface water	1.77e-06	0	0	0	1.77e-06	8.49e-08
Boron (B III)	surface water	1.75e-06	0	0	0	1.75e-06	8.39e-08
Cadmium cmpds	surface water	5.59e-07	2.94e-10	0	8.03e-10	5.60e-07	2.68e-08
Calcium (+2)	surface water	4.96e-03	0	0	0	4.96e-03	2.38e-04
Carbon tetrachloride	surface water	0	0	0	8.41e-11	8.41e-11	4.03e-12
Carbonate ion	surface water	4.83e-03	0	0	0	4.83e-03	2.31e-04
Cesium (+2)	surface water	1.93e-08	0	0	0	1.93e-08	9.24e-10
Chloride ions	surface water	4.29e-01	6.48e+00	0	-2.39e-02	6.88e+00	32.95%
Chlorine	surface water	8.94e-07	0	0	0	8.94e-07	4.28e-08
Chloroform	surface water	1.75e-11	0	0	8.41e-11	1.02e-10	4.87e-12
Chromium	surface water	8.20e-08	0	0	0	8.20e-08	3.93e-09
Chromium (III)	surface water	2.73e-05	3.77e-08	0	1.32e-08	2.74e-05	1.31e-06
Chromium (VI)	surface water	4.68e-07	3.77e-08	0	1.32e-08	5.19e-07	2.49e-08
Chromium ore	surface water	0	1.02e-05	0	0	1.02e-05	4.90e-07
Chromium ore	treatment	0	1.03e-06	0	0	1.03e-06	4.95e-08
Cobalt (Co I, Co II, Co III)	surface water	2.45e-06	0	0	0	2.45e-06	1.17e-07
COD	surface water	1.00e-02	1.60e+00	0	-3.94e-03	1.61e+00	7.71%
COD	treatment	0	8.33e-03	0	0	8.33e-03	3.99e-04
Copper	surface water	0	1.80e-06	0	0	1.80e-06	8.63e-08
Copper (+1 & +2)	surface water	1.61e-05	5.87e-09	0	-1.52e-11	1.61e-05	7.70e-07
Copper (+1 & +2)	treatment	0	9.71e-05	0	0	9.71e-05	4.65e-06
Cyanide (-1)	surface water	1.85e-06	6.06e-07	0	-1.07e-12	2.46e-06	1.18e-07
Dichloromethane	surface water	5.02e-08	0	0	1.35e-10	5.03e-08	2.41e-09
Dissolved organic matter (chlorinated)	surface water	2.27e-06	0	0	0	2.27e-06	1.08e-07
Dissolved organics	surface water	5.54e-04	2.71e-07	0	-1.26e-08	5.55e-04	2.66e-05

Table J-5. CRT water outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Dissolved solids	surface water	5.30e-03	3.62e+00	0	-8.77e-05	3.62e+00	17.36%
Dissolved solids	treatment	0	8.01e-02	0	0	8.01e-02	3.84e-03
Edetic acid (EDTA)	surface water	3.01e-09	0	0	0	3.01e-09	1.44e-10
Ethylbenzene	surface water	6.70e-07	0	0	3.04e-10	6.71e-07	3.21e-08
Fluoride	surface water	1.89e-05	3.45e-03	0	0	3.47e-03	1.66e-04
Fluoride	treatment	0	3.51e-04	0	0	3.51e-04	1.68e-05
Fluorides (F-)	surface water	9.63e-05	2.97e-03	0	-7.72e-06	3.06e-03	1.46e-04
Formaldehyde	surface water	2.20e-13	0	0	0	2.20e-13	1.05e-14
Halogenated matter (organic)	surface water	2.71e-10	1.17e-10	0	-3.05e-13	3.88e-10	1.86e-11
Hexachloroethane	surface water	3.09e-17	0	0	0	3.09e-17	1.48e-18
Hydrazine	surface water	1.38e-09	0	0	0	1.38e-09	6.62e-11
Hydrocarbons, remaining unspeciated	surface water	1.58e-04	3.52e-04	0	-4.25e-07	5.09e-04	2.44e-05
Hypochlorite	surface water	5.26e-09	0	0	0	5.26e-09	2.52e-10
Hypochlorous acid	surface water	5.26e-09	0	0	0	5.26e-09	2.52e-10
Iodide (-1)	surface water	3.23e-06	0	0	0	3.23e-06	1.54e-07
Iron	surface water	0	2.93e-03	0	0	2.93e-03	1.40e-04
Iron (+2 & +3)	surface water	1.76e-03	3.55e-07	0	-1.57e-08	1.76e-03	8.42e-05
Lead	surface water	0	4.64e-05	0	0	4.64e-05	2.22e-06
Lead	treatment	0	1.03e-06	0	0	1.03e-06	4.95e-08
Lead cmpds	surface water	1.59e-05	1.17e-09	0	1.60e-09	1.59e-05	7.59e-07
Lead cmpds	treatment	0	1.62e-05	0	0	1.62e-05	7.75e-07
Lithium salts	surface water	1.55e-10	0	0	0	1.55e-10	7.40e-12
Magnesium (+2)	surface water	2.68e-03	0	0	0	2.68e-03	1.28e-04
Manganese	surface water	0	3.60e-06	0	0	3.60e-06	1.73e-07
Manganese cmpds	surface water	1.02e-04	0	0	0	1.02e-04	4.88e-06
Mercury compounds	surface water	9.68e-07	1.35e-12	0	4.33e-11	9.68e-07	4.63e-08
Metals, remaining unspeciated	surface water	6.74e-04	9.75e-03	0	-3.42e-05	1.04e-02	4.98e-04
Molybdenum	surface water	0	1.20e-07	0	0	1.20e-07	5.77e-09
Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	surface water	8.27e-06	0	0	0	8.27e-06	3.96e-07
Morpholine	surface water	1.46e-08	0	0	0	1.46e-08	7.01e-10
Nickel	surface water	0	7.94e-05	0	0	7.94e-05	3.80e-06
Nickel (+2)	surface water	6.69e-07	0	0	0	6.69e-07	3.20e-08
Nickel cmpds	surface water	1.75e-05	5.87e-10	0	-1.52e-12	1.75e-05	8.38e-07
Nitrate	surface water	9.24e-05	6.10e-05	0	-1.96e-06	1.51e-04	7.25e-06
Nitrates/nitrites	surface water	2.29e-05	3.95e-06	0	0	2.69e-05	1.29e-06
Nitrites	surface water	1.91e-06	0	0	0	1.91e-06	9.15e-08
Nitrogen	surface water	4.46e-05	7.18e-03	0	0	7.23e-03	3.46e-04
Nitrogen dioxide	surface water	6.20e-04	0	0	0	6.20e-04	2.97e-05
Oil & grease	surface water	0	7.46e-03	0	0	7.46e-03	3.57e-04
Other nitrogen	surface water	5.28e-04	1.59e-08	0	-4.11e-11	5.28e-04	2.53e-05
Other organics	surface water	3.98e-05	0	0	0	3.98e-05	1.90e-06
Oxalic acid	surface water	6.02e-09	0	0	0	6.02e-09	2.88e-10
o-xylene	surface water	0	0	0	7.84e-10	7.84e-10	3.76e-11
Phenol	surface water	6.25e-05	3.63e-03	0	-9.41e-06	3.68e-03	1.76e-04
Phosphate (PO43-)	surface water	1.75e-04	0	0	0	1.75e-04	8.39e-06
Phosphate as P2O5	surface water	0	1.21e-06	0	0	1.21e-06	5.80e-08
Phosphates	surface water	3.36e-05	5.85e-07	0	6.93e-09	3.42e-05	1.64e-06
Phosphorus (yellow or white)	surface water	3.94e-06	5.05e-05	0	0	5.44e-05	2.61e-06

Table J-5. CRT water outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Phosphorus pentoxide	surface water	2.45e-08	0	0	0	2.45e-08	1.18e-09
Polycyclic aromatic hydrocarbons	surface water	7.88e-06	1.41e-09	0	-3.66e-12	7.88e-06	3.77e-07
Potassium (+1)	surface water	1.12e-03	0	0	0	1.12e-03	5.38e-05
Rubidium ion (Rb+)	surface water	1.93e-07	0	0	0	1.93e-07	9.26e-09
Salts (unspecified)	surface water	1.71e-03	1.62e-03	0	-4.21e-06	3.33e-03	1.59e-04
Sand	surface water	1.80e-08	0	0	0	1.80e-08	8.62e-10
Saponifiable oils and fats	surface water	2.38e-04	0	0	0	2.38e-04	1.14e-05
Selenium	surface water	1.34e-05	0	0	8.15e-11	1.34e-05	6.44e-07
Silver compounds	surface water	1.16e-08	0	0	2.55e-09	1.41e-08	6.78e-10
Sodium	surface water	9.07e-05	0	0	0	9.07e-05	4.34e-06
Sodium (+1)	surface water	2.90e-01	7.04e+00	0	-3.08e-02	7.30e+00	34.94%
Strontium (Sr II)	surface water	3.73e-04	0	0	0	3.73e-04	1.79e-05
Sulfate ion (-4)	surface water	3.75e-02	9.61e-04	0	-1.85e-06	3.84e-02	1.84e-03
Sulfate ion (-4)	treatment	0	1.09e-03	6.84e-02	6.84e-06	6.95e-02	3.33e-03
Sulfide	surface water	3.99e-06	5.97e-08	0	-2.64e-09	4.05e-06	1.94e-07
Sulfites	surface water	1.73e-06	0	0	0	1.73e-06	8.27e-08
Sulfur	surface water	3.32e-11	0	0	0	3.32e-11	1.59e-12
Suspended solids	surface water	7.72e-03	8.69e-01	0	-2.11e-03	8.74e-01	4.19%
Suspended solids	treatment	0	1.29e-03	1.78e-03	1.78e-07	3.07e-03	1.47e-04
Tars (unspecified)	surface water	1.53e-14	0	0	0	1.53e-14	7.34e-16
Tetrachloroethylene	surface water	7.61e-14	0	0	8.41e-11	8.42e-11	4.03e-12
Tin (Sn++, Sn4+)	surface water	1.35e-04	0	0	0	1.35e-04	6.45e-06
Titanium tetrachloride	surface water	1.59e-04	0	0	0	1.59e-04	7.60e-06
TOCs	surface water	2.85e-03	8.81e-07	0	-2.28e-09	2.86e-03	1.37e-04
Toluene	surface water	8.52e-06	1.29e-08	0	2.90e-09	8.54e-06	4.09e-07
Trichloroethylene	surface water	4.68e-12	0	0	8.41e-11	8.88e-11	4.25e-12
Triethylene glycol	surface water	1.00e-05	0	0	0	1.00e-05	4.81e-07
Vanadium (V3+, V5+)	surface water	1.42e-05	0	0	0	1.42e-05	6.78e-07
Vinyl chloride	surface water	0	0	0	1.69e-10	1.69e-10	8.07e-12
VOCs, remaining unspeciated	surface water	6.75e-06	0	0	0	6.75e-06	3.23e-07
Waste metals, unspecified	surface water	2.14e-04	0	0	0	2.14e-04	1.03e-05
Waste oil	surface water	3.65e-03	1.01e-01	0	-3.13e-04	1.04e-01	4.98e-03
Xylene (mixed isomers)	surface water	2.17e-05	0	0	7.31e-10	2.17e-05	1.04e-06
Zinc (+2)	surface water	6.66e-05	1.23e-08	0	-3.17e-10	6.66e-05	3.19e-06
Zinc (elemental)	surface water	0	1.39e-05	0	0	1.39e-05	6.64e-07
Zinc (elemental)	treatment	0	1.03e-06	0	0	1.03e-06	4.95e-08
Total water pollutants		8.12e-01	2.01e+01	7.02e-02	-6.18e-02	2.09e+01	100.00%

Table J-6. CRT hazardous waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Barium debris (D008 waste)	landfill	0	2.14E-04	0	0	2.14E-04	2.26E-05
Broken CRT glass	landfill	0	1.88E-03	0	0	1.88E-03	1.99E-04
Carbon and filmer waste	landfill	0	1.03E-03	0	0	1.03E-03	1.09E-04
Chrome debris (D007 waste)	treatment	0	1.47E-04	0	0	1.47E-04	1.56E-05
Chrome liquid waste (D007 waste)	recycling/reuse	0	9.80E-03	0	0	9.80E-03	1.04E-03
cinders from CRT glass mfg (70% PbO)	landfill	0	8.26E-03	0	0	8.26E-03	8.73E-04
CRT glass faceplate EP dust (Pb) (D008 waste)	landfill	0	1.03E-03	0	0	1.03E-03	1.09E-04
CRT glass funnel EP dust (Pb) (D008 waste)	recycling/reuse	0	5.01E-03	0	0	5.01E-03	5.30E-04
CRT glass, cullet	recycling/reuse	0	0	0	4.84E-01	4.84E-01	5.12%
CRT glass, funnel	recycling/reuse	0	0	0	2.29E-01	2.29E-01	2.42%
EOL CRT Monitor, landfilled	landfill	0	0	0	7.20E+00	7.20E+00	76.11%
Frit	landfill	0	2.99E-03	0	0	2.99E-03	3.16E-04
General Hazardous Waste	landfill	4.85E-02	0	0	-9.61E-05	4.84E-02	5.12E-03
General Hazardous Waste	treatment	0	1.24E-01	0	0	1.24E-01	1.31E-02
Hazardous sludge (Pb) (D008)	landfill	0	1.52E-03	0	0	1.52E-03	1.60E-04
Hazardous waste	landfill	3.85E-04	6.15E-01	0	-1.50E-03	6.14E-01	6.49%
Hydrofluoric acid	landfill	0	1.78E-03	0	0	1.78E-03	1.88E-04
Lead contaminated grit (D008 waste)	landfill	0	3.46E-05	0	0	3.46E-05	3.65E-06
Lead debris (D008 waste)	landfill	0	2.14E-04	0	0	2.14E-04	2.26E-05
Lead sulfate cake	landfill	0	2.67E-05	0	0	2.67E-05	2.82E-06
Printed wiring board (PWB)	recycling/reuse	0	0	0	1.46E-01	1.46E-01	1.54E-02
PWB-Decontaminating debris	treatment	0	1.55E-02	0	0	1.55E-02	1.64E-03
PWB-Lead contaminated waste oil	treatment	0	1.16E-02	0	0	1.16E-02	1.23E-03
PWB-Route dust	recycling/reuse	0	1.20E-02	0	0	1.20E-02	1.27E-03
PWB-Solder dross	recycling/reuse	0	6.70E-02	0	0	6.70E-02	7.09E-03
PWB-Waste cupric etchant	recycling/reuse	0	2.25E-01	0	0	2.25E-01	2.38%
Silica coat waste	treatment	0	2.86E-04	0	0	2.86E-04	3.02E-05
Slag and ash	landfill	0	2.47E-03	0	0	2.47E-03	2.61E-04
sludge from CRT glass mfg (1% PbO)	landfill	0	8.77E-04	0	0	8.77E-04	9.28E-05
Slurry scrap (chromium-based)	landfill	0	8.62E-04	0	0	8.62E-04	9.12E-05
Spent solvent, unspecified	treatment	0	2.75E-04	0	0	2.75E-04	2.90E-05
Transformer	recycling/reuse	0	0	0	2.28E-01	2.28E-01	2.41%
Unspecified sludge	landfill	0	5.22E-03	0	0	5.22E-03	5.52E-04
Unspecified sludge	recycling/reuse	0	5.56E-03	0	0	5.56E-03	5.88E-04
Waste acid (mostly 3% HCl solution)	recycling/reuse	0	3.93E-03	0	0	3.93E-03	4.16E-04
Waste Batch (Ba, Pb) (D008 waste)	landfill	0	1.41E-03	0	0	1.41E-03	1.50E-04
Waste finishing sludge (Pb) (D008 waste)	landfill	0	2.56E-04	0	0	2.56E-04	2.70E-05
Waste oxygenated solvents	treatment	0	9.48E-05	0	0	9.48E-05	1.00E-05
Waste water treatment (WWT) filters	landfill	0	3.40E-04	0	0	3.40E-04	3.60E-05
Total hazardous waste		4.89E-02	1.13E+00	0.00E+00	8.28E+00	9.46E+00	100.00%

Table J-7. CRT solid waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
abrasive sludge	recycling/reuse	0	4.21E-02	0	0	4.21E-02	2.44E-04
acid absorbent	landfill	0	8.13E-05	0	0	8.13E-05	4.72E-07
Aluminum (elemental)	landfill	5.68E-05	0	0	0	5.68E-05	3.29E-07
Aluminum scrap	recycling/reuse	0	1.82E-04	0	1.10E-01	1.10E-01	6.37E-04
Aluminum scrap, Wabash 319	recycling/reuse	0	5.08E-07	0	0	5.08E-07	2.95E-09
Arsenic	landfill	2.27E-08	0	0	0	2.27E-08	1.32E-10
Bauxite residues	landfill	0	1.21E-02	0	-2.96E-05	1.21E-02	7.03E-05
blasting media	landfill	0	3.66E-04	0	0	3.66E-04	2.12E-06
Broken CRT glass	recycling/reuse	0	1.08E+00	0	0	1.08E+00	0.62%
Cables/wires	recycling/reuse	0	8.86E-03	0	0	8.86E-03	5.14E-05
Cadmium	landfill	1.65E-09	0	0	0	1.65E-09	9.59E-12
Calcium	landfill	2.27E-04	0	0	0	2.27E-04	1.32E-06
Carbon	landfill	1.75E-04	0	0	0	1.75E-04	1.01E-06
Carbon Steel Scrap	recycling/reuse	0	0	0	4.10E-01	4.10E-01	0.24%
Cardboard	recycling/reuse	9.81E-05	0	0	0	9.81E-05	5.69E-07
Chromium (III)	landfill	1.42E-07	0	0	0	1.42E-07	8.23E-10
Chromium (VI)	landfill	1.42E-07	0	0	0	1.42E-07	8.23E-10
Coal waste	landfill	0	1.46E+00	5.09E+01	5.09E-03	5.23E+01	30.37%
Cobalt	landfill	1.00E-09	0	0	0	1.00E-09	5.81E-12
Cobalt nitrate	treatment	0	6.10E-05	0	0	6.10E-05	3.54E-07
Copper	landfill	5.01E-09	0	0	0	5.01E-09	2.91E-11
Copper scrap	recycling/reuse	0	0	0	6.67E-02	6.67E-02	3.87E-04
CRT glass, faceplate	landfill	0	2.43E-02	0	0	2.43E-02	1.41E-04
CRT glass, faceplate	recycling/reuse	0	0	0	3.54E-01	3.54E-01	0.21%
Diesel fuel	treatment	0	4.07E-05	0	0	4.07E-05	2.36E-07
Dust	treatment	0	3.43E-03	0	0	3.43E-03	1.99E-05
Dust/sludge	landfill	0	5.64E-01	1.97E+01	1.97E-03	2.02E+01	11.75%
EOL CRT Monitor, incinerated	treatment	0	0	0	3.31E+00	3.31E+00	1.92%
EOL CRT Monitor, landfilled	landfill	0	0	0	3.91E+00	3.91E+00	2.27%
EOL CRT Monitor, recycled	recycling/reuse	0	0	0	2.42E+00	2.42E+00	1.40%
EOL CRT Monitor, remanufactured	recycling/reuse	0	0	0	6.60E-01	6.60E-01	0.38%
Ferric chloride	recycling/reuse	0	3.69E-01	0	0	3.69E-01	0.21%
FGD sludge	landfill	0	2.14E-01	0	-9.24E-04	2.14E-01	0.12%
flame retardant high-impact polystyrene (HIPS)	recycling/reuse	0	0	0	4.03E-01	4.03E-01	0.23%
Fly/bottom ash	landfill	0	3.65E-01	1.27E+01	1.27E-03	1.31E+01	7.59%
Iron	landfill	1.14E-04	0	0	0	1.14E-04	6.59E-07
Iron scrap	recycling/reuse	3.43E-01	0	0	2.50E+00	2.85E+00	1.65%
Lead	landfill	2.29E-08	0	0	0	2.29E-08	1.33E-10
Manganese	landfill	2.27E-06	0	0	0	2.27E-06	1.32E-08
Mercury	landfill	1.42E-10	0	0	0	1.42E-10	8.21E-13
Mineral waste	landfill	4.42E-01	2.61E-03	0	-6.76E-06	4.44E-01	0.26%
Mining waste	landfill	4.48E-01	0	0	-1.90E-06	4.48E-01	0.26%
Mixed industrial (waste)	landfill	4.87E-02	1.00E+00	0	-5.12E-04	1.05E+00	0.61%
Nickel	landfill	7.50E-09	0	0	0	7.50E-09	4.35E-11
Nickel nitrate	treatment	0	6.10E-05	0	0	6.10E-05	3.54E-07
Nitrogen	landfill	4.23E-08	0	0	0	4.23E-08	2.45E-10
Non mineral waste (inert)	landfill	2.95E-05	0	0	0	2.95E-05	1.71E-07
Non toxic chemical waste (unspecified)	landfill	4.07E-03	6.11E-04	0	-1.58E-06	4.68E-03	2.71E-05

Table J-7. CRT solid waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Oily rags & filter media	landfill	0	3.25E-04	0	0	3.25E-04	1.89E-06
Oily rags & filter media	recycling/reuse	0	4.07E-05	0	0	4.07E-05	2.36E-07
parts cleaner solvent	recycling/reuse	0	8.13E-05	0	0	8.13E-05	4.72E-07
Phosphorus (yellow or white)	landfill	2.90E-06	0	0	0	2.90E-06	1.68E-08
Plating process sludge	landfill	0	3.28E-04	0	0	3.28E-04	1.90E-06
PM	landfill	0	5.33E-04	0	0	5.33E-04	3.09E-06
Potassium Carbonate	landfill	0	3.30E-03	0	0	3.30E-03	1.91E-05
Printed wiring board (PWB)	recycling/reuse	0	3.70E-02	0	0	3.70E-02	2.15E-04
PWB-Drill dust	landfill	0	1.49E-02	0	0	1.49E-02	8.67E-05
Sewage sludge (unspecified)	landfill	6.64E-05	0	0	0	6.64E-05	3.85E-07
Slag and ash	landfill	9.65E-02	6.66E+01	0	-1.49E+01	5.18E+01	30.06%
Slag and ash	recycling/reuse	0	6.85E-01	0	-3.01E-03	6.82E-01	0.40%
Sludge (aquadag)	landfill	0	2.22E-03	0	0	2.22E-03	1.29E-05
sludge (calcium fluoride, CaF2)	recycling/reuse	0	1.75E-02	0	0	1.75E-02	1.02E-04
Sludge (phosphor)	landfill	0	4.31E-03	0	0	4.31E-03	2.50E-05
Sodium Carbonate	landfill	0	3.29E-03	0	0	3.29E-03	1.91E-05
Spent solvents (toluene,xylene,dimethyl formamide,isopropyl alcohol)	recycling/reuse	0	4.17E-02	0	0	4.17E-02	2.42E-04
Stannous sludge	recycling/reuse	6.64E-04	0	0	0	6.64E-04	3.85E-06
Steel scrap (tinplated)	recycling/reuse	1.58E-01	0	0	0	1.58E-01	9.15E-04
Sulfur	landfill	2.55E-05	0	0	0	2.55E-05	1.48E-07
Unspecified sludge	landfill	0	7.69E-03	0	0	7.69E-03	4.46E-05
Unspecified sludge	recycling/reuse	0	1.26E-01	0	0	1.26E-01	7.29E-04
Unspecified solid waste	landfill	4.94E+00	0	0	-7.86E-01	4.15E+00	2.41%
Unspecified solid waste	recycling/reuse	3.07E+00	4.33E-01	0	0	3.50E+00	2.03%
Unspecified solid waste	treatment	0	3.66E+00	0	0	3.66E+00	2.12%
Unspecified solid waste (incinerated)	treatment	4.24E-03	1.33E-02	0	-5.82E-05	1.75E-02	1.01E-04
Unspecified waste	landfill	0	3.38E+00	0	-1.49E-02	3.36E+00	1.95%
Unspecified waste	recycling/reuse	0	0	0	-8.90E-02	-8.90E-02	-5.17E-04
Waste alkali (cleaning caustic and alkali soda effluent)	recycling/reuse	0	2.12E-02	0	0	2.12E-02	1.23E-04
Waste alkali, unspecified	treatment	0	4.21E-05	0	0	4.21E-05	2.44E-07
Waste metals, unspecified	recycling/reuse	0	8.79E-02	0	0	8.79E-02	5.10E-04
Waste oil	landfill	8.15E-05	0	0	0	8.15E-05	4.73E-07
Waste oil	recycling/reuse	0	1.43E-03	0	0	1.43E-03	8.29E-06
Waste oil	treatment	0	9.09E-03	0	0	9.09E-03	5.28E-05
Waste Plastic (packing material)	treatment	0	3.01E-02	0	0	3.01E-02	1.75E-04
Waste Plastic (styrene foam)	recycling/reuse	0	3.77E-03	0	0	3.77E-03	2.19E-05
Waste plastics from CRT monitor	recycling/reuse	0	8.09E-02	0	0	8.09E-02	4.70E-04
Waste refractory	landfill	0	2.44E-03	0	0	2.44E-03	1.42E-05
Waste water treatment (WWT) sludge	landfill	0	3.43E-01	0	0	3.43E-01	0.20%
Waste water treatment (WWT) sludge	recycling/reuse	0	3.72E-01	0	0	3.72E-01	0.22%
Wastepaper	recycling/reuse	0	8.34E-03	0	0	8.34E-03	4.84E-05
Wood, average	landfill	0	4.94E-03	0	0	4.94E-03	2.87E-05
Zinc (elemental)	landfill	9.01E-07	0	0	0	9.01E-07	5.23E-09
Total solid waste		9.55E+00	8.12E+01	8.33E+01	-1.66E+00	1.72E+02	100.00%

Table J-8. CRT radioactive waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Highly radioactive waste (Class C)	landfill	8.65e-06	0	0	0	8.65e-06	2.98e-03
Low-level radioactive waste	landfill	4.11e-04	1.38e-04	1.76e-03	1.76e-07	2.31e-03	79.47%
Radioactive waste (unspecified)	landfill	1.88e-05	0	0	0	1.88e-05	6.46e-03
Uranium, depleted	landfill	0	4.15e-05	5.27e-04	5.27e-08	5.69e-04	19.59%
Total radioactive waste		4.39e-04	1.80e-04	2.28e-03	2.29e-07	2.90e-03	100.00%

Table J-9. CRT radioactivity outputs (Bq/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Americium-241 (isotope)	landfill	3.00e+02	0	0	0	3.00e+02	3.34e-06
Americium-243 (isotope)	landfill	6.53e+00	0	0	0	6.53e+00	7.26e-08
Antimony-124 (isotope)	surface water	6.75e-02	0	0	0	6.75e-02	7.52e-10
Antimony-124 (isotope)	treatment	0	6.21e-01	7.89e+00	7.89e-04	8.51e+00	9.47e-08
Antimony-125 (isotope)	treatment	0	2.47e+00	3.14e+01	3.14e-03	3.39e+01	3.77e-07
Argon-41 (isotope)	air	0	1.26e+03	1.60e+04	1.60e+00	1.72e+04	1.92e-04
Barium-140 (isotope)	treatment	0	4.60e-02	5.85e-01	5.85e-05	6.31e-01	7.02e-09
Bromine-89 (isotope)	air	0	1.45e-04	1.85e-03	1.85e-07	1.99e-03	2.22e-11
Bromine-90 (isotope)	air	0	5.91e-05	7.51e-04	7.52e-08	8.10e-04	9.02e-12
Carbon-14 (isotope)	air	2.97e+01	0	0	0	2.97e+01	3.31e-07
Cesium-134 (isotope)	air	1.14e-03	3.99e-03	5.07e-02	5.07e-06	5.58e-02	6.22e-10
Cesium-134 (isotope)	surface water	5.94e-02	0	0	0	5.94e-02	6.61e-10
Cesium-134 (isotope)	treatment	0	1.66e+00	2.11e+01	2.11e-03	2.28e+01	2.53e-07
Cesium-135 (isotope)	landfill	1.46e+05	0	0	0	1.46e+05	1.63e-03
Cesium-136 (isotope)	treatment	0	1.44e-02	9.03e-01	9.04e-05	9.18e-01	1.02e-08
Cesium-137 (isotope)	air	1.14e-03	3.01e-02	3.83e-01	3.83e-05	4.14e-01	4.61e-09
Cesium-137 (isotope)	landfill	4.09e-01	0	0	0	4.09e-01	4.55e-09
Cesium-137 (isotope)	surface water	8.71e-02	0	0	0	8.71e-02	9.69e-10
Cesium-137 (isotope)	treatment	0	2.49e+00	3.17e+01	3.17e-03	3.42e+01	3.80e-07
Chromium-51 (isotope)	air	0	7.89e-02	1.00e+00	1.00e-04	1.08e+00	1.20e-08
Chromium-51 (isotope)	treatment	0	2.99e+00	3.80e+01	3.80e-03	4.10e+01	4.56e-07
Cobalt-57 (isotope)	air	0	2.12e-04	2.69e-03	2.69e-07	2.90e-03	3.23e-11
Cobalt-57 (isotope)	treatment	0	7.25e-02	9.20e-01	9.21e-05	9.93e-01	1.11e-08
Cobalt-58 (isotope)	air	1.14e-03	5.49e+01	3.44e+03	3.44e-01	3.49e+03	3.89e-05
Cobalt-58 (isotope)	surface water	1.95e-01	0	0	0	1.95e-01	2.17e-09
Cobalt-58 (isotope)	treatment	0	2.95e+01	3.74e+02	3.75e-02	4.04e+02	4.50e-06
Cobalt-60 (isotope)	air	1.14e-03	2.04e-02	2.59e-01	2.59e-05	2.80e-01	3.12e-09
Cobalt-60 (isotope)	surface water	1.22e-01	0	0	0	1.22e-01	1.36e-09
Cobalt-80 (isotope)	treatment	0	7.74e+00	9.83e+01	9.83e-03	1.06e+02	1.18e-06
Curium-244 (isotope)	landfill	6.08e+02	0	0	0	6.08e+02	6.77e-06
Curium-245 (isotope)	landfill	6.78e-02	0	0	0	6.78e-02	7.55e-10
Iodine-129 (isotope)	landfill	9.58e-03	0	0	0	9.58e-03	1.07e-10
Iodine-131 (isotope)	air	6.67e-03	9.51e-02	1.21e+00	1.21e-04	1.31e+00	1.46e-08
Iodine-131 (isotope)	surface water	7.40e-03	0	0	0	7.40e-03	8.24e-11
Iodine-131 (isotope)	treatment	0	1.38e+00	1.75e+01	1.75e-03	1.89e+01	2.10e-07
Iodine-132 (isotope)	air	0	1.93e-02	2.45e-01	2.46e-05	2.65e-01	2.95e-09
Iodine-132 (isotope)	treatment	0	5.22e-01	6.64e+00	6.64e-04	7.16e+00	7.97e-08
Iodine-133 (isotope)	air	1.30e-02	8.82e+01	1.12e+03	1.12e-01	1.21e+03	1.35e-05
Iodine-133 (isotope)	treatment	0	5.91e-01	7.51e+00	7.52e-04	8.10e+00	9.02e-08
Iodine-134 (isotope)	air	0	1.00e-01	1.27e+00	1.27e-04	1.37e+00	1.53e-08
Iodine-135 (isotope)	air	0	5.03e-03	6.39e-02	6.39e-06	6.89e-02	7.67e-10
Iodine-135 (isotope)	treatment	0	4.24e-01	5.39e+00	5.39e-04	5.82e+00	6.47e-08
Iron-55 (isotope)	treatment	0	7.05e+00	8.95e+01	8.96e-03	9.66e+01	1.07e-06
Iron-59 (isotope)	treatment	0	3.62e-01	4.60e+00	4.60e-04	4.96e+00	5.52e-08
Krypton-85 (isotope)	air	1.73e+02	2.08e+03	2.65e+04	2.65e+00	2.87e+04	3.20e-04
Krypton-85M (isotope)	air	0	1.01e+02	1.28e+03	1.28e-01	1.38e+03	1.54e-05
Krypton-85M (isotope)	treatment	0	1.86e+00	2.37e+01	2.37e-03	2.55e+01	2.84e-07

Table J-9. CRT radioactivity outputs (Bq/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Krypton-87 (isotope)	air	0	3.76e+01	4.78e+02	4.78e-02	5.15e+02	5.74e-06
Krypton-88 (isotope)	air	0	1.76e+02	2.24e+03	2.24e-01	2.42e+03	2.69e-05
Lanthanum-140 (isotope)	treatment	0	4.93e-02	6.26e-01	6.26e-05	6.75e-01	7.52e-09
Lead-210 (isotope)	air	1.02e+00	0	0	0	1.02e+00	1.14e-08
Manganese-54 (isotope)	air	0	1.12e-03	1.42e-02	1.42e-06	1.53e-02	1.71e-10
Manganese-54 (isotope)	surface water	9.76e-03	0	0	0	9.76e-03	1.09e-10
Manganese-54 (isotope)	treatment	0	1.97e+00	2.50e+01	2.51e-03	2.70e+01	3.01e-07
Molybdenum-99 (isotope)	treatment	0	3.72e+06	4.73e+07	4.73e+03	5.10e+07	56.75%
Neptunium-237 (isotope)	landfill	9.39e+01	0	0	0	9.39e+01	1.05e-06
Niobium-95 (isotope)	air	0	4.45e-05	5.65e-04	5.65e-08	6.09e-04	6.78e-12
Niobium-95 (isotope)	treatment	0	5.08e-01	6.45e+00	6.45e-04	6.96e+00	7.74e-08
Palladium-107 (isotope)	landfill	3.30e-02	0	0	0	3.30e-02	3.67e-10
Plutonium-239 (isotope)	landfill	1.14e+05	0	0	0	1.14e+05	1.26e-03
Plutonium-240 (isotope)	landfill	1.62e+05	0	0	0	1.62e+05	1.80e-03
Plutonium-241 (isotope)	landfill	3.74e+07	0	0	0	3.74e+07	41.67%
Plutonium-242 (isotope)	landfill	6.10e+02	0	0	0	6.10e+02	6.79e-06
Polonium-210 (isotope)	air	1.76e+00	0	0	0	1.76e+00	1.96e-08
Potassium-40 (isotope)	air	2.73e-01	0	0	0	2.73e-01	3.04e-09
Protactinium-234 (isotope)	air	1.61e-02	0	0	0	1.61e-02	1.79e-10
Protactinium-234 (isotope)	surface water	2.98e-01	0	0	0	2.98e-01	3.32e-09
Radioactive aerosols and halogenes (unspecified)	air	8.95e-02	0	0	0	8.95e-02	9.96e-10
radioactive gas (unspecified)	air	2.86e+03	0	0	0	2.86e+03	3.18e-05
Radioactive substance (unspecified)	air	8.69e+02	9.19e+02	0	-2.38e+00	1.79e+03	1.99e-05
Radioactive substance (unspecified)	surface water	1.61e+01	8.52e+00	0	-2.21e-02	2.46e+01	2.73e-07
Radium-222 (isotope)	air	1.04e+01	0	0	0	1.04e+01	1.16e-07
Radium-224 (isotope)	surface water	9.67e-01	0	0	0	9.67e-01	1.08e-08
Radium-226 (isotope)	air	1.37e+00	0	0	0	1.37e+00	1.53e-08
Radium-226 (isotope)	landfill	6.35e+02	0	0	0	6.35e+02	7.07e-06
Radium-226 (isotope)	surface water	5.73e+02	0	0	0	5.73e+02	6.38e-06
Radium-228 (isotope)	air	1.35e-01	0	0	0	1.35e-01	1.50e-09
Radium-228 (isotope)	surface water	1.93e+00	0	0	0	1.93e+00	2.15e-08
Radon-220 (isotope)	air	3.17e+00	0	0	0	3.17e+00	3.53e-08
Radon-222 (isotope)	air	1.37e+05	0	0	0	1.37e+05	1.52e-03
Rubidium-88 (isotope)	air	0	4.13e-01	5.25e+00	5.25e-04	5.66e+00	6.30e-08
Ruthenium-103 (isotope)	treatment	0	6.21e-02	7.89e-01	7.89e-05	8.51e-01	9.47e-09
Samarium-151 (isotope)	landfill	1.35e+02	0	0	0	1.35e+02	1.50e-06
Selenium-79 (isotope)	landfill	1.05e-01	0	0	0	1.05e-01	1.17e-09
Silver-110M (isotope)	air	0	1.33e-06	1.68e-05	1.68e-09	1.82e-05	2.02e-13
Silver-110M (isotope)	surface water	2.93e-01	0	0	0	2.93e-01	3.26e-09
Silver-110M (isotope)	treatment	0	7.25e-01	9.20e+00	9.21e-04	9.93e+00	1.11e-07
Sodium-24 (isotope)	treatment	0	1.10e-01	1.40e+00	1.40e-04	1.51e+00	1.68e-08
Strontium-89 (isotope)	treatment	0	1.19e-01	1.52e+00	1.52e-04	1.63e+00	1.82e-08
Strontium-90 (isotope)	landfill	2.18e+04	0	0	0	2.18e+04	2.43e-04
Strontium-90 (isotope)	treatment	0	2.80e-02	3.56e-01	3.56e-05	3.84e-01	4.28e-09
Strontium-95 (isotope)	treatment	0	3.09e-01	3.93e+00	3.93e-04	4.23e+00	4.71e-08
Sulfur-136 (isotope)	treatment	0	6.65e-02	8.45e-01	8.46e-05	9.12e-01	1.01e-08

Table J-9. CRT radioactivity outputs (Bq/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Technetium-99M (isotope)	air	0	5.96e-06	7.57e-05	7.58e-09	8.17e-05	9.10e-13
Technetium-99M (isotope)	landfill	4.46e+00	0	0	0	4.46e+00	4.97e-08
Technetium-99M (isotope)	treatment	0	4.33e-02	5.50e-01	5.50e-05	5.93e-01	6.60e-09
Thorium-228 (isotope)	air	1.14e-01	0	0	0	1.14e-01	1.27e-09
Thorium-228 (isotope)	surface water	3.87e+00	0	0	0	3.87e+00	4.30e-08
Thorium-230 (isotope)	air	2.33e-01	0	0	0	2.33e-01	2.59e-09
Thorium-230 (isotope)	landfill	6.35e+02	0	0	0	6.35e+02	7.07e-06
Thorium-230 (isotope)	surface water	2.79e+01	0	0	0	2.79e+01	3.10e-07
Thorium-232 (isotope)	air	7.28e-02	0	0	0	7.28e-02	8.10e-10
Thorium-234 (isotope)	air	1.61e-02	0	0	0	1.61e-02	1.79e-10
Thorium-234 (isotope)	surface water	2.98e-01	0	0	0	2.98e-01	3.32e-09
Tin-113 (isotope)	treatment	0	6.85e-02	8.70e-01	8.71e-05	9.39e-01	1.04e-08
Tin-126 (isotope)	landfill	1.84e-01	0	0	0	1.84e-01	2.05e-09
Tritium-3 (isotope)	air	3.47e+02	2.95e+03	3.74e+04	3.75e+00	4.07e+04	4.53e-04
Tritium-3 (isotope)	surface water	3.56e+03	0	0	0	3.56e+03	3.96e-05
Tritium-3 (isotope)	treatment	0	2.20e+04	2.80e+05	2.80e+01	3.02e+05	3.36e-03
Uranium-234 (isotope)	air	4.07e-01	0	0	0	4.07e-01	4.53e-09
Uranium-234 (isotope)	landfill	4.82e+02	0	0	0	4.82e+02	5.36e-06
Uranium-234 (isotope)	surface water	9.84e+00	0	0	0	9.84e+00	1.10e-07
Uranium-235 (isotope)	air	3.04e-03	0			3.04e-03	3.38e-11
Uranium-235 (isotope)	landfill	8.69e+00	0	0	0	8.69e+00	9.67e-08
Uranium-235 (isotope)	surface water	4.27e-01	0	0	0	4.27e-01	4.75e-09
Uranium-238 (isotope)	air	6.69e-01	0	0	0	6.69e-01	7.44e-09
Uranium-238 (isotope)	landfill	1.35e+02	0	0	0	1.35e+02	1.50e-06
Uranium-238 (isotope)	surface water	9.23e+00	0	0	0	9.23e+00	1.03e-07
Xenon-131M (isotope)	air	0	1.70e+02	2.16e+03	2.16e-01	2.33e+03	2.59e-05
Xenon-131M (isotope)	treatment	0	2.27e+01	2.88e+02	2.88e-02	3.11e+02	3.46e-06
Xenon-133 (isotope)	air	2.43e+03	6.28e+03	3.12e+05	3.12e+01	3.21e+05	3.57e-03
Xenon-133 (isotope)	treatment	0	3.48e+03	4.43e+04	4.43e+00	4.78e+04	5.31e-04
Xenon-133M (isotope)	air	0	1.99e+04	2.07e+04	2.07e+00	4.06e+04	4.52e-04
Xenon-133M (isotope)	treatment	0	2.85e+01	3.62e+02	3.63e-02	3.91e+02	4.35e-06
Xenon-135 (isotope)	air	0	9.27e+02	1.18e+04	1.18e+00	1.27e+04	1.41e-04
Xenon-135 (isotope)	treatment	0	2.60e+01	3.30e+02	3.30e-02	3.56e+02	3.96e-06
Xenon-135M (isotope)	air	0	1.77e+01	2.25e+02	2.25e-02	2.42e+02	2.70e-06
Xenon-138 (isotope)	air	0	5.87e+01	7.45e+02	7.45e-02	8.04e+02	8.95e-06
Zinc-85 (isotope)	treatment	0	3.33e-02	4.23e-01	4.23e-05	4.56e-01	5.07e-09
Zirconium-93 (isotope)	landfill	5.87e-01	0	0	0	5.87e-01	6.53e-09
Zirconium-95 (isotope)	air	0	1.15e-04	1.46e-03	1.46e-07	1.57e-03	1.75e-11
Total radioactivity outputs		3.80e+07	3.78e+06	4.80e+07	4.80e+03	8.98e+07	100.00%

Table J-10. LCD primary material inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
1,4-butanolide	0	4.06e-04	0	0	4.06E-04	1.12E-06
15" LCD light guide	0	3.74e-01	0	0	3.74E-01	1.03E-03
1-methyl-2-pyrrolidinone	0	4.06e-04	0	0	4.06E-04	1.12E-06
2-(2-butoxyethoxy)-ethanol acetate	0	8.08e-06	0	0	8.08E-06	2.23E-08
3,4,5-trifluorobromobenzene	0	2.64e-04	0	0	2.64E-04	7.29E-07
3,4-difluorobromobenzene	0	3.65e-04	0	0	3.65E-04	1.01E-06
4-4(-propylcyclohexyl)cyclohexanone	0	2.18e-04	0	0	2.18E-04	6.00E-07
4-bromophenol	0	3.27e-04	0	0	3.27E-04	9.00E-07
4-ethylphenol	0	7.00e-05	0	0	7.00E-05	1.93E-07
4-pentylphenol	0	3.42e-04	0	0	3.42E-04	9.43E-07
4-propionylphenol	0	1.94e-04	0	0	1.94E-04	5.36E-07
AlNd	0	2.97e-05	0	0	2.97E-05	8.18E-08
Aluminum (elemental)	0	1.34e-01	0	0	1.34E-01	3.70E-04
Argon	0	3.53e-05	0	0	3.53E-05	9.74E-08
Assembled 15" LCD backlight unit	0	1.48e+00	0	0	1.48E+00	4.07E-03
Assembled LCD monitor	0	0	6.50E+00	0	6.50E+00	1.79%
Backlight lamp (CCFL)	0	1.94e-03	0	0	1.94E-03	5.34E-06
Barium Carbonate	0	1.37e-02	0	0	1.37E-02	3.79E-05
Bauxite (Al2O3, ore)	0	5.09e-01	0	0	5.09E-01	1.40E-03
Cables/wires	0	2.34e-01	0	0	2.34E-01	6.45E-04
Coal, average (in ground)	1.72E+00	8.03E+00	6.69E+01	1.27E-02	7.67E+01	21.15%
Fuel oil #4	0	0	0	-6.18E-02	-6.18E-02	-1.70E-04
Glass, unspecified	0	4.37E-02	0	0	4.37E-02	1.20E-04
Glycol ethers	0	4.06E-04	0	0	4.06E-04	1.12E-06
Indium tin oxide	0	5.26E-04	0	0	5.26E-04	1.45E-06
Iron (Fe, ore)	3.26E+00	0	0	0	3.26E+00	8.98E-03
Iron scrap	4.63E-01	0	0	0	4.63E-01	1.28E-03
LCD front glass (with color filters)	0	1.78E-01	0	0	1.78E-01	4.92E-04
LCD glass	0	4.52E-01	0	0	4.52E-01	1.25E-03
LCD material (confidential)	0	3.11E-04	0	0	3.11E-04	8.56E-07
LCD module	0	1.18E+00	0	0	1.18E+00	3.26E-03
LCD spacers, unspecified	0	1.69E-05	0	0	1.69E-05	4.66E-08
Liquid crystals, for 15" LCD	0	1.24E-03	0	0	1.24E-03	3.43E-06
Mercury	0	3.99E-06	0	0	3.99E-06	1.10E-08
Metals, remaining unspeciated	0	6.81E-04	0	0	6.81E-04	1.88E-06
Mild fiber	0	7.34E-07	0	0	7.34E-07	2.02E-09
Molybdenum	0	1.78E-04	0	0	1.78E-04	4.92E-07
MoW	0	9.09E-04	0	0	9.09E-04	2.51E-06
Natural gas	0	4.22E+00	5.22E+00	-5.75E-02	9.39E+00	2.59%
Natural gas (in ground)	2.29E+02	5.16E+00	0	-1.08E+00	2.33E+02	64.25%
Neon	0	6.31E-05	0	0	6.31E-05	1.74E-07
Petroleum (in ground)	7.09E-01	2.23E+01	1.42E+00	-1.00E+00	2.34E+01	6.45%
Pigment color resist, unspecified	0	3.72E-02	0	0	3.72E-02	1.03E-04
Polarizer	0	4.07E-02	0	0	4.07E-02	1.12E-04
Poly(methyl methacrylate)	0	3.83E-01	0	0	3.83E-01	1.06E-03
Polycarbonate resin	0	5.16E-01	0	0	5.16E-01	1.42E-03
Polyester adhesive	0	6.25E-04	0	0	6.25E-04	1.72E-06
Polyethylene terephthalate	0	5.88E-02	0	0	5.88E-02	1.62E-04

Table J-10. LCD primary material inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Polyimide alignment layer, unspecified	0	4.86E-04	0	0	4.86E-04	1.34E-06
Polyvinyl alcohol	0	8.61E-03	0	0	8.61E-03	2.37E-05
Potassium Carbonate	0	1.75E-02	0	0	1.75E-02	4.83E-05
PPE	0	3.00E-01	0	0	3.00E-01	8.27E-04
Printed wiring board (PWB)	0	3.74E-01	0	0	3.74E-01	1.03E-03
PWB-laminate	0	3.74E-01	0	0	3.74E-01	1.03E-03
Recycled LCD glass	0	9.54E-02	0	0	9.54E-02	2.63E-04
Rubber, unspecified	0	6.01E-04	0	0	6.01E-04	1.66E-06
Sand	0	1.11E-01	0	0	1.11E-01	3.07E-04
Sodium Carbonate	0	2.26E-02	0	0	2.26E-02	6.23E-05
Solder (60% tin, 40% lead)	0	3.81E-02	0	0	3.81E-02	1.05E-04
Solder (63% tin; 37% lead)	0	2.24E-02	0	0	2.24E-02	6.18E-05
Steel	0	2.53E+00	0	0	2.53E+00	6.97E-03
Strontium Carbonate	0	1.53E-02	0	0	1.53E-02	4.23E-05
Styrene-butadiene copolymers	0	3.62E-01	0	0	3.62E-01	9.97E-04
Titanium	0	1.33E-04	0	0	1.33E-04	3.67E-07
Triallyl isocyanurate	0	1.54E-05	0	0	1.54E-05	4.26E-08
Triphenyl phosphate	0	9.25E-02	0	0	9.25E-02	2.55E-04
Unspecified LCD material	0	1.19E-04	0	0	1.19E-04	3.29E-07
Uranium, yellowcake	0	1.03E-03	1.81E-03	3.4352E-07	2.84E-03	7.84E-06
Zircon Sand	0	1.31E-03	0	0	1.31E-03	3.62E-06
Total primary inputs	2.35E+02	4.97E+01	8.01E+01	-2.19E+00	3.63E+02	100.00%

Table J-11. LCD ancillary material inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
1,4-butanolide	0	4.04e-05	0	0	4.04e-05	1.94e-07
1-Methoxy-2-propanol	0	1.10e-02	0	0	1.10e-02	5.27e-05
2-(2-butoxyethoxy)-ethanol	0	3.04e-02	0	0	3.04e-02	1.46e-04
2,2,4-trimethylpentane	0	1.52e-05	0	0	1.52e-05	7.32e-08
2-ethoxyl ethylacetate	0	1.78e-03	0	0	1.78e-03	8.53e-06
Acetic acid	0	6.40e-03	0	0	6.40e-03	3.07e-05
Acetone	0	1.56e-01	0	0	1.56e-01	7.50e-04
Al-etchant, unspecified	0	5.88e-03	0	0	5.88e-03	2.83e-05
Aluminum Oxide	0	1.56e-03	0	0	1.56e-03	7.50e-06
Aluminum sulfate	3.63e-04	1.05e-01	0	0	1.05e-01	5.04e-04
Ammonia	0	1.55e-02	0	0	1.55e-02	7.46e-05
Ammonium bifluoride	0	2.36e-03	0	0	2.36e-03	1.13e-05
Ammonium chloride	0	3.42e-02	0	0	3.42e-02	1.64e-04
Ammonium fluoride	0	1.14e-02	0	0	1.14e-02	5.48e-05
Ammonium hydroxide	0	3.42e-02	0	0	3.42e-02	1.64e-04
Argon	0	7.87e-03	0	0	7.87e-03	3.78e-05
Barium sulfate	9.64e-04	0	0	0	9.64e-04	4.63e-06
Bauxite	2.10e-04	0	0	0	2.10e-04	1.01e-06
Bauxite (Al2O3, ore)	5.59e-04	2.16e-03	0	-7.63e-05	2.64e-03	1.27e-05
Bentonite (in ground)	1.00e-03	0	0	0	1.00e-03	4.82e-06
Borax	0	9.13e-05	0	0	9.13e-05	4.39e-07
Calcium hydroxide	0	1.39e-01	0	0	1.39e-01	6.67e-04
Calcium sulfate	7.37e-06	0	0	0	7.37e-06	3.54e-08
Calcium sulfate (CaSO4, ore)	9.75e-06	0	0	0	9.75e-06	4.68e-08
Carbon dioxide	0	4.86e-03	0	0	4.86e-03	2.33e-05
Cerium Oxide	0	1.52e-04	0	0	1.52e-04	7.29e-07
Chlorine	0	1.55e-02	0	0	1.55e-02	7.46e-05
Chromium ore	1.79e-08	0	0	0	1.79e-08	8.59e-11
Chromium Oxide	0	2.60e-06	0	0	2.60e-06	1.25e-08
Clay (in ground)	1.30e-03	0	0	1.69e+00	1.69e+00	8.12e-03
Cleaner, unspecified	0	1.47e-04	0	0	1.47e-04	7.05e-07
Coal, average (in ground)	0	0	0	7.38e-04	7.38e-04	3.54e-06
Copper (Cu, ore)	2.63e-04	0	0	0	2.63e-04	1.26e-06
Cresol-formaldehyde resin	0	8.29e-04	0	0	8.29e-04	3.98e-06
Cr-etchant, unspecified	0	1.77e-02	0	0	1.77e-02	8.49e-05
Cyclohexane	0	3.91e-03	0	0	3.91e-03	1.88e-05
Deoiling agent (unspecified)	6.53e-04	0	0	0	6.53e-04	3.14e-06
Developing solution, unspecified	0	4.00e-02	0	0	4.00e-02	1.92e-04
Diethyl ether	0	9.28e-05	0	0	9.28e-05	4.46e-07
Diluent, unspecified	0	8.27e-03	0	0	8.27e-03	3.97e-05
Dimethylsulfoxide	0	6.63e-02	0	0	6.63e-02	3.18e-04
Dioctyl Sebacate	1.14e-04	0	0	0	1.14e-04	5.47e-07
Dolomite (in ground)	2.08e-03	0	0	0	2.08e-03	9.98e-06
Ethanol	0	2.53e-02	0	0	2.53e-02	1.21e-04
Ethanol amine	0	7.85e-02	0	0	7.85e-02	3.77e-04
Ethylacetate	0	9.68e-04	0	0	9.68e-04	4.65e-06
Etoxy Naphtol Sulphonic Acid (ENSA)	4.88e-05	0	0	0	4.88e-05	2.34e-07
Exfoliation liquid, unspecified	0	1.43e-02	0	0	1.43e-02	6.86e-05
Explosive (unspecified)	9.77e-05	0	0	0	9.77e-05	4.69e-07

Table J-11. LCD ancillary material inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Ferric chloride	0	8.92e-03	0	0	8.92e-03	4.28e-05
Ferromanganese (Fe, Mn, C)	3.83e-07	0	0	0	3.83e-07	1.84e-09
Fluorocarbon resin	0	3.38e-06	0	0	3.38e-06	1.63e-08
Fluorspar (CaF2, ore)	5.37e-06	0	0	0	5.37e-06	2.58e-08
Flux, unspecified	0	7.35e-05	0	0	7.35e-05	3.53e-07
Formaldehyde	0	2.91e-03	0	0	2.91e-03	1.40e-05
Glycol ethers	0	3.16e-02	0	0	3.16e-02	1.52e-04
Gravel	9.08e-08	0	0	0	9.08e-08	4.36e-10
Gravel/Sand	1.01e-03	0	0	0	1.01e-03	4.85e-06
HCFC-225ca	0	1.37e-04	0	0	1.37e-04	6.57e-07
HCFC-225cb	0	1.37e-04	0	0	1.37e-04	6.57e-07
Helium	0	6.18e-04	0	0	6.18e-04	2.97e-06
Heptane	0	1.03e-02	0	0	1.03e-02	4.93e-05
Hexamethyldisilizane	0	2.58e-04	0	0	2.58e-04	1.24e-06
Hydrochloric acid	0	1.29e-01	0	0	1.29e-01	6.21e-04
Hydrofluoric acid	0	4.58e-02	0	0	4.58e-02	2.20e-04
Hydrogen	0	4.44e-01	0	0	4.44e-01	2.13e-03
Hydrogen peroxide	0	1.38e-02	0	0	1.38e-02	6.65e-05
Iron (Fe, ore)	7.65e-03	0	0	7.04e-04	8.35e-03	4.01e-05
Iron sulfate (FeSO4, ore)	7.99e-06	0	0	0	7.99e-06	3.84e-08
Isopropyl alcohol	0	3.49e-01	0	0	3.49e-01	1.67e-03
ITO etchant, unspecified	0	2.94e-03	0	0	2.94e-03	1.41e-05
Krypton	0	2.58e-05	0	0	2.58e-05	1.24e-07
Lead (Pb, ore)	2.47e-05	0	0	0	2.47e-05	1.19e-07
Lime	0	4.74e-02	3.95e-01	7.49e-05	4.42e-01	2.12e-03
Limestone	0	1.08e-01	8.99e-01	1.71e-04	1.01e+00	4.84e-03
Limestone (CaCO3, in ground)	5.07e-01	5.49e-02	0	-1.55e-01	4.06e-01	1.95e-03
LNG	0	1.94e+02	0	0	1.94e+02	9.32e-01
Lubricant (unspecified)	2.02e-02	0	0	0	2.02e-02	9.68e-05
Manganese (Mn, ore)	1.04e-08	0	0	0	1.04e-08	5.00e-11
Methyl ethyl ketone	0	4.91e-04	0	0	4.91e-04	2.36e-06
Monosilane	0	1.12e-03	0	0	1.12e-03	5.40e-06
Natural gas (in ground)	0	0	0	1.09e-03	1.09e-03	5.22e-06
N-Butylacetate	0	3.83e-02	0	0	3.83e-02	1.84e-04
Nickel (Ni, ore)	6.05e-09	0	0	0	6.05e-09	2.91e-11
Nitric acid	0	7.23e-02	0	0	7.23e-02	3.47e-04
Nitric acid second cerium ammonium	0	1.13e-02	0	0	1.13e-02	5.43e-05
Nitrogen	0	6.02e+00	0	0	6.02e+00	2.89e-02
Nitrogen fluoride	0	1.08e-01	0	0	1.08e-01	5.19e-04
Nitrous oxide	0	1.36e-03	0	0	1.36e-03	6.51e-06
Oil (in ground)	0	0	0	8.06e-03	8.06e-03	3.87e-05
Olivine	2.72e-07	0	0	0	2.72e-07	1.31e-09
Olivine ore	7.92e-06	0	0	0	7.92e-06	3.80e-08
Orthoboric acid	0	7.30e-04	0	0	7.30e-04	3.51e-06
Oxygen	0	7.75e-03	0	0	7.75e-03	3.72e-05
Perchloric acid	0	3.82e-03	0	0	3.82e-03	1.84e-05
Perfluoromethane	0	1.29e-03	0	0	1.29e-03	6.18e-06
Phenolsulphonic Acid	1.53e-03	0	0	0	1.53e-03	7.34e-06
Phosphine	0	2.69e-02	0	0	2.69e-02	1.29e-04

Table J-11. LCD ancillary material inputs (kg/functional unit)

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Phosphoric acid	0	3.95e-02	0	0	3.95e-02	1.90e-04
Photoresist, unspecified	0	1.68e-02	0	0	1.68e-02	8.05e-05
Polyaluminum chloride	0	6.40e-03	0	0	6.40e-03	3.07e-05
Polyethylene glycol	0	2.23e-02	0	0	2.23e-02	1.07e-04
Polyethylene mono(nonylphenyl) ether glycol	0	3.40e-04	0	0	3.40e-04	1.63e-06
Polyethylene terephthalate	0	3.20e-02	0	0	3.20e-02	1.53e-04
Polyimide, unspecified	0	2.94e-05	0	0	2.94e-05	1.41e-07
Potassium chloride (KCl, as K2O, in ground)	3.03e-05	0	0	0	3.03e-05	1.45e-07
Potassium hydroxide	0	1.88e-02	0	0	1.88e-02	9.04e-05
Potassium permanganate	0	5.14e-04	0	0	5.14e-04	2.47e-06
Potassium peroxymonosulfate	0	3.12e-02	0	0	3.12e-02	1.50e-04
Process material for backlight assembly	0	7.03e-05	0	0	7.03e-05	3.37e-07
Propylene glycol	0	4.46e-03	0	0	4.46e-03	2.14e-05
Propylene glycol monomethyl ether acetate	0	1.56e-02	0	0	1.56e-02	7.50e-05
Pumice	0	3.64e-03	0	0	3.64e-03	1.75e-05
PWB-solder mask solids	0	1.93e-02	0	0	1.93e-02	9.25e-05
Pyrite (FeS2, ore)	3.77e-02	0	0	0	3.77e-02	1.81e-04
Raw materials (unspecified)	4.06e-03	0	0	0	4.06e-03	1.95e-05
Rinse, unspecified	0	5.27e-02	0	0	5.27e-02	2.53e-04
Sand (in ground)	9.55e-03	1.32e-03	0	5.60e-01	5.71e-01	2.74e-03
Silver (Ag, ore)	4.51e-10	0	0	0	4.51e-10	2.17e-12
Sodium Carbonate	0	1.42e-02	0	0	1.42e-02	6.82e-05
Sodium chloride (NaCl, in ground or in sea)	4.37e-01	6.08e-04	0	1.08e-05	4.38e-01	2.10e-03
Sodium Dichromate	1.29e-04	0	0	0	1.29e-04	6.19e-07
Sodium dihydrogen phosphate dihydrate	0	4.06e-06	0	0	4.06e-06	1.95e-08
Sodium hydroxide	0	4.45e-01	0	0	4.45e-01	2.14e-03
Solder, unspecified	0	7.35e-05	0	0	7.35e-05	3.53e-07
Sulfur (S, in ground)	1.53e-02	0	0	0	1.53e-02	7.34e-05
Sulfur hexafluoride	0	1.62e-02	0	0	1.62e-02	7.79e-05
Sulfuric acid	0	3.25e-01	0	0	3.25e-01	1.56e-03
Surfactant, unspecified	0	1.09e-04	0	0	1.09e-04	5.25e-07
Synthetic resin, unspecified	0	6.57e-04	0	0	6.57e-04	3.16e-06
Tetrahydrofuran	0	3.82e-03	0	0	3.82e-03	1.84e-05
Tetramethyl ammonium hydroxide	0	1.29e-01	0	0	1.29e-01	6.18e-04
Tin (Sn, ore)	1.19e-02	0	0	0	1.19e-02	5.72e-05
Toluene	0	2.75e-02	0	0	2.75e-02	1.32e-04
Unspecified ancillary material	0	4.19e-04	0	0	4.19e-04	2.01e-06
Unspecified LCD process material	0	2.57e-02	0	0	2.57e-02	1.23e-04
Unspecified LCD process material ("Natural Sweeper")	0	1.09e-04	0	0	1.09e-04	5.23e-07
Uranium (U, ore)	0	0	0	1.00e-08	1.00e-08	4.81e-11
Water	0	6.88e-02	0	0	6.88e-02	3.30e-04
Xylene (mixed isomers)	0	1.57e-03	0	0	1.57e-03	7.54e-06
Zinc (Zn, ore)	6.61e-10	0	0	0	6.61e-10	3.18e-12
Total ancillary inputs	1.06e+00	2.04e+02	1.29e+00	2.11e+00	2.08e+02	100.00%

Table J-12. LCD utility inputs

Material	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Fuels (kg/functional unit):						
Fuel Oil #2 (distillate)	0	5.42E-02	0	0	5.42E-02	0.14%
Fuel oil #4 (avg. of #2 + #6)	0	2.11E-01	0	-9.09E-01	-6.99E-01	-1.81%
Fuel oil #6 (residual)	0	1.25E-01	0	0	1.25E-01	0.33%
Kerosene	0	4.65E-01	0	0	4.65E-01	1.21%
LNG	0	3.22E+00	0	0	3.22E+00	8.34%
LPG	0	1.68E+01	0	1.38E-03	1.68E+01	43.63%
Natural gas	0	1.16E+00	0	-8.61E-01	3.01E-01	0.78%
Steam	0	1.45E-01	0	0	1.45E-01	0.37%
Coal, average (in ground)	2.49E+00	6.86E-01	0	-7.66E-03	3.17E+00	8.21%
Coal, lignite (in ground)	4.10E-01	0	0	0	4.10E-01	1.06%
Natural gas (in ground)	1.03E+01	2.41E+00	0	-1.38E-01	1.26E+01	32.66%
Petroleum (in ground)	1.52E+00	4.84E-01	0	-3.81E-02	1.96E+00	5.08%
Uranium (U, ore)	7.86E-05	1.15E-05	0	-1.32E-07	9.01E-05	2.33E-06
Total fuels	1.47E+01	2.58E+01	0	-1.95E+00	3.86E+01	100.00%
Electricity (MJ/functional unit):						
Electricity	3.46E+01	3.16E+02	8.53E+02	1.62E-01	1.20E+03	
Water (kg or L/functional unit):						
Water	2.63E+02	2.15E+03	4.25E+02	-1.80E+01	2.82E+03	
Total energy (fuels and electricity, MJ/functional unit):						
Energy	6.33E+02	1.44E+03	8.53E+02	-8.44E+01	2.84E+03	

Table J-13. LCD air emissions (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	Fraction of Total
1,1,1-Trichloroethane	Air	1.62e-08	2.28e-07	7.16e-07	-1.95e-08	9.40e-07	2.72e-09
1,2-Dichloroethane	Air	3.24e-08	1.75e-07	1.34e-06	-3.85e-08	1.51e-06	4.36e-09
1,2-Dichlorotetrafluoroethane	Air	8.90e-08	0	0	0	8.90e-08	2.57e-10
1,4-Dichlorobenzene	Air	1.89e-07	1.89e-08	0	-1.49e-09	2.06e-07	5.96e-10
2,3,7,8-TCDD	Air	0	5.90e-14	4.79e-13	9.08e-17	5.38e-13	1.55e-15
2,3,7,8-TCDF	Air	0	2.05e-13	1.71e-12	3.24e-16	1.91e-12	5.53e-15
2,4-Dinitrotoluene	Air	2.27e-10	1.22e-09	9.37e-09	-2.74e-10	1.05e-08	3.05e-11
2-Chloroacetophenone	Air	5.67e-09	3.06e-08	2.34e-07	-9.35e-11	2.70e-07	7.82e-10
2-Methylnaphthalene	Air	3.78e-09	1.18e-09	9.95e-10	-3.53e-11	5.92e-09	1.71e-11
3-Methylcholanthrene	Air	2.83e-10	2.84e-11	0	-2.66e-12	3.09e-10	8.94e-13
5-Methyl chrysene	Air	1.78e-11	9.60e-11	7.36e-10	-2.15e-11	8.29e-10	2.40e-12
Acenaphthene	Air	9.25e-10	1.49e-08	2.12e-08	-5.04e-10	3.65e-08	1.06e-10
Acenaphthylene	Air	4.89e-10	1.27e-09	8.42e-09	-2.47e-10	9.93e-09	2.87e-11
Acetaldehyde	Air	7.90e-07	2.49e-06	1.91e-05	-5.57e-07	2.18e-05	6.30e-08
Acetic acid	Air	4.22e-06	1.36e-03	0	0	1.36e-03	3.93e-06
Acetone	Air	3.26e-07	1.86e-04	0	0	1.86e-04	5.39e-07
Acetophenone	Air	1.22e-08	6.55e-08	5.02e-07	-1.47e-08	5.65e-07	1.63e-09
Acetylene	Air	1.14e-05	0	0	0	1.14e-05	3.30e-08
Acrolein	Air	2.35e-07	1.27e-06	9.71e-06	-2.83e-07	1.09e-05	3.16e-08
Adsorbable organic halides	Air	3.56e-17	0	0	0	3.56e-17	1.03e-19
Alcohols	Air	2.85e-06	0	0	0	2.85e-06	8.23e-09
Aldehydes	Air	8.53e-04	8.98e-05	0	-1.05e-04	8.37e-04	2.42e-06
Al-etchant, unspecified	Air	0	1.37e-02	0	0	1.37e-02	3.97e-05
Alkane (unspecified)	Air	1.07e-04	0	0	0	1.07e-04	3.10e-07
Alkenes	Air	1.79e-05	0	0	0	1.79e-05	5.18e-08
Alkyne (unspecified)	Air	5.46e-08	0	0	0	5.46e-08	1.58e-10
Aluminum (elemental)	Air	8.09e-05	9.59e-07	0	-5.72e-08	8.18e-05	2.36e-07
Ammonia	Air	1.12e-02	6.26e-02	0	-6.95e-05	7.37e-02	2.13e-04
Anthracene	Air	5.61e-10	1.68e-09	7.27e-09	-2.09e-10	9.30e-09	2.69e-11
Antimony	Air	2.28e-07	3.24e-06	1.63e-06	-4.25e-08	5.05e-06	1.46e-08
Argon	Air	0	5.80e-03	0	0	5.80e-03	1.68e-05
Aromatic hydrocarbons	Air	7.67e-05	2.55e-09	0	-9.05e-11	7.67e-05	2.22e-07
Arsenic	Air	1.63e-06	3.14e-06	1.40e-05	-1.72e-06	1.70e-05	4.93e-08
Barium	Air	1.39e-06	1.76e-06	7.67e-07	-1.65e-08	3.91e-06	1.13e-08
Benzaldehyde	Air	2.78e-14	0	0	0	2.78e-14	8.04e-17
Benzene	Air	8.85e-02	2.70e-03	4.36e-05	-4.82e-04	9.07e-02	2.62e-04
Benzo[a]anthracene	Air	3.92e-10	2.78e-09	3.46e-09	-8.13e-11	6.55e-09	1.89e-11
Benzo[a]pyrene	Air	4.40e-08	1.91e-10	1.27e-09	-3.93e-11	4.54e-08	1.31e-10
Benzo[b,j,k]fluoranthene	Air	8.92e-11	1.37e-09	3.97e-09	-1.07e-10	5.32e-09	1.54e-11
Benzo[b]fluoranthene	Air	2.91e-10	3.09e-11	0	-2.79e-12	3.19e-10	9.24e-13
Benzo[g,h,i]perylene	Air	2.23e-10	1.48e-09	1.35e-09	-2.83e-11	3.02e-09	8.74e-12
Benzo[k]fluoranthene	Air	2.91e-10	3.09e-11	0	-2.79e-12	3.19e-10	9.24e-13
Benzyl chloride	Air	5.67e-07	3.05e-06	2.34e-05	-6.84e-07	2.64e-05	7.62e-08
Beryllium	Air	2.19e-07	1.86e-07	7.12e-07	-1.99e-07	9.18e-07	2.65e-09
Biphenyl	Air	1.38e-09	7.42e-09	5.69e-08	-1.66e-09	6.40e-08	1.85e-10
Boron	Air	1.79e-05	0	0	0	1.79e-05	5.16e-08
Bromine	Air	9.94e-07	0	0	0	9.94e-07	2.87e-09
Bromoform	Air	3.16e-08	1.70e-07	1.31e-06	-3.81e-08	1.47e-06	4.25e-09
Bromomethane	Air	1.30e-07	6.98e-07	5.36e-06	-1.56e-07	6.03e-06	1.74e-08

Table J-13. LCD air emissions (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	Fraction of Total
Butane	Air	3.42e-04	3.31e-05	0	-3.11e-06	3.72e-04	1.07e-06
Butene	Air	1.09e-07	0	0	0	1.09e-07	3.15e-10
Cadmium	Air	2.93e-07	5.25e-07	1.80e-06	-6.58e-08	2.55e-06	7.37e-09
Calcium	Air	8.74e-05	8.31e-07	0	-4.96e-08	8.82e-05	2.55e-07
Carbon dioxide	Air	1.07e+02	6.22e+01	1.66e+02	1.39e+00	3.36e+02	9.72e-01
Carbon disulfide	Air	1.05e-07	5.67e-07	4.35e-06	-1.27e-07	4.90e-06	1.42e-08
Carbon monoxide	Air	3.74e-01	3.85e-02	3.02e-02	-3.45e-03	4.39e-01	1.27e-03
Carbon tetrachloride	Air	0	0	0	5.85e-10	5.85e-10	1.69e-12
Chloride ions	Air	1.77e-04	2.09e-04	6.78e-05	-1.64e-06	4.52e-04	1.31e-06
Chlorine	Air	6.64e-07	1.01e-09	0	-1.80e-10	6.65e-07	1.92e-09
Chloroacetophenone	Air	0	0	0	-6.74e-09	-6.74e-09	-1.95e-11
Chlorobenzene	Air	1.78e-08	9.60e-08	7.36e-07	-2.15e-08	8.29e-07	2.40e-09
Chloroform	Air	4.78e-08	2.57e-07	1.97e-06	-5.70e-08	2.22e-06	6.43e-09
Chromium	Air	6.40e-09	0	0	0	6.40e-09	1.85e-11
Chromium (III)	Air	1.50e-06	2.96e-06	9.07e-06	-1.43e-06	1.21e-05	3.50e-08
Chromium (VI)	Air	1.50e-06	1.52e-06	2.69e-06	-1.43e-06	4.29e-06	1.24e-08
Chrysene	Air	3.77e-10	1.89e-09	3.81e-09	-1.00e-10	5.98e-09	1.73e-11
Cobalt	Air	5.36e-07	4.13e-06	4.54e-06	-1.30e-07	9.07e-06	2.62e-08
Copper	Air	8.26e-07	1.15e-06	3.72e-07	-1.65e-08	2.33e-06	6.75e-09
Cr-etchant, unspecified	Air	0	4.12e-02	0	0	4.12e-02	1.19e-04
Cumene	Air	4.30e-09	2.75e-09	1.77e-07	-5.18e-09	1.79e-07	5.18e-10
Cumene hydroperoxide	Air	0	2.04e-08	0	0	2.04e-08	5.89e-11
Cyanide (-1)	Air	2.04e-06	1.09e-05	8.37e-05	-2.44e-06	9.42e-05	2.72e-07
Cyclohexane	Air	0	4.85e-05	0	0	4.85e-05	1.40e-07
Di(2-ethylhexyl)phthalate	Air	5.92e-08	3.19e-07	2.44e-06	-7.13e-08	2.75e-06	7.95e-09
Dibenzo[a,h]anthracene	Air	1.98e-10	1.02e-09	3.26e-10	-1.85e-12	1.54e-09	4.46e-12
Dichlorobenzene (mixed isomers)	Air	0	0	0	-2.82e-10	-2.82e-10	-8.16e-13
Dichloromethane	Air	2.35e-07	1.27e-06	9.71e-06	-2.82e-07	1.09e-05	3.16e-08
Diethyl ether	Air	0	9.26e-05	0	0	9.26e-05	2.68e-07
Diethylene glycol	Air	0	9.69e-05	0	0	9.69e-05	2.80e-07
Dimethyl sulfate	Air	3.89e-08	2.09e-07	1.61e-06	-4.69e-08	1.81e-06	5.23e-09
Dimethylbenzanthracene	Air	2.36e-09	2.36e-10	0	-2.23e-11	2.58e-09	7.45e-12
Dioxins, remaining unspeciated	Air	1.32e-11	8.22e-12	2.18e-11	1.33e-10	1.76e-10	5.08e-13
Ethane	Air	6.08e-04	4.88e-05	0	-4.59e-06	6.53e-04	1.89e-06
Ethanethiol	Air	4.50e-07	0	0	0	4.50e-07	1.30e-09
Ethanol	Air	6.51e-07	4.63e-05	0	0	4.69e-05	1.36e-07
Ethyl Chloride	Air	3.40e-08	1.83e-07	1.41e-06	-4.10e-08	1.58e-06	4.57e-09
Ethylacetate	Air	0	1.22e-07	0	0	1.22e-07	3.53e-10
Ethylacetate	Treatment	0	2.32e-06	0	0	2.32e-06	6.70e-09
Ethylbenzene	Air	2.28e-07	4.48e-07	3.16e-06	-9.00e-08	3.75e-06	1.08e-08
Ethylene	Air	1.02e-04	0	0	0	1.02e-04	2.94e-07
Ethylene dibromide	Air	9.73e-10	5.24e-09	4.02e-08	-1.17e-09	4.52e-08	1.31e-10
Fluoranthene	Air	1.07e-09	6.31e-09	2.50e-08	-6.98e-10	3.17e-08	9.17e-11
Fluorene	Air	1.20e-09	6.68e-09	3.13e-08	-8.93e-10	3.83e-08	1.11e-10
Fluoride	Air	0	3.78e-08	7.29e-06	1.38e-09	7.33e-06	2.12e-08
Fluorides (F-)	Air	9.48e-07	2.24e-05	0	-2.05e-07	2.32e-05	6.69e-08
Fluorine	Air	2.83e-07	0	0	0	2.83e-07	8.18e-10
Formaldehyde	Air	1.87e-05	1.09e-04	3.16e-05	-5.78e-06	1.54e-04	4.45e-07
Furans, remaining unspeciated	Air	6.10e-11	3.02e-11	3.48e-11	-7.40e-11	5.20e-11	1.50e-13

Table J-13. LCD air emissions (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	Fraction of Total
Halogenated hydrocarbons (unspecified)	Air	1.12e-06	1.42e-14	0	-4.93e-16	1.12e-06	3.24e-09
Halogenated matter (unspecified)	Air	4.67e-19	0	0	0	4.67e-19	1.35e-21
HALON-1301	Air	7.95e-08	2.47e-11	0	-8.75e-13	7.95e-08	2.30e-10
HCFC-225ca	Air	0	1.40e-04	0	0	1.40e-04	4.05e-07
HCFC-225cb	Air	0	1.40e-04	0	0	1.40e-04	4.05e-07
Heptane	Air	1.09e-06	7.77e-05	0	0	7.88e-05	2.28e-07
Hexamethyldisilizane	Air	0	1.37e-06	0	0	1.37e-06	3.97e-09
Hexane	Air	2.86e-04	2.86e-05	2.24e-06	-2.73e-06	3.14e-04	9.07e-07
Hydrocarbons, remaining unspeciated	Air	9.30e-03	7.75e-03	0	-6.51e-04	1.64e-02	4.74e-05
Hydrochloric acid	Air	1.50e-03	6.58e-02	4.02e-02	-6.88e-04	1.07e-01	3.09e-04
Hydrofluoric acid	Air	2.27e-04	5.27e-02	5.02e-03	-1.47e-04	5.78e-02	1.67e-04
Hydrogen	Air	2.99e-04	1.33e-04	0	0	4.32e-04	1.25e-06
Hydrogen cyanide	Air	3.83e-06	0	0	0	3.83e-06	1.11e-08
Hydrogen sulfide	Air	1.55e-05	1.51e-04	0	-8.88e-06	1.57e-04	4.55e-07
Indeno(1,2,3-cd)pyrene	Air	3.44e-10	1.57e-09	2.46e-09	-6.23e-11	4.31e-09	1.25e-11
Iodine	Air	2.95e-07	0	0	0	2.95e-07	8.52e-10
Iron	Air	4.76e-05	1.85e-06	0	-1.11e-07	4.94e-05	1.43e-07
Isophorone	Air	4.70e-07	2.53e-06	1.94e-05	-5.67e-07	2.18e-05	6.32e-08
Isopropyl alcohol	Air	0	1.78e-02	0	0	1.78e-02	5.13e-05
Isopropylpropionate	Air	9.91e-11	0	0	0	9.91e-11	2.87e-13
ITO etchant, unspecified	Air	0	6.86e-03	0	0	6.86e-03	1.98e-05
Lanthanum	Air	2.63e-08	0	0	0	2.63e-08	7.61e-11
Lead	Air	3.13e-06	6.63e-07	4.76e-06	4.76e-06	1.33e-05	3.85e-08
Lead (Pb, ore)	Air	1.48e-06	0	0	0	1.48e-06	4.29e-09
Magnesium	Air	4.06e-05	4.80e-05	3.68e-04	-1.07e-05	4.46e-04	1.29e-06
Manganese	Air	2.94e-06	1.24e-06	1.70e-05	-3.23e-06	1.80e-05	5.19e-08
Manganese (Mn, ore)	Air	0	3.67e-06	0	0	3.67e-06	1.06e-08
Mercaptans	Air	1.81e-07	0	0	0	1.81e-07	5.24e-10
Mercury	Air	8.53e-07	4.57e-07	2.80e-06	-8.64e-08	4.03e-06	1.16e-08
Metals, remaining unspeciated	Air	2.64e-05	1.60e-08	0	-7.10e-10	2.64e-05	7.63e-08
Methane	Air	3.54e+00	1.22e-01	2.41e-01	-2.82e-02	3.87e+00	1.12e-02
Methanol	Air	1.11e-06	0	0	0	1.11e-06	3.20e-09
Methyl chloride	Air	4.30e-07	2.31e-06	1.77e-05	-5.18e-07	2.00e-05	5.77e-08
Methyl ethyl ketone	Air	3.16e-07	2.43e-06	1.31e-05	-3.81e-07	1.54e-05	4.46e-08
Methyl ethyl ketone	Treatment	0	1.34e-04	0	0	1.34e-04	3.88e-07
Methyl hydrazine	Air	1.38e-07	7.42e-07	5.69e-06	-1.66e-07	6.40e-06	1.85e-08
Methyl methacrylate	Air	1.62e-08	8.73e-08	6.69e-07	-1.95e-08	7.53e-07	2.18e-09
Methyl tert-butyl ether	Air	2.84e-08	1.52e-07	1.17e-06	-3.81e-07	9.71e-07	2.81e-09
Molybdenum	Air	2.98e-07	6.21e-07	2.18e-07	-1.35e-08	1.12e-06	3.25e-09
Monosilane	Air	0	1.54e-03	0	0	1.54e-03	4.44e-06
Naphthalene	Air	1.30e-07	7.67e-07	6.82e-07	-1.90e-08	1.56e-06	4.51e-09
N-bromoacetamide	Air	0	9.18e-03	0	0	9.18e-03	2.65e-05
Nickel	Air	8.06e-06	5.57e-05	2.56e-05	-2.98e-06	8.64e-05	2.50e-07
Nitric acid	Air	0	2.69e-04	0	0	2.69e-04	7.76e-07
Nitrogen dioxide	Air	3.08e-02	0	0	4.46e-04	3.12e-02	9.03e-05
Nitrogen fluoride	Air	0	2.45e-01	0	0	2.45e-01	7.09e-04
Nitrogen oxides	Air	6.56e-01	7.62e-01	4.39e-01	-1.36e-02	1.84e+00	5.33e-03
Nitrous oxide	Air	1.24e-03	1.20e-03	1.27e-03	-7.19e-04	2.98e-03	8.63e-06

Table J-13. LCD air emissions (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	Fraction of Total
Nonmethane hydrocarbons, remaining unspeciated	Air	2.07e-01	8.87e-03	0	-1.26e-03	2.15e-01	6.22e-04
n-Propane	Air	4.49e-05	8.67e-08	0	-2.40e-07	4.48e-05	1.29e-07
Other organics	Air	4.45e-01	1.35e-02	0	-2.41e-03	4.56e-01	1.32e-03
o-xylene	Air	4.83e-06	2.24e-07	2.13e-08	-2.50e-08	5.05e-06	1.46e-08
Pentane	Air	4.18e-04	4.10e-05	0	-3.85e-06	4.55e-04	1.31e-06
Perfluoroethane	Air	5.36e-06	0	0	0	5.36e-06	1.55e-08
Perfluoromethane	Air	4.83e-05	0	0	0	4.83e-05	1.40e-07
Phenanthrene	Air	4.92e-09	1.92e-08	9.35e-08	-2.66e-09	1.15e-07	3.33e-10
Phenol	Air	9.34e-07	6.98e-08	5.36e-07	-1.56e-08	1.52e-06	4.41e-09
Phosphine	Air	0	6.26e-02	0	0	6.26e-02	1.81e-04
Phosphoric acid	Air	0	4.85e-05	0	0	4.85e-05	1.40e-07
Phosphorus (yellow or white)	Air	7.54e-07	6.20e-07	1.85e-06	-7.84e-08	3.14e-06	9.09e-09
Phosphorus pentoxide	Air	2.56e-10	0	0	0	2.56e-10	7.40e-13
PM	Air	9.16e-02	6.99e-03	0	-1.24e-02	8.62e-02	2.49e-04
PM-10	Air	3.45e-07	6.85e-03	2.16e-02	3.43e-06	2.84e-02	8.21e-05
Polycyclic aromatic hydrocarbons	Air	6.77e-06	2.84e-12	0	-1.01e-13	6.77e-06	1.96e-08
Polyimide, unspecified	Air	0	1.40e-04	0	0	1.40e-04	4.04e-07
Potassium	Air	1.10e-05	0	0	0	1.10e-05	3.19e-08
Process material for backlight assembly	Air	0	7.03e-05	0	0	7.03e-05	2.03e-07
Propionaldehyde	Air	3.08e-07	1.66e-06	1.27e-05	-3.71e-07	1.43e-05	4.14e-08
Propylene	Air	1.18e-05	0	0	0	1.18e-05	3.42e-08
Pyrene	Air	1.08e-09	4.51e-09	1.24e-08	-3.30e-10	1.77e-08	5.11e-11
Scandium	Air	6.40e-09	0	0	0	6.40e-09	1.85e-11
Selenium	Air	1.21e-06	6.11e-06	4.36e-05	-1.27e-06	4.97e-05	1.44e-07
Silicon	Air	2.89e-04	8.31e-07	0	-4.96e-08	2.90e-04	8.37e-07
Sodium	Air	7.73e-06	4.92e-06	0	-2.93e-07	1.24e-05	3.57e-08
Strontium	Air	1.65e-06	0	0	0	1.65e-06	4.78e-09
Styrene	Air	2.03e-08	1.09e-07	8.37e-07	-2.44e-08	9.42e-07	2.72e-09
Sulfur dioxide	Air	4.63e-02	2.95e-01	9.30e-01	2.96e-04	1.27e+00	3.68e-03
Sulfur hexafluoride	Air	0	7.30e-03	0	0	7.30e-03	2.11e-05
Sulfur oxides	Air	2.57e-02	4.07e-02	0	-1.93e-02	4.71e-02	1.36e-04
Sulfuric acid	Air	6.31e-07	0	0	0	6.31e-07	1.82e-09
Tars (unspecified)	Air	3.09e-13	0	0	0	3.09e-13	8.92e-16
Tetrachloroethylene	Air	3.49e-08	1.88e-07	1.44e-06	-4.14e-08	1.62e-06	4.68e-09
Tetramethyl ammonium hydroxide	Air	0	6.43e-01	0	0	6.43e-01	1.86e-03
Thallium	Air	4.36e-09	0	0	0	4.36e-09	1.26e-11
Thorium	Air	1.41e-08	0	0	0	1.41e-08	4.09e-11
Tin	Air	8.21e-09	0	0	0	8.21e-09	2.37e-11
Titanium	Air	2.85e-06	0	0	0	2.85e-06	8.24e-09
TOCs, remaining unspeciated	Air	0	6.74e-04	2.15e-03	4.08e-07	2.82e-03	8.16e-06
Toluene	Air	1.05e-05	5.95e-05	9.49e-06	-2.95e-07	7.92e-05	2.29e-07
Trichloroethylene	Air	0	0	0	5.85e-10	5.85e-10	1.69e-12
Unspecified LCD process material	Air	0	4.49e-02	0	0	4.49e-02	1.30e-04
Uranium	Air	1.39e-08	0	0	0	1.39e-08	4.01e-11
Vanadium	Air	1.77e-05	3.22e-05	6.57e-06	-9.16e-07	5.56e-05	1.61e-07
Vinyl acetate	Air	6.16e-09	3.31e-08	2.54e-07	-7.42e-09	2.86e-07	8.28e-10
Vinyl chloride	Air	0	0	0	1.17e-09	1.17e-09	3.38e-12
Waste metals, unspecified	Air	6.33e-06	0	0	0	6.33e-06	1.83e-08

Table J-13. LCD air emissions (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	Fraction of Total
Xylene (mixed isomers)	Air	9.57e-06	1.49e-07	1.24e-06	-2.71e-08	1.09e-05	3.16e-08
Zinc (elemental)	Air	6.60e-06	1.80e-05	5.69e-06	-1.81e-07	3.01e-05	8.69e-08
Zirconium	Air	6.71e-09	0	0	0	6.71e-09	1.94e-11
Total air emissions		1.12e+02	6.48e+01	1.68e+02	1.30e+00	3.46e+02	1.00e+00

Table J-14. LCD water outputs (wastewater and water pollutants) (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
WASTEWATER STREAM							
Wastewater stream	surface water	8.57e+00	2.52e+03	0	-2.41e+00	2.53e+03	80.91%
Wastewater stream	treatment	0	5.97e+02	0	0	5.97e+02	19.09%
Total wastewater streams		8.57e+00	3.12e+03	0	-2.41e+00	3.13e+03	100.00%
WATER POLLUTANTS							
1,1,1-Trichloroethane	surface water	2.78e-14	2.29e-08	0	0	2.29e-08	1.36E-08
1,2-Dichloroethane	surface water	0	0	0	1.74e-11	1.74e-11	1.03E-11
Acids (H+)	surface water	1.34e-04	1.76e-08	0	-3.15e-09	1.34e-04	0.0080%
Adsorbable organic halides	surface water	5.26e-08	1.82e-11	0	-6.44e-13	5.26e-08	3.14E-08
Alcohols	surface water	3.75e-08	0	0	0	3.75e-08	2.23E-08
Aldehydes	surface water	5.08e-10	0	0	0	5.08e-10	3.03E-10
Alkane (unspecified)	surface water	1.92e-06	0	0	0	1.92e-06	0.0001%
Alkenes	surface water	1.77e-07	0	0	0	1.77e-07	1.06E-07
Aluminum (+3)	surface water	6.00e-04	6.88e-06	0	-2.44e-07	6.07e-04	0.0361%
Aluminum hydroxide	surface water	4.36e-10	0	0	0	4.36e-10	2.60E-10
Ammonia	surface water	6.23e-04	0	0	-3.91e-06	6.19e-04	0.0369%
Ammonia ions	surface water	2.51e-05	1.33e-03	0	-4.38e-05	1.31e-03	0.0782%
Antimony	surface water	0	1.14e-07	0	0	1.14e-07	6.80E-08
Aromatic hydrocarbons	surface water	8.45e-06	4.25e-09	0	-1.51e-10	8.46e-06	0.0005%
Arsenic	surface water	0	1.14e-07	0	0	1.14e-07	6.80E-08
Arsenic cmpds	surface water	1.24e-06	0	0	5.34e-09	1.24e-06	0.0001%
Barium cmpds	surface water	8.36e-05	1.36e-08	0	7.51e-08	8.37e-05	0.0050%
Barium sulfate	surface water	1.86e-04	0	0	0	1.86e-04	0.0111%
Benzene	surface water	1.93e-06	0	0	1.74e-11	1.93e-06	0.0001%
BOD	surface water	7.72e-04	2.79e-02	0	-3.18e-04	2.83e-02	1.6873%
BOD	treatment	0	5.74e-02	0	0	5.74e-02	3.4201%
Borax	treatment	0	1.31e-06	0	0	1.31e-06	0.0001%
Boric acid	surface water	5.57e-07	0	0	0	5.57e-07	3.32E-07
Boron	surface water	0	4.58e-06	0	0	4.58e-06	0.0003%
Boron (B III)	surface water	9.79e-08	0	0	0	9.79e-08	5.83E-08
Cadmium	surface water	0	1.14e-07	0	0	1.14e-07	6.80E-08
Cadmium cmpds	surface water	1.89e-07	1.42e-11	0	2.85e-10	1.89e-07	1.13E-07
Calcium (+2)	surface water	1.37e-03	0	0	0	1.37e-03	0.0816%
Carbon tetrachloride	surface water	0	0	0	1.74e-11	1.74e-11	1.03E-11
Carbonate ion	surface water	2.69e-03	0	0	0	2.69e-03	0.1601%
Cesium (+2)	surface water	5.92e-09	0	0	0	5.92e-09	3.53E-09
Chloride ions	surface water	2.33e-01	3.12e-01	0	-1.58e-02	5.29e-01	31.5275%
Chlorine	surface water	6.36e-07	0	0	0	6.36e-07	3.79E-07
Chloroform	surface water	2.87e-12	0	0	1.74e-11	2.02e-11	1.21E-11
Chromium	surface water	0	8.84e-06	0	0	8.84e-06	0.0005%
Chromium (III)	surface water	6.23e-06	3.49e-09	0	1.80e-09	6.23e-06	0.0004%
Chromium (VI)	surface water	2.94e-07	2.33e-07	0	1.80e-09	5.29e-07	3.15E-07
Cobalt (Co I, Co II, Co III)	surface water	7.70e-10	0	0	0	7.70e-10	4.59E-10
COD	surface water	7.67e-03	8.20e-02	0	-2.69e-03	8.70e-02	5.1827%
COD	treatment	0	3.90e-02	0	0	3.90e-02	2.3251%
Colon bacillus (bacteria in large intestine)	surface water	0	3.89e-03	0	0	3.89e-03	0.2320%
Copper	surface water	0	9.18e-07	0	0	9.18e-07	0.0001%
Copper (+1 & +2)	surface water	3.80e-06	2.84e-10	0	-1.01e-11	3.80e-06	0.0002%

Table J-14. LCD water outputs (wastewater and water pollutants) (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Copper (+1 & +2)	treatment	0	4.28e-05	0	0	4.28e-05	0.0026%
Cyanide (-1)	surface water	4.49e-06	3.66e-06	0	-7.04e-13	8.15e-06	0.0005%
Cyanide (-1)	treatment	0	6.67e-07	0	0	6.67e-07	3.97E-07
Dichloromethane	surface water	8.22e-09	0	0	2.78e-11	8.25e-09	4.91E-09
Dissolved organic matter (chlorinated)	surface water	1.31e-06	0	0	0	1.31e-06	0.0001%
Dissolved organics	surface water	1.20e-03	4.67e-08	0	-8.34e-09	1.20e-03	0.0716%
Dissolved solids	surface water	3.21e-03	1.75e-01	0	-5.69e-05	1.78e-01	10.6251%
Edetic acid (EDTA)	surface water	9.46e-10	0	0	0	9.46e-10	5.63E-10
Ethylbenzene	surface water	1.43e-07	0	0	6.28e-11	1.43e-07	8.50E-08
Fluoride	surface water	3.39e-06	0	0	0	3.39e-06	0.0002%
Fluorides (F-)	surface water	5.14e-05	1.29e-02	0	-5.01e-06	1.30e-02	0.7724%
Fluorides (F-)	treatment	0	2.40e-04	0	0	2.40e-04	0.0143%
Formaldehyde	surface water	3.54e-14	0	0	0	3.54e-14	2.11E-14
Halogenated matter (organic)	surface water	1.65e-13	5.67e-12	0	-2.01e-13	5.64e-12	3.36E-12
Hexachloroethane	surface water	5.06e-18	0	0	0	5.06e-18	3.01E-18
Hexane	surface water	0	5.88e-04	0	0	5.88e-04	0.0351%
Hydrazine	surface water	4.35e-10	0	0	0	4.35e-10	2.59E-10
Hydrocarbons, remaining unspeciated	surface water	8.97e-05	1.70e-05	0	-7.87e-07	1.06e-04	0.0063%
Hydrochloric acid	treatment	0	3.29e-06	0	0	3.29e-06	0.0002%
Hypochlorite	surface water	8.62e-10	0	0	0	8.62e-10	5.14E-10
Hypochlorous acid	surface water	8.62e-10	0	0	0	8.62e-10	5.14E-10
Iodide (-1)	surface water	5.93e-07	0	0	0	5.93e-07	3.53E-07
Iron	surface water	0	1.31e-04	0	0	1.31e-04	0.0078%
Iron	treatment	0	8.33e-05	0	0	8.33e-05	0.0050%
Iron (+2 & +3)	surface water	3.71e-04	1.73e-08	0	-1.02e-08	3.71e-04	0.0221%
Lead	surface water	0	8.18e-06	0	0	8.18e-06	0.0005%
Lead	treatment	0	8.33e-07	0	0	8.33e-07	4.96E-07
Lead cmpds	surface water	3.68e-06	5.67e-11	0	4.98e-10	3.68e-06	0.0002%
Lead cmpds	treatment	0	7.14e-06	0	0	7.14e-06	0.0004%
Lithium salts	surface water	4.86e-11	0	0	0	4.86e-11	2.89E-11
Magnesium (+2)	surface water	5.13e-04	0	0	0	5.13e-04	0.0305%
Manganese	surface water	0	2.29e-07	0	0	2.29e-07	1.36E-07
Manganese cmpds	surface water	1.48e-05	0	0	0	1.48e-05	0.0009%
Mercury	treatment	0	8.33e-08	0	0	8.33e-08	4.96E-08
Mercury	surface water	9.08e-08	9.69e-08	0	0	1.88e-07	1.12E-07
Mercury compounds	surface water	5.82e-07	6.52e-14	0	1.62e-11	5.82e-07	3.47E-07
Metals, remaining unspeciated	surface water	3.55e-04	4.72e-04	0	-2.45e-05	8.03e-04	0.0478%
Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	surface water	1.88e-06	0	0	0	1.88e-06	0.0001%
Morpholine	surface water	4.60e-09	0	0	0	4.60e-09	2.74E-09
Nickel	surface water	0	2.33e-07	0	0	2.33e-07	1.39E-07
Nickel	treatment	0	3.33e-06	0	0	3.33e-06	0.0002%
Nickel (+2)	surface water	4.39e-07	0	0	0	4.39e-07	2.62E-07
Nickel cmpds	surface water	3.29e-06	2.84e-11	0	-1.01e-12	3.29e-06	0.0002%
Nitrate	surface water	1.97e-05	3.15e-06	0	-1.27e-06	2.15e-05	0.0013%
Nitrates/nitrites	surface water	8.00e-05	0	0	0	8.00e-05	0.0048%
Nitrites	surface water	4.23e-07	0	0	0	4.23e-07	2.52E-07
Nitrogen	surface water	1.44e-05	7.98e-02	0	0	7.98e-02	4.7566%

Table J-14. LCD water outputs (wastewater and water pollutants) (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Nitrogen	treatment	0	1.26e-02	0	0	1.26e-02	0.7494%
Nitrogen dioxide	surface water	3.04e-04	0	0	0	3.04e-04	0.0181%
Oil & grease	surface water	2.18e-06	5.36e-04	0	0	5.38e-04	0.0321%
Oil & grease	treatment	0	3.61e-03	0	0	3.61e-03	0.2150%
Organic phosphorus, unspecified	surface water	0	2.29e-07	0	0	2.29e-07	1.36E-07
Orthoboric acid	treatment	0	1.31e-06	0	0	1.31e-06	0.0001%
Other nitrogen	surface water	2.25e-04	7.66e-10	0	-2.72e-11	2.25e-04	0.0134%
Other organics	surface water	2.12e-05	0	0	0	2.12e-05	0.0013%
Oxalic acid	surface water	1.89e-09	0	0	0	1.89e-09	1.13E-09
o-xylene	surface water	0	0	0	1.37e-10	1.37e-10	8.14E-11
Phenol	surface water	4.50e-05	1.76e-04	0	-6.22e-06	2.14e-04	0.0128%
Phosphate (PO43-)	surface water	1.11e-04	0	0	0	1.11e-04	0.0066%
Phosphates	surface water	2.23e-07	2.83e-08	0	7.27e-10	2.52e-07	1.50E-07
Phosphorus (yellow or white)	surface water	1.92e-06	4.33e-03	0	0	4.33e-03	0.2581%
Phosphorus (yellow or white)	treatment	0	6.91e-03	0	0	6.91e-03	0.4114%
Phosphorus pentoxide	surface water	7.63e-09	0	0	0	7.63e-09	4.54E-09
Polychlorinated biphenyls	surface water	0	1.14e-08	0	0	1.14e-08	6.80E-09
Polycyclic aromatic hydrocarbons	surface water	2.87e-06	6.81e-11	0	-2.41e-12	2.87e-06	0.0002%
Potassium (+1)	surface water	2.46e-04	0	0	0	2.46e-04	0.0146%
Rubidium ion (Rb+)	surface water	5.93e-08	0	0	0	5.93e-08	3.53E-08
Salts (unspecified)	surface water	2.54e-04	7.84e-05	0	-2.78e-06	3.29e-04	0.0196%
Sand	surface water	2.95e-09	0	0	0	2.95e-09	1.76E-09
Saponifiable oils and fats	surface water	7.30e-05	0	0	0	7.30e-05	0.0044%
Selenium	surface water	2.99e-06	0	0	2.88e-11	2.99e-06	0.0002%
Silver compounds	surface water	3.56e-09	0	0	5.26e-10	4.09e-09	2.43E-09
Sodium (+1)	surface water	1.73e-01	3.41e-01	0	-2.03e-02	4.94e-01	29.4192%
Strontium (Sr II)	surface water	9.60e-05	0	0	0	9.60e-05	0.0057%
Sulfate ion (-4)	surface water	2.40e-02	2.94e-03	0	-1.20e-06	2.69e-02	1.6033%
Sulfate ion (-4)	treatment	0	1.32e-04	2.55e-02	4.84e-06	2.57e-02	1.5285%
Sulfide	surface water	2.20e-06	9.86e-09	0	-1.74e-09	2.20e-06	0.0001%
Sulfites	surface water	4.80e-07	0	0	0	4.80e-07	2.86E-07
Sulfur	surface water	1.04e-11	0	0	0	1.04e-11	6.18E-12
Suspended solids	surface water	4.98e-03	5.80e-02	0	-1.44e-03	6.15e-02	3.6643%
Suspended solids	treatment	0	5.60e-03	6.65e-04	1.26e-07	6.26e-03	0.3732%
Tars (unspecified)	surface water	5.06e-15	0	0	0	5.06e-15	3.01E-15
Tetrachloroethylene	surface water	1.26e-14	2.29e-08	0	1.74e-11	2.29e-08	1.37E-08
Tin	surface water	0	4.58e-07	0	0	4.58e-07	2.73E-07
Tin (Sn++, Sn4+)	surface water	5.11e-05	0	0	0	5.11e-05	0.0030%
Titanium tetrachloride	surface water	3.52e-05	0	0	0	3.52e-05	0.0021%
TOCs	surface water	8.96e-04	4.25e-08	0	-1.51e-09	8.96e-04	0.0534%
Toluene	surface water	1.60e-06	6.24e-10	0	5.83e-10	1.60e-06	0.0001%
Trichloroethylene	surface water	7.66e-13	2.29e-08	0	1.74e-11	2.29e-08	1.37E-08
Triethylene glycol	surface water	1.86e-06	0	0	0	1.86e-06	0.0001%
Vanadium (V3+, V5+)	surface water	3.18e-06	0	0	0	3.18e-06	0.0002%
Vinyl chloride	surface water	0	0	0	3.48e-11	3.48e-11	2.07E-11
VOCs, remaining unspeciated	surface water	2.07e-06	0	0	0	2.07e-06	0.0001%
Waste metals, unspecified	surface water	9.37e-05	0	0	0	9.37e-05	0.0056%
Waste oil	surface water	1.75e-03	4.87e-03	0	-2.06e-04	6.41e-03	0.3817%
Xylene (mixed isomers)	surface water	6.41e-06	0	0	1.76e-10	6.41e-06	0.0004%
Zinc (+2)	surface water	7.41e-06	1.40e-09	0	-2.09e-10	7.41e-06	0.0004%
Zinc (elemental)	surface water	0	2.63e-06	0	0	2.63e-06	0.0002%
Total water pollutants		4.60e-01	1.23e+00	2.62e-02	-4.09e-02	1.68e+00	100.00%

Table J-15. LCD hazardous waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Acetic acid	landfill	0	4.46E-03	0	0	4.46E-03	7.09E-04
Acetone	treatment	0	2.77E-02	0	0	2.77E-02	4.40E-03
Acid waste (D002 waste)	treatment	0	1.19E-03	0	0	1.19E-03	1.89E-04
Barium debris (D008 waste)	landfill	0	9.91E-06	0	0	9.91E-06	1.57E-06
Chrome debris (D007 waste)	treatment	0	6.83E-06	0	0	6.83E-06	1.08E-06
Chrome liquid waste (D007 waste)	recycling/reuse	0	4.54E-04	0	0	4.54E-04	7.22E-05
Chromium	landfill	0	1.52E-06	0	0	1.52E-06	2.41E-07
EOL LCD Monitor, landfilled	landfill	0	0	0	1.64E+00	1.64E+00	26.13%
Ferric chloride	recycling/reuse	0	1.37E-02	0	0	1.37E-02	2.18E-03
Flammable liquids (F003 waste)	treatment	0	9.13E-04	0	0	9.13E-04	1.45E-04
Hazardous waste, unspecified	landfill	6.72E-03	2.97E-02	0	-1.05E-03	3.54E-02	5.62E-03
Hazardous waste, unspecified	recycling/reuse	0	1.42E-02	0	0	1.42E-02	2.26E-03
Hazardous waste, unspecified	treatment	0	6.16E-02	0	0	6.16E-02	9.78E-03
HCFC-225ca	recycling/reuse	0	3.11E-05	0	0	3.11E-05	4.94E-06
HCFC-225cb	recycling/reuse	0	3.11E-05	0	0	3.11E-05	4.94E-06
Hydrofluoric acid	landfill	0	8.24E-05	0	0	8.24E-05	1.31E-05
Isopropyl alcohol	recycling/reuse	0	1.69E-01	0	0	1.69E-01	2.69%
Isopropyl alcohol	treatment	0	1.91E+00	0	0	1.91E+00	30.41%
Mercury	recycling/reuse	0	2.00E-06	0	0	2.00E-06	3.18E-07
Nitric acid	landfill	0	3.43E-04	0	0	3.43E-04	5.45E-05
Phosphoric acid	landfill	0	1.44E-02	0	0	1.44E-02	2.29E-03
PWB-Decontaminating debris	treatment	0	6.85E-03	0	0	6.85E-03	1.09E-03
PWB-Lead contaminated waste oil	treatment	0	5.14E-03	0	0	5.14E-03	8.16E-04
PWB-Route dust	recycling/reuse	0	5.31E-03	0	0	5.31E-03	8.43E-04
PWB-Solder dross	recycling/reuse	0	2.96E-02	0	0	2.96E-02	4.70E-03
PWB-Waste cupric etchant	recycling/reuse	0	9.93E-02	0	0	9.93E-02	1.58%
Remover, unspecified	recycling/reuse	0	8.84E-02	0	0	8.84E-02	1.40%
Remover, unspecified	treatment	0	3.03E-01	0	0	3.03E-01	4.81%
Rinse, unspecified	recycling/reuse	0	4.67E-02	0	0	4.67E-02	7.42E-03
Silver	landfill	0	2.72E-09	0	0	2.72E-09	4.33E-10
Sodium sulfate	recycling/reuse	0	2.44E-01	0	0	2.44E-01	3.89%
Spent solvent (non-halogenated)	treatment	0	4.66E-02	0	0	4.66E-02	7.41E-03
Spent solvent (with halogenated materials)	treatment	0	1.55E-02	0	0	1.55E-02	2.47E-03
Spent solvents (F003 waste)	treatment	0	2.74E-04	0	0	2.74E-04	4.35E-05
Tetramethyl ammonium hydroxide	recycling/reuse	0	1.42E-01	0	0	1.42E-01	2.26%
Thinner, unspecified	treatment	0	5.40E-01	0	0	5.40E-01	8.57%
Unspecified sludge	land (other than	0	3.09E-02	0	0	3.09E-02	4.91E-03
Waste acid (chrome mixed acid)	recycling/reuse	0	7.18E-03	0	0	7.18E-03	1.14E-03
Waste acid (mainly HF)	recycling/reuse	0	5.69E-01	0	0	5.69E-01	9.04%
Waste acid (mainly HF)	treatment	0	1.36E-01	0	0	1.36E-01	2.15%
Waste acid (mostly 3% HCl solution)	recycling/reuse	0	1.82E-04	0	0	1.82E-04	2.89E-05
Waste acids, unspecified	recycling/reuse	0	3.24E-02	0	0	3.24E-02	5.15E-03
Waste Batch (Ba, Pb) (D008 waste)	landfill	0	6.55E-05	0	0	6.55E-05	1.04E-05
Waste CCFL, with lead	treatment	0	8.17E-08	0	0	8.17E-08	1.30E-08
Waste CCFL, with mercury	treatment	0	8.17E-10	0	0	8.17E-10	1.30E-10
Waste glass, with mercury	landfill	0	1.05E-10	0	0	1.05E-10	1.67E-11
Waste metals, unspecified	recycling/reuse	0	1.17E-03	0	0	1.17E-03	1.85E-04
Waste solvent (photoresist)	recycling/reuse	0	2.05E-02	0	0	2.05E-02	3.26E-03
Waste solvent (photoresist)	treatment	0	2.17E-02	0	0	2.17E-02	3.45E-03
Total hazardous waste		6.72E-03	4.64E+00	0.00E+00	1.64E+00	6.29E+00	100.00%

Table J-16. LCD solid waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
abrasive sludge	recycling/reuse	0	1.95E-03	0	0	1.95E-03	3.73E-05
acid absorbent	landfill	0	3.77E-06	0	0	3.77E-06	7.20E-08
Aluminum (elemental)	landfill	1.23E-05	0	0	0	1.23E-05	2.35E-07
Aluminum scrap	recycling/reuse	2.55E-07	8.77E-06	0	9.52E-03	9.53E-03	1.82E-04
Aluminum scrap, Wabash 319	recycling/reuse	0	2.37E-08	0	0	2.37E-08	4.53E-10
Arsenic	landfill	4.91E-09	0	0	0	4.91E-09	9.38E-11
Bauxite residues	landfill	1.70E-05	5.87E-04	0	-1.96E-05	5.84E-04	1.12E-05
blasting media	landfill	0	1.70E-05	0	0	1.70E-05	3.24E-07
Broken CCFL	landfill	0	2.69E-07	0	0	2.69E-07	5.14E-09
Cadmium	landfill	4.92E-10	0	0	0	4.92E-10	9.40E-12
Calcium	landfill	4.91E-05	0	0	0	4.91E-05	9.38E-07
Carbon	landfill	3.79E-05	0	0	0	3.79E-05	7.24E-07
CARBON STEEL SCRAP	recycling/reuse	0	0	0	4.58E-01	4.58E-01	8.75E-03
Cardboard	treatment	0	1.82E-05	0	0	1.82E-05	3.47E-07
Chromium (III)	landfill	3.07E-08	0	0	0	3.07E-08	5.87E-10
Chromium (VI)	landfill	3.07E-08	0	0	0	3.07E-08	5.87E-10
Cinders from LCD glass mfg	landfill	0	3.83E-04	0	0	3.83E-04	7.31E-06
Coal waste	landfill	0	2.28E+00	1.90E+01	3.60E-03	2.13E+01	40.64%
Cobalt	landfill	2.36E-10	0	0	0	2.36E-10	4.51E-12
Cobalt nitrate	treatment	0	2.83E-06	0	0	2.83E-06	5.40E-08
Copper	landfill	1.18E-09	0	0	0	1.18E-09	2.26E-11
Diesel fuel	treatment	0	1.88E-06	0	0	1.88E-06	3.60E-08
Dust	treatment	0	1.59E-04	0	0	1.59E-04	3.03E-06
Dust/sludge	landfill	0	8.80E-01	7.34E+00	1.39E-03	8.23E+00	15.72%
EOL LCD Monitor, incinerated	treatment	0	0	0	9.75E-01	9.75E-01	1.86%
EOL LCD Monitor, landfilled	landfill	0	0	0	8.94E-01	8.94E-01	1.71%
EOL LCD Monitor, recycled	recycling/reuse	0	0	0	9.75E-01	9.75E-01	1.86%
EOL LCD Monitor, remanufactured	recycling/reuse	0	0	0	9.75E-01	9.75E-01	1.86%
FGD sludge	landfill	2.45E-02	1.09E-02	0	-6.11E-04	3.48E-02	6.64E-04
Fly/bottom ash	landfill	0	5.70E-01	4.75E+00	9.01E-04	5.32E+00	10.16%
Iron	landfill	2.46E-05	0	0	0	2.46E-05	4.70E-07
Iron scrap	recycling/reuse	1.67E-01	0	0	1.10E+00	1.27E+00	2.42%
Isopropyl alcohol	recycling/reuse	0	2.53E-02	0	0	2.53E-02	4.84E-04
Isopropyl alcohol	treatment	0	1.03E-02	0	0	1.03E-02	1.97E-04
LCD glass	recycling/reuse	0	0	0	8.77E-02	8.77E-02	1.68E-03
LCD glass EP dust	landfill	0	4.77E-05	0	0	4.77E-05	9.12E-07
LCD glass EP dust	recycling/reuse	0	2.32E-04	0	0	2.32E-04	4.43E-06
LCD glass, unspecified	landfill	0	1.13E-03	0	0	1.13E-03	2.15E-05
LCD panel waste	landfill	0	2.43E-02	0	0	2.43E-02	4.64E-04
Lead	landfill	5.42E-09	0	0	0	5.42E-09	1.04E-10
Manganese	landfill	4.91E-07	0	0	0	4.91E-07	9.38E-09
Mercury	landfill	3.33E-11	0	0	0	3.33E-11	6.36E-13
Mineral waste	landfill	2.20E-01	1.26E-04	0	-4.46E-06	2.21E-01	4.21E-03
Mining waste	landfill	1.41E-01	0	0	-1.23E-06	1.41E-01	2.69E-03
Mixed industrial (waste)	landfill	4.34E-02	4.83E-02	0	-1.35E-03	9.04E-02	1.73E-03
Nickel	landfill	1.77E-09	0	0	0	1.77E-09	3.38E-11
Nickel nitrate	treatment	0	2.83E-06	0	0	2.83E-06	5.40E-08
Nitrogen	landfill	9.83E-09	0	0	0	9.83E-09	1.88E-10
Non mineral waste (inert)	landfill	9.80E-06	0	0	0	9.80E-06	1.87E-07
Non toxic chemical waste (unspecified)	landfill	5.72E-03	2.95E-05	0	-1.05E-06	5.75E-03	1.10E-04
Oily rags & filter media	landfill	0	1.51E-05	0	0	1.51E-05	2.88E-07
Oily rags & filter media	recycling/reuse	0	1.88E-06	0	0	1.88E-06	3.60E-08

Table J-16. LCD solid waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
parts cleaner solvent	recycling/reuse	0	3.77E-06	0	0	3.77E-06	7.20E-08
Phosphorus (yellow or white)	landfill	6.29E-07	0	0	0	6.29E-07	1.20E-08
Plating process sludge	landfill	0	1.52E-05	0	0	1.52E-05	2.90E-07
Polycarbonate	recycling/reuse	0	0	0	3.90E-01	3.90E-01	7.46E-03
Polyester resin	recycling/reuse	0	3.20E-02	0	0	3.20E-02	6.11E-04
Polyethylene, foamed	treatment	0	9.99E-04	0	0	9.99E-04	1.91E-05
Polyethylene/polypropylene waste	treatment	0	2.72E-03	0	0	2.72E-03	5.20E-05
Potassium Carbonate	landfill	0	1.53E-04	0	0	1.53E-04	2.91E-06
Printed wiring board (PWB)	landfill	0	7.50E-03	0	0	7.50E-03	1.43E-04
PWB-Drill dust	landfill	0	6.59E-03	0	0	6.59E-03	1.26E-04
Remover, unspecified	treatment	0	3.09E-02	0	0	3.09E-02	5.90E-04
Sewage sludge (unspecified)	landfill	3.25E-05	0	0	0	3.25E-05	6.22E-07
Slag and ash	recycling/reuse	8.02E+00	3.40E+00	0	-9.67E+00	1.75E+00	3.35%
Slag and ash	landfill	8.19E-02	3.49E-02	0	-1.99E-03	1.15E-01	2.19E-03
sludge (calcium fluoride, CaF2)	recycling/reuse	0	8.13E-04	0	0	8.13E-04	1.55E-05
Sludge from LCD glass mfg	landfill	0	4.06E-05	0	0	4.06E-05	7.77E-07
Sodium Carbonate	landfill	0	1.53E-04	0	0	1.53E-04	2.91E-06
Stannous sludge	recycling/reuse	3.25E-04	0	0	0	3.25E-04	6.22E-06
Steel scrap (tinplated)	recycling/reuse	7.73E-02	0	0	0	7.73E-02	1.48E-03
Sulfur	landfill	7.37E-06	0	0	0	7.37E-06	1.41E-07
Unspecified nonhazardous waste	recycling/reuse	0	1.26E-04	0	0	1.26E-04	2.40E-06
Unspecified sludge	landfill	0	3.56E-04	0	0	3.56E-04	6.80E-06
Unspecified sludge	recycling/reuse	0	8.46E-01	0	0	8.46E-01	1.62%
Unspecified sludge	treatment	0	5.73E-02	0	0	5.73E-02	1.09E-03
Unspecified solid waste	landfill	2.40E+00	0	0	-5.10E-01	1.89E+00	3.62%
Unspecified solid waste	recycling/reuse	1.50E+00	2.11E-01	0	0	1.71E+00	3.27%
Unspecified solid waste	treatment	0	1.63E+00	0	0	1.63E+00	3.11%
Unspecified solid waste (incinerated)	treatment	4.61E-04	6.44E-04	0	-3.84E-05	1.07E-03	2.04E-05
Unspecified waste	recycling/reuse	4.05E-01	1.72E-01	0	-9.83E-03	5.67E-01	1.08E-02
Unspecified waste	landfill	0	0	0	-9.74E-02	-9.74E-02	-1.86E-03
Used silica gel	landfill	0	6.22E-04	0	0	6.22E-04	1.19E-05
Waste acid (containing F and detergents)	landfill	0	2.70E-01	0	0	2.70E-01	5.16E-03
Waste acids, unspecified	treatment	0	1.05E-01	0	0	1.05E-01	2.00E-03
Waste alkali (color filter developer,	recycling/reuse	0	8.91E-02	0	0	8.91E-02	1.70E-03
Waste alkali, unspecified	recycling/reuse	0	3.23E-01	0	0	3.23E-01	6.18E-03
Waste alkali, unspecified	treatment	0	1.95E-06	0	0	1.95E-06	3.73E-08
Waste backlight casing (PC)	landfill	0	1.46E-05	0	0	1.46E-05	2.79E-07
Waste backlight light guide (PMMA)	landfill	0	1.52E-03	0	0	1.52E-03	2.90E-05
Waste LCD glass	landfill	0	2.63E-01	0	0	2.63E-01	5.03E-03
Waste LCD glass	recycling/reuse	0	7.20E-01	0	0	7.20E-01	1.38%
Waste metals, unspecified	recycling/reuse	0	2.93E-03	0	0	2.93E-03	5.61E-05
Waste oil	treatment	0	1.64E-02	0	0	1.64E-02	3.14E-04
Waste oil	landfill	3.17E-05	0	0	0	3.17E-05	6.05E-07
Waste plastic from LCD modules	recycling/reuse	0	7.40E-02	0	0	7.40E-02	1.41E-03
Waste plastic from LCD modules	treatment	0	4.03E-01	0	0	4.03E-01	7.70E-03
Waste plastics from LCD monitor	landfill	0	4.05E-02	0	0	4.05E-02	7.75E-04
Waste refractory	landfill	0	1.13E-04	0	0	1.13E-04	2.16E-06
Zinc (elemental)	landfill	1.96E-07	0	0	0	1.96E-07	3.75E-09
Total solid waste		1.31E+01	1.26E+01	3.11E+01	-4.42E+00	5.23E+01	100.00%

Table J-17. LCD radioactive waste outputs (kg/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% of Total
Highly radioactive waste (Class C)	landfill	2.72e-06	0	0	0	2.72e-06	0.18%
Low-level radioactive waste	landfill	1.28e-04	3.74e-04	6.56e-04	1.24e-07	1.16e-03	78.49%
Radioactive waste (unspecified)	landfill	5.77e-06	0	0	0	5.77e-06	0.39%
Uranium, depleted	landfill	0	1.12e-04	1.97e-04	3.73e-08	3.09e-04	20.93%
Total radioactive waste		1.37e-04	4.87e-04	8.52e-04	1.62e-07	1.48e-03	100.00%

Table J-18. LCD radioactivity outputs (Bq/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Americium-241 (isotope)	landfill	9.42e+01	0	0	0	9.42e+01	0.0002%
Americium-243 (isotope)	landfill	2.05e+00	0	0	0	2.05e+00	5.11E-08
Antimony-124 (isotope)	surface water	2.12e-02	0	0	0	2.12e-02	5.29E-10
Antimony-124 (isotope)	treatment	0	1.68e+00	2.94e+00	5.59e-04	4.63e+00	1.15E-07
Antimony-125 (isotope)	treatment	0	6.70e+00	1.17e+01	2.23e-03	1.84e+01	4.59E-07
Argon-41 (isotope)	air	0	3.40e+03	5.96e+03	1.13e+00	9.36e+03	0.0233%
Barium-140 (isotope)	treatment	0	1.25e-01	2.18e-01	4.14e-05	3.43e-01	8.55E-09
Bromine-89 (isotope)	air	0	3.93e-04	6.89e-04	1.31e-07	1.08e-03	2.70E-11
Bromine-90 (isotope)	air	0	1.60e-04	2.80e-04	5.32e-08	4.40e-04	1.10E-11
Carbon-14 (isotope)	air	9.35e+00	0	0	0	9.35e+00	2.33E-07
Cesium-134 (isotope)	air	3.58e-04	1.08e-02	1.89e-02	3.59e-06	3.01e-02	7.50E-10
Cesium-134 (isotope)	surface water	1.87e-02	0	0	0	1.87e-02	4.65E-10
Cesium-134 (isotope)	treatment	0	4.49e+00	7.87e+00	1.49e-03	1.24e+01	3.08E-07
Cesium-135 (isotope)	landfill	4.59e+04	0	0	0	4.59e+04	0.1145%
Cesium-136 (isotope)	treatment	0	1.75e-03	3.37e-01	6.40e-05	3.39e-01	8.45E-09
Cesium-137 (isotope)	air	3.58e-04	8.15e-02	1.43e-01	2.71e-05	2.25e-01	5.60E-09
Cesium-137 (isotope)	landfill	1.28e-01	0	0	0	1.28e-01	3.20E-09
Cesium-137 (isotope)	surface water	2.74e-02	0	0	0	2.74e-02	6.82E-10
Cesium-137 (isotope)	treatment	0	6.75e+00	1.18e+01	2.24e-03	1.86e+01	4.63E-07
Chromium-51 (isotope)	air	0	2.13e-01	3.74e-01	7.09e-05	5.87e-01	1.46E-08
Chromium-51 (isotope)	treatment	0	8.10e+00	1.42e+01	2.69e-03	2.23e+01	0.0001%
Cobalt-57 (isotope)	air	0	5.74e-04	1.00e-03	1.91e-07	1.58e-03	3.94E-11
Cobalt-57 (isotope)	treatment	0	1.96e-01	3.43e-01	6.52e-05	5.40e-01	1.35E-08
Cobalt-58 (isotope)	air	3.58e-04	6.66e+00	1.28e+03	2.43e-01	1.29e+03	0.0032%
Cobalt-58 (isotope)	surface water	6.14e-02	0	0	0	6.14e-02	1.53E-09
Cobalt-58 (isotope)	treatment	0	7.98e+01	1.40e+02	2.65e-02	2.20e+02	0.0005%
Cobalt-60 (isotope)	air	3.58e-04	5.51e-02	9.65e-02	1.83e-05	1.52e-01	3.79E-09
Cobalt-60 (isotope)	surface water	3.84e-02	0	0	0	3.84e-02	9.56E-10
Cobalt-80 (isotope)	treatment	0	2.09e+01	3.67e+01	6.96e-03	5.76e+01	0.0001%
Curium-244 (isotope)	landfill	1.91e+02	0	0	0	1.91e+02	0.0005%
Curium-245 (isotope)	landfill	2.13e-02	0	0	0	2.13e-02	5.31E-10
Iodine-129 (isotope)	landfill	3.01e-03	0	0	0	3.01e-03	7.50E-11
Iodine-131 (isotope)	air	2.10e-03	2.57e-01	4.51e-01	8.56e-05	7.11e-01	1.77E-08
Iodine-131 (isotope)	surface water	2.33e-03	0	0	0	2.33e-03	5.80E-11
Iodine-131 (isotope)	treatment	0	3.73e+00	6.54e+00	1.24e-03	1.03e+01	2.56E-07
Iodine-132 (isotope)	air	0	5.23e-02	9.16e-02	1.74e-05	1.44e-01	3.59E-09
Iodine-132 (isotope)	treatment	0	1.41e+00	2.48e+00	4.70e-04	3.89e+00	9.70E-08
Iodine-133 (isotope)	air	4.09e-03	2.39e+02	4.18e+02	7.94e-02	6.57e+02	0.0016%
Iodine-133 (isotope)	treatment	0	1.60e+00	2.80e+00	5.32e-04	4.40e+00	1.10E-07
Iodine-134 (isotope)	air	0	2.71e-01	4.74e-01	9.00e-05	7.45e-01	1.86E-08
Iodine-135 (isotope)	air	0	1.36e-02	2.38e-02	4.52e-06	3.74e-02	9.33E-10
Iodine-135 (isotope)	treatment	0	1.15e+00	2.01e+00	3.82e-04	3.16e+00	7.88E-08
Iron-55 (isotope)	treatment	0	1.91e+01	3.34e+01	6.34e-03	5.25e+01	0.0001%
Iron-59 (isotope)	treatment	0	9.79e-01	1.72e+00	3.25e-04	2.69e+00	6.72E-08
Krypton-85 (isotope)	air	5.45e+01	5.64e+03	9.88e+03	1.88e+00	1.56e+04	0.0388%
Krypton-85M (isotope)	air	0	2.73e+02	4.79e+02	9.09e-02	7.53e+02	0.0019%
Krypton-85M (isotope)	treatment	0	5.04e+00	8.83e+00	1.68e-03	1.39e+01	3.46E-07
Krypton-87 (isotope)	air	0	1.02e+02	1.78e+02	3.38e-02	2.80e+02	0.0007%
Krypton-88 (isotope)	air	0	4.77e+02	8.37e+02	1.59e-01	1.31e+03	0.0033%
Lanthanum-140 (isotope)	treatment	0	1.33e-01	2.34e-01	4.43e-05	3.67e-01	9.15E-09
Lead-210 (isotope)	air	3.21e-01	0	0	0	3.21e-01	7.99E-09

Table J-18. LCD radioactivity outputs (Bq/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Manganese-54 (isotope)	air	0	3.03e-03	5.30e-03	1.01e-06	8.33e-03	2.08E-10
Manganese-54 (isotope)	surface water	3.07e-03	0	0	0	3.07e-03	7.65E-11
Manganese-54 (isotope)	treatment	0	5.34e+00	9.35e+00	1.77e-03	1.47e+01	3.66E-07
Molybdenum-99 (isotope)	treatment	0	1.01e+07	1.76e+07	3.35e+03	2.77e+07	69.0936%
Neptunium-237 (isotope)	landfill	2.95e+01	0	0	0	2.95e+01	0.0001%
Niobium-95 (isotope)	air	0	1.20e-04	2.11e-04	4.00e-08	3.31e-04	8.25E-12
Niobium-95 (isotope)	treatment	0	1.37e+00	2.41e+00	4.57e-04	3.78e+00	9.43E-08
Palladium-107 (isotope)	landfill	1.04e-02	0	0	0	1.04e-02	2.58E-10
Plutonium-239 (isotope)	landfill	3.57e+04	0	0	0	3.57e+04	0.0890%
Plutonium-240 (isotope)	landfill	5.08e+04	0	0	0	5.08e+04	0.1267%
Plutonium-241 (isotope)	landfill	1.18e+07	0	0	0	1.18e+07	29.3291%
Plutonium-242 (isotope)	landfill	1.92e+02	0	0	0	1.92e+02	0.0005%
Polonium-210 (isotope)	air	5.52e-01	0	0	0	5.52e-01	1.38E-08
Potassium-40 (isotope)	air	8.57e-02	0	0	0	8.57e-02	2.14E-09
Protactinium-234 (isotope)	air	5.06e-03	0	0	0	5.06e-03	1.26E-10
Protactinium-234 (isotope)	surface water	9.36e-02	0	0	0	9.36e-02	2.33E-09
Radioactive aerosols and halogenes (unspecified)	air	2.81e-02	0	0	0	2.81e-02	7.01E-10
radioactive gas (unspecified)	air	8.98e+02	0	0	0	8.98e+02	0.0022%
Radioactive substance (unspecified)	air	1.29e+00	4.44e+01	0	-1.57e+00	4.41e+01	0.0001%
Radioactive substance (unspecified)	surface water	1.20e-02	4.11e-01		-1.46e-02	4.09e-01	1.02E-08
Radium-222 (isotope)	air	3.26e+00	0	0	0	3.26e+00	8.13E-08
Radium-224 (isotope)	surface water	2.97e-01	0	0	0	2.97e-01	7.40E-09
Radium-226 (isotope)	air	4.31e-01	0	0	0	4.31e-01	1.07E-08
Radium-226 (isotope)	landfill	2.44e+02	0	0	0	2.44e+02	0.0006%
Radium-226 (isotope)	surface water	1.80e+02	0	0	0	1.80e+02	0.0004%
Radium-228 (isotope)	air	4.23e-02	0	0	0	4.23e-02	1.05E-09
Radium-228 (isotope)	surface water	5.93e-01	0	0	0	5.93e-01	1.48E-08
Radon-220 (isotope)	air	9.93e-01	0	0	0	9.93e-01	2.47E-08
Radon-222 (isotope)	air	4.30e+04	0	0	0	4.30e+04	0.1072%
Rubidium-88 (isotope)	air	0	1.12e+00	1.96e+00	3.72e-04	3.08e+00	7.67E-08
Ruthenium-103 (isotope)	treatment	0	1.68e-01	2.94e-01	5.59e-05	4.63e-01	1.15E-08
Samarium-151 (isotope)	landfill	4.25e+01	0	0	0	4.25e+01	0.0001%
Selenium-79 (isotope)	landfill	3.31e-02	0	0	0	3.31e-02	8.25E-10
Silver-110M (isotope)	air	0	3.59e-06	6.29e-06	1.19e-09	9.88e-06	2.46E-13
Silver-110M (isotope)	surface water	9.21e-02	0	0	0	9.21e-02	2.29E-09
Silver-110M (isotope)	treatment	0	1.96e+00	3.43e+00	6.52e-04	5.40e+00	1.35E-07
Sodium-24 (isotope)	treatment	0	2.99e-01	5.23e-01	9.93e-05	8.22e-01	2.05E-08
Strontium-89 (isotope)	treatment	0	3.23e-01	5.65e-01	1.07e-04	8.88e-01	2.21E-08
Strontium-90 (isotope)	landfill	6.86e+03	0	0	0	6.86e+03	0.0171%
Strontium-90 (isotope)	treatment	0	7.59e-02	1.33e-01	2.52e-05	2.09e-01	5.21E-09
Strontium-95 (isotope)	treatment	0	8.36e-01	1.47e+00	2.78e-04	2.30e+00	5.74E-08
Sulfur-136 (isotope)	treatment	0	1.80e-01	3.15e-01	5.99e-05	4.96e-01	1.24E-08
Technetium-99M (isotope)	air	0	1.61e-05	2.83e-05	5.36e-09	4.44e-05	1.11E-12
Technetium-99M (isotope)	landfill	1.40e+00	0	0	0	1.40e+00	3.50E-08
Technetium-99M (isotope)	treatment	0	1.17e-01	2.05e-01	3.89e-05	3.22e-01	8.03E-09
Thorium-228 (isotope)	air	3.57e-02	0	0	0	3.57e-02	8.89E-10
Thorium-228 (isotope)	surface water	1.19e+00	0	0	0	1.19e+00	2.96E-08
Thorium-230 (isotope)	air	7.31e-02	0	0	0	7.31e-02	1.82E-09
Thorium-230 (isotope)	landfill	2.44e+02	0	0	0	2.44e+02	0.0006%
Thorium-230 (isotope)	surface water	8.76e+00	0	0	0	8.76e+00	2.18E-07
Thorium-232 (isotope)	air	2.28e-02	0	0	0	2.28e-02	5.68E-10

Table J-18. LCD radioactivity outputs (Bq/functional unit)

Material	Disposition	Upstream	Mfg	Use	EOL	Total	% or Fraction of Total
Thorium-234 (isotope)	air	5.06e-03	0	0	0	5.06e-03	1.26E-10
Thorium-234 (isotope)	surface water	9.36e-02	0	0	0	9.36e-02	2.33E-09
Tin-113 (isotope)	treatment	0	1.85e-01	3.25e-01	6.16e-05	5.10e-01	1.27E-08
Tin-126 (isotope)	landfill	5.79e-02	0	0	0	5.79e-02	1.44E-09
Tritium-3 (isotope)	air	1.09e+02	7.98e+03	1.40e+04	2.65e+00	2.21e+04	0.0550%
Tritium-3 (isotope)	surface water	1.12e+03	0	0	0	1.12e+03	0.0028%
Tritium-3 (isotope)	treatment	0	5.96e+04	1.04e+05	1.98e+01	1.64e+05	0.4091%
Uranium-234 (isotope)	air	1.28e-01	0	0	0	1.28e-01	3.19E-09
Uranium-234 (isotope)	landfill	1.51e+02	0	0	0	1.51e+02	0.0004%
Uranium-234 (isotope)	surface water	3.09e+00	0	0	0	3.09e+00	7.71E-08
Uranium-235 (isotope)	air	9.55e-04	0	0	0	9.55e-04	2.38E-11
Uranium-235 (isotope)	landfill	2.73e+00	0	0	0	2.73e+00	6.81E-08
Uranium-235 (isotope)	surface water	1.34e-01	0	0	0	1.34e-01	3.35E-09
Uranium-238 (isotope)	air	2.10e-01	0	0	0	2.10e-01	5.23E-09
Uranium-238 (isotope)	landfill	4.23e+01	0	0	0	4.23e+01	0.0001%
Uranium-238 (isotope)	surface water	2.90e+00	0	0	0	2.90e+00	7.23E-08
Xenon-131M (isotope)	air	0	4.60e+02	8.06e+02	1.53e-01	1.27e+03	0.0032%
Xenon-131M (isotope)	treatment	0	6.14e+01	1.07e+02	2.04e-02	1.69e+02	0.0004%
Xenon-133 (isotope)	air	7.63e+02	4.98e+03	1.16e+05	2.21e+01	1.22e+05	0.3045%
Xenon-133 (isotope)	treatment	0	9.43e+03	1.65e+04	3.13e+00	2.60e+04	0.0647%
Xenon-133M (isotope)	air	0	6.59e+04	7.73e+03	1.47e+00	7.36e+04	0.1835%
Xenon-133M (isotope)	treatment	0	7.72e+01	1.35e+02	2.57e-02	2.13e+02	0.0005%
Xenon-135 (isotope)	air	0	2.51e+03	4.39e+03	8.33e-01	6.90e+03	0.0172%
Xenon-135 (isotope)	treatment	0	7.03e+01	1.23e+02	2.34e-02	1.93e+02	0.0005%
Xenon-135M (isotope)	air	0	4.79e+01	8.39e+01	1.59e-02	1.32e+02	0.0003%
Xenon-138 (isotope)	air	0	1.59e+02	2.78e+02	5.28e-02	4.37e+02	0.0011%
Zinc-85 (isotope)	treatment	0	9.00e-02	1.58e-01	2.99e-05	2.48e-01	6.18E-09
Zirconium-93 (isotope)	landfill	1.84e-01	0	0	0	1.84e-01	4.60E-09
Zirconium-95 (isotope)	air	0	3.11e-04	5.44e-04	1.03e-07	8.55e-04	2.13E-11
Total radioactivity outputs		1.20e+07	1.02e+07	1.79e+07	3.40e+03	4.01e+07	100%

APPENDIX K

LCIA SUPPORTING TABLES

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APPENDIX K

LCIA SUPPORTING TABLES

Table K-1. Fuel conversion factors

Fuel	Heat Value (H) (MJ/L)	Reference	Density (D) (kg/L)	Reference
Fuel oil # 2 (distillate)	36.739	(1)	0.843	(2)
Fuel oil # 6 (residual)	38.579	(1)	0.944	(2)
Fuel oil # 4 (average # 2 & # 6)	37.659	(1)	0.894	(2)
Liquified natural gas (LNG) [a]	21.185	(3)	0.412	(4)
Liquified petroleum gas (LPG)	23.276	(1)	0.542	(2)
Natural gas	0.034	(5)	7.58×10^{-4}	(6)

[a] At -260 °F; 1 ft^3 of liquid methane = 630 ft^3 of gaseous methane.

References:

1. Davis, S.C. 1999. *Transportation Energy Data Book, Edition 19.* 1999. Center for Transportation Analysis, Oak Ridge National Laboratory, ORNL 6958, Appendix B, Table B1. Oak Ridge, Tennessee. September.
2. Energy Information Administration (EIA) 1999. International Energy Annual 1997. U.S. Department of Energy. DOE/EIA-0219 (97), Washington, DC. April.
3. Natural Gas Vehicle Quick Reference Fuel Guide. http:\naturalfuels.com\quick_ref_fuel_guide.htm. Downloaded 8/25/00.
4. Perry, R.H. and Green, D. (Eds.) 1984. Perry's Chemical Engineer's Handbook, 6th Edition, page 9-14. McGraw Hill, Inc., New York, NY.
5. Based on: Wang, M. 1999. The Greenhouse Gases, Regulated Emissions, and energy Use in Transportation (GREET) Model, Version 1.5. Argonne National Laboratory, University of Chicago.
6. Calculated from: Perry, R.H. and D. Green (Eds.) 1984. Perry's Chemical Engineer's Handbook, 6th Edition, page 9-15, Table 9-13, and p. 9-16, Table 9-14. McGraw-Hill, Inc., New York, NY.

Table K-2. Global warming potentials (GWP)

Chemical	Synonym	CAS #	GWP [a]
carbon dioxide	CO_2	124-38-9	1
trifluoromethane	HFC-23	75-46-7	11,700
difluoromethane	HFC-32	75-10-5	650
methyl fluoride	HFC-41	593-53-3	150
1,1,1,2,2,3,4,5,5,5-decafluoropentane	HFC-43-10mee20.8	138495-42-8	1300
pentafluoroethane	HFC-125	354-33-6	2800
1,1,2,2-tetrafluoro-1,2-diiodoethane	HFC-134	359-35-3	1000
1,1,1,2-tetrafluoroethane	HFC-134a	811-97-2	1300
1,1-difluoroethane	HFC-152a	75-37-6	140
1,1,2-trifluoroethane	HFC-143	430-66-0	300
1,1,1-trifluoroethane	HFC-143a	420-46-2	3800
1,1,1,2,3,3,3-heptafluoropropane	HFC-227ea	431-89-0	2900
1,1,1,3,3,3-hexafluoropropane	HFC-236fa	690-39-1	6300
1,1,2,2,3-pentafluoropropane	HFC-245ca	679-86-7	560
sulfur hexafluoride	sulfur hexafluoride	2551-62-4	23,900
carbon tetrafluoride	perfluoromethane	75-73-0	6500
hexafluoroethane/Freon 116	perfluoroethane	76-16-4	9200
octafluoropropane	perfluoropropane	76-19-7	7000
decafluorobutane	perfluorobutane	355-25-9	7000
cyclooctafluorobutane	perfluorocyclobutane	115-25-3	8700
dodecafluoro-pentane	perfluoropentane	678-26-2	7500
tetradecafluorohexane	perfluorohexane	355-42-0	7400
methane	methane	74-82-8	21
nitrous oxide	nitrous oxide	10024-97-2	310

[a] IPCC's 1995 GWP estimates, 100-year time horizon. Because of the difficulties in calculating indirect effects of CFCs and halons, no indirect values were included.

Source: Houghton *et al.* 1996.

Table K-3. Ozone depletion potentials (ODP)

Chemical	Synonym(s)	CAS #	Ozone Depletion Potential [e]	
			ODP [a]	ODP [b]
1,1,1-trichloroethane [c]	methyl chloroform	71-55-56	0.12	0.1
1,2,2-trichloroethane [c]	methyl chloroform	79-00-5	--	--
CFC-11 [c]	trichlorofluoromethane	75-69-4	1	1.0
CFC-113 [c]	trichlorotrifluoroethane	76-13-1	1.07	0.8
CFC-114 [c]	dichlorotetrafluoroethane	76-14-2	0.8	1.0
CFC-115 [c]	(mono)chloropentafluoroethane	76-15-3	0.5	0.6
CFC-12 [c]	dichlorodifluoromethane	75-71-8	1	1.0
CFC-13 [c]	chlorotrifluoromethane	75-72-9	1	1.0
CFC-111 [c]	pentachlorofluoroethane	354-56-3	--	1.0
CFC-112 [c]	tetrachlorodifluoroethane	76-12-0	--	1.0
CFC-211 [c]	heptachlorofluoropropane	N/A	--	1.0
CFC-212 [c]	hexachlorodifluoropropane	76564-99-3	--	1.0
CFC-213 [c]	pentachlorotrifluoropropane	2354-06-5	--	1.0
CFC-214 [c]	tetrachlorotetrafluoropropane	2268-46-4	--	1.0
CFC-215 [c]	trichloropentafluoropropane	4259-43-2	--	1.0
CFC-216 [c]	dichlorohexafluoropropane	661-97-2	--	1.0
CFC-217 [c]	monochloroheptafluoropropane	422-86-6	--	1.0
CHF2Br	HBFC-22B1; bromodifluoromethane	1511-62-2	0.74	--
carbon tetrachloride [c]	tetrachloromethane	56-23-5	1.08	1.1
HALON-1201	--	--	1.4	--
HALON-1202	difluorodibromomethane	75-61-6	1.25	--
HALON-1211 [c]	bromochlorodifluoromethane	353-59-3	4	3.0
HALON-1301 [c]	bromotrifluoromethane	75-63-8	16	10.0
HALON-2311	--	–	0.14	--
HALON-2401	--	--	0.25	--
HALON-2402 [c]	dibromotetrafluoroethane	124-73-2	7	6.0
HCFC-123 [d]	2,2-dichloro-1,1,1-trifluoroethane	306-83-2	0.02	0.02
HCFC-124 [d]	2-chloro-1,1,1,2-tetrafluorethane	2837-89-0	0.022	0.02
HCFC-141b [d]	1,1-dichloro-1-fluoroethane	1717-00-6	0.11	0.1
HCFC-142b [d]	1-chloro-1,1-difluoroethane	75-68-3	0.065	0.06
HCFC-22 [d]	chlorodifluoromethane	75-45-6	0.055	0.05
HCFC-225ca [d]	3,3-dichloro-1,1,1,2,2-pentafluoropropane	442-56-0	0.025	--
HCFC-225cb [d]	1,3-dichloro-1,1,2,2,3-pentafluoropropane	507-55-1	0.033	--
bromomethane [c]	methyl bromide	74-83-9	0.6	0.7

[a] Source: Heijungs *et al.* 1992.

[b] Listed in Title VI of the 1990 Clean Air Act Amendments (CAAA).

[c] Class I substance as listed in Title VI of the 1990 CAAA..

[d] Class II substance as listed in Title VI of the 1990 CAAA. (Additional Class III substances listed in the CAAA but not listed here currently have no ODP data.)

[e] Weight ratios, compared to CFC-11 = 1.

"–" represents no data.

Table K-4. Photochemical oxidant creation potentials (POCP)

Chemical/Material	Synonym(s)	CAS #	POCP [a]
1,1,1-trichloroethane	methyl chloroform	71-55-6	0.021
1,2-dichloroethane	ethylene dichloride	107-06-2	0.021
acetone	--	67-64-1	0.178
acetylene	--	74-86-2	0.168
alcohols [b]	--	N/A	0.196
aldehydes [b]	--	N/A	0.443
benzene	--	71-43-2	0.189
caprolactam	aminocaproic lactum	105-60-2	0.761
chlorophenols [b]	--	20-05-3	0.761
crude oil [b]	--	8002-05-9	0.398
CxHy [b]	hydrocarbons	N/A	0.398
CxHy aliphatic [b]	aliphatic hydrocarbons	N/A	0.398
CxHy aromatic [b]	aromatic hydrocarbons	N/A	0.761
CxHy chloro [b]	chlorinated hydrocarbons	N/A	0.021
dichloromethane	methylene chloride	75-09-2	0.021
diethyl ether	ethyl ether	66-29-7	0.398
diphenyl	biphenyl	92-52-4	0.761
ethanol	ethyl alcohol	64-17-5	0.268
ethene	ethylene	74-85-1	1
ethylene glycol	--	107-21-1	0.196
ethylene oxide	--	75-21-8	0.377
formaldehyde	--	50-00-0	0.421
hexachlorobiphenyl	2,2',4,4',5'5'-hexachloro-1,1-biphenyl	35065-27-1	0.761
hydroxy compounds [b]	--	N/A	0.377
isopropanol	isopropyl alcohol; 2-propanol	67-63-0	0.196
ketones [b]	--	N/A	0.326
methane	--	74-82-8	0.007
methyl ethyl ketone	MEK	78-93-3	0.473
methyl mercaptan	--	74-93-1	0.377
naphthalene	--	91-20-3	0.761
non methane VOC [b]	--	N/A	0.416
PAH [b]	PAC; polycyclic aromatic hydrocarbons	N/A	0.761
pentane	--	109-66-0	0.408
petrol [b]	gasoline	N/A	0.398
phenol	--	108-95-2	0.761
phthalic acid anhydride	phthalic anhydride	85-44-9	0.761
propane	--	74-98-6	0.42
propene	propylene	115-07-1	1.03
propionaldehyde	propanal	123-38-6	0.603

Table K-4. Photochemical oxidant creation potentials (POCP)

Chemical/Material	Synonym(s)	CAS #	POCP [a]
styrene	vinyl benzene	100-42-5	0.761
terpentine [b]	--	N/A	0.377
tetrachloromethane	carbon tetrachloride	56-23-5	0.021
toluene	--	108-88-3	0.563
trichloroethene	trichloroethylene	79-01-6	0.066
vinyl acetate	--	108-05-4	0.223
vinyl chloride	--	75-01-4	0.021

Source: Heijungs *et al.* 1992.
"–" represents no data.

Table K-5. Acidification potentials (AP)

Chemical	Synonym(s)	CAS #	AP [a]
ammonia	NH_3	7664-41-7	1.88 [b]
hydrochloric acid	HCl	7647-01-0	0.88 [b]
hydrofluoric acid	hydrogen fluoride, HF	7664-39-3	1.6 [b]
nitric oxide	NO	10102-43-9	1.07 [b]
nitrogen dioxide	NO_2	10102-44-0	0.7 [b]
nitrogen oxides	NO_X	N/A	0.7 [b]
sulfur dioxide	SO_2	7446-09-5	1 [b]
sulfur oxides	SO_X	N/A	1 [b]
sulfur trioxide	SO_3	7446-11-9	0.80 [c]
nitric acid	HNO_3	7697-37-2	0.51 [c]
sulfuric acid	H_2SO_4	7664-93-9	0.65 [c]
phosphoric acid	H_3O_4P	7664-38-2	0.98 [c]
hydrogen sulfide	H_2S	7783-06-4	1.88 [c]

[a] Ratios per equal weights, compared to SO_2, SO_X = 1 for emissions to air.
[b] Source: Heijungs *et al.* 1992.
[c] Source: Hauschild and Wenzel 1997.

Table K-6. Eutrophication potential nutrient enrichment chemicals

Chemical/Parameter (releases to water)	Synonym	CAS #	EP [a]
COD	chemical oxygen demand	N/A	0.022 [b]
ammonia	NH_3	7664-41-7	0.33 [b]
ammonium ion	NH_4^+	N/A	0.33 [b]
total nitrogen	N	N/A	0.42 [b]
phosphate	PO_4^{-3}	N/A	1.0 [b]
total phosphorus	P	N/A	3.06 [b]
nitrate	NO_3^-	NA	0.10 [c]

[a] Ratios per equal weights, compared to phosphate = 1.

[b] Source: Heijungs *et al.* 1992.

[c] Source: Lindfors *et al.* 1995.

NOTE: Eutrophication potentials for releases to air are available but not used in this methodology because partitioning between air and water phases is not considered in this methodology.

Table K-7. Odor threshold values (OTV)

Chemical	Synonym(s)	CAS #	OTV (mg/m^3)
acetaldehyde	ethanal	75-07-0	0.00027 [a]
acetic acid	succinate	64-19-7	0.061 [a]
acetonitrile	methyl cyanide	75-05-8	<67 [b]
acetophenone	acetylbenzene	98-86-2	1.5 [b]
acrolein	2-propenal	107-02-8	0.069 [a]
acrylic acid	propenoic acid	79-10-7	0.27 [b]
acrylontirile	vinyl cyanide	107-13-1	3.4 [b]
ammonia	NH_3	7664-41-7	1.0 [a]
aniline	--	62-53-3	38 [b]
benzene	--	71-43-2	108 [b]
benzyl chloride	alpha-chlorotoluene	100-44-7	0.21 [b]
1,3-butadiene	butadiene	106-99-0	1 [b]
butanal	butyraldehyde	123-72-8	0.00084 [a]
butanoic acid	butyric acid	107-92-6	0.00035 [a]
1-butanol	butyl alcohol, –	71-36-3	0.077 [a]
2-butanone	methyl ethyl ketone	78-93-3	0.68 [a]
n-butylacetate	--	123-86-4	0.031 [a]
butylacrylate	--	141-32-2	0.0015 [a]
n-butylpropionate	--	590-01-2	0.086 [a]
carbon disulfide	CS_2	75-15-0	0.18 [a]
carbon tetrachloride	tetrachloromethane	56-23-5	884 [b]
carbonyl sulfide	carbon oxysulfide	463-58-1	0.25 [b]
chlorine	--	7782-50-5	0.23 [b]
2-chloroacetophenone	phenyl chloromethyl ketone	532-27-4	0.1 - 0.7 [b]
chlorobenzene	--	108-90-7	1.0 [a]
chloroform	trichloromethane	67-66-3	650 [b]
m-cresol	3-methylphenol	108-93-4	0.00022 - 0.035 [b]
cumene	isopropylbenzene	98-82-8	0.04 [b]
decaline	veraline (-)form	14727-56-1	2.8 [a]
P-dichlorobenzene	1,4-dichlorobenzene	106-46-7	0.73 [b]
dichloromethane	methylene chloride	75-09-2	640 [a]
diethylamine	--	109-89-7	0.09 [a]
dimethylamine	--	124-40-3	0.0014 [a]
1,2-dimethylbenzene	o-xylene	95-47-6	0.78 [a]
1,3-dimethylbenzene	m-xylene	108-38-3	0.54 [a]
1,4-dimethylbenzene	p-xylene	106-42-3	0.52 [a]
1,1-dimethylhydrazine	N,N-dimethylhydrazine	57-14-7	15 - 65 [b]
dioxane	1,4-diethylene dioxide; 1,4-dioxane	123-91-1	2.9 [b]

Table K-7. Odor threshold values (OTV)

Chemical	Synonym(s)	CAS #	OTV (mg/m^3)
ethanal	acetaldehyde	75-07-0	0.00027 [a]
ethanethiol	ethylmercaptan	75-08-1	0.000044 [a]
ethanol	ethyl alcohol	64-17-5	0.64 [a]
ethyl acetate	--	141-78-6	2.1 [a]
ethyl acrylate	--	140-88-5	0.00082 [a]
2-ethyl-5,5-dimethyl-1,3-dioxane	--	--	0.0000056 [a]
ethyl butyrate	--	105-54-4	0.00003 [a]
ethylene dichloride	1,2-dichloroethane	107-06-2	25 [b]
ethylene oxide	oxirane	75-21-8	470 [b]
ethylthioethane	diethylsulfide	352-93-2	0.0014 [a]
hydrazine	--	302-01-2	3.9 - 5.2 [b]
hydrogen sulfide	H_2S	7783-06-4	0.00043 [a]
isopentylacetate	iso-amylacetate	123-92-2	0.075 [a]
isophorone	3,5,5-trimethyl-2-cyclohexenone	78-59-1	1.1 [b]
isopropylbenzene	cumene	98-82-8	0.073 [a]
isopropylpropionate	--	637-78-5	0.32 [a]
methanal	formaldehyde	50-00-0	0.49 [a]
methanethiol	methyl mercaptan	74-93-1	0.00024 [a]
methanol	methyl alcohol	67-56-1	5.5 [b]
methyl acetate	acetic acid	79-20-9	22 [a]
methylamine	--	74-89-5	0.0012 [a]
3-methylbutanoic acid	isovaleric acid	503-74-2	0.00022 [a]
methyldithiomethane	dimethyldisulfide	624-92-0	0.0015 [a]
methyl hydrazine	--	60-34-4	1.9 - 5.7 [b]
methyl methacrylate	2-propenoic acid	80-62-6	0.2 [b]
4-methylpentanon-2	methylisobutylketone, MIBK	108-10-1	0.4 [b]
o-cresol	2-methylphenol	95-48-7	0.0018 [a]
m-cresol	3-methylphenol	108-37-4	0.00057 [a]
p-cresol	4-methylphenol	106-44-5	0.00018 [a]
2-methylpropanoic acid	isobutyric acid	79-31-2	0.005 [a]
2-methylpropanol-1	isobutanol	78-73-1	0.035 [a]
2-methylpropene	isobutene	115-11-7	15 [a]
methyl acrylate	2-propenoic acid, methyl	96-33-3	0.01 [a]
methyl propionate	--	554-12-1	3.5 [a]
methylthiomethane	dimethylsulfide	75-18-3	0.0003 [a]
naphthalene	--	91-20-3	0.2 [b]
nitrobenzene	--	98-95-3	906 [b]
pentanal	valeraldehyde	110-62-3	0.0024 [a]

Table K-7. Odor threshold values (OTV)

Chemical	Synonym(s)	CAS #	OTV (mg/m^3)
phenol	--	108-95-2	0.039 [a]
phosphine	--	7803-51-2	0.014 - 2.8 [b]
propanal	propionaldehyde	123-38-6	0.0035 [a]
propanoic acid	propionic acid	79-09-4	0.0052 [a]
2-propanon	acetone	67-64-1	72 [a]
2-propenal	acrolein	107-02-8	0.069 [a]
propionaldehyde	2-propynal	123-38-6	0.003 [a]
propylene dichloride	1,2-dichloropropane	78-87-5	1.2 [b]
propylene oxide	methyloxidrane	75-56-9	24 [b]
pyridine	--	110-86-1	0.12 [a]
quinoline	--	91-22-5	28 [b]
styrene	vinylbenzene	100-42-5	0.068 [a]
styrene oxide	1-phenyl-1,2-epoxyethane	96-09-3	0.3 [b]
tetrachloroethene	perchloroethene; tetrachloroethylene	127-18-4	8.3 [a]
1,1,2,2-tetrachloroethane	acetylene tetrachloride	79-34-5	50 [b]
terephthaloyldichloride	terephthalic acid dichloride	100-20-9	0.0032 [a]
toluene	methylbenzene	108-88-3	0.6 [b]
trichloroethene	trichloroethylene	79-01-6	3.9 [a]
1,1,1-trichloroethane	methyl chloroform	71-55-6	5.3 [a]
2,4,6-trichlorophenol	--	88-06-2	0.00016 [b]
triethylamine	--	121-44-8	1.1 [b]
trimethylamine	--	75-50-3	0.00026 [a]
1,2,4-trimethylbenzene	pseudocumene	95-63-6	0.14 [a]
1,3,5-trimethylbenzene	mesitylene	108-67-8	0.18 [a]
vinyl acetate	--	108-05-4	0.4 [b]
glycol ethers	--	N/A	0.3 [b]
3-methylindole	skatole	83-34-1	0.1 [b]
polycyclic organic matter	--	N/A	0.074 [b]

[a] Source: Roos C. 1989 (as cited in Hiejungs *et al.* 1992).

[b] EPA 1992. *Reference Guide to Odor Thresholds for Hazardous Air Pollutants Listed in the Clean Air Act Amendments of 1990*. Washington, DC. EPA/600/R/92/047.

NOTE: When values were available from both sources, the lower value was used.

"–" represents no data.

Table K-8. Chemicals in the CDP inventory classified as potentially toxic

Cas #	Material	Chronic							Aquatic ecotoxicity	
		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
71-55-6	1,1,1-trichloroethane	- -	- -	- -	2.50e+02	1.21e+03	X	X	48.0	7.0
76-14-2	1,2-dichlorotetrafluoroethane (CFC 114)	- -	- -	- -	2.73e+02	X	X	X	XX	XX
106-99-0	1,3-butadiene	X	1.8	B2,2B	X	2.80e+03	X	X	4.0	1.0
96-48-0	1,4-butanolide	X	X	3	X	X	100	X	XX	XX
107-98-2	1-Methoxy-2-propanol	- -	- -	- -	X	658	X	X	XX	XX
872-50-4	1-Methyl-2-pyrrolidinone (NMP)	- -	- -	- -	X	X	X	40	XX	XX
112-34-5	2-(2-butoxyethoxy)ethanol (glycol ether)	- -	- -	- -	X	X		X	XX	XX
124-17-4	2-(2-butoxyethoxy)ethyl acetate	- -	- -	- -	1000	X	X	X	XX	XX
540-84-1	2,2,4-trimethylpentane (Isooctane)	- -	- -	- -	- -	- -	- -	- -	XX	XX
51207-31-9	2,3,7,8-Tetrachlorodibenzo Furan	1.50e+04	1.50e+04	3	- -	- -	- -[24]	- -	XX	XX
1746-01-6	2,3,7,8-Tetrachlorodibenzo-p-Dioxin	1.50e+05	1.50e+05	1	9.00e-08	X	X	X	XX	XX
121-14-2	2,4-Dinitrotoluene	0.68	X	B2	0.2	X	X	X	24.0	6.0
532-27-4	2-Chloroacetophenone	- -	- -	- -	X	X	X	1.0	XX	XX
111-15-9	2-ethoxyl ethylacetate	- -	- -	- -	- -	- -	- -	- -	XX	XX
91-57-6	2-Methylnaphthalene	- -	- -	- -	- -	- -	- -	- -	XX	XX
138526-69-9	3,4,5-trifluorobromobenzene	- -	- -	- -	- -	- -	- -	- -	XX	XX
348-61-8	3,4-difluorobromobenzene	- -	- -	- -	- -	- -	- -	- -	XX	XX
56-49-5	3-Methylcholanthrene	- -	- -	- -	X	X	2.86	X	XX	XX
82832-73-3 (d)	4-(4-propylcyclohexyl)cyclohexanone	- -	- -	- -	- -	- -	- -	- -	XX	XX
106-41-2	4-bromophenol	- -	- -	- -	- -	- -	- -	- -	XX	XX
123-07-9	4-ethylphenol	- -	- -	- -	- -	- -	- -	- -	XX	XX
14938-35-3	4-pentylphenol	- -	- -	- -	- -	- -	- -	- -	XX	XX
70-70-2	4-propionylphenol	- -	- -	- -	- -	- -	- -	- -	XX	XX
3697-24-3	5-Methyl chrysene (category: PAH)	X	X	2B	- -	- -	- -	- -	XX	XX
83-32-9	Acenaphthene (category: PAH)	- -	- -	- -	175	X	350	X	XX	XX
208-96-8	Acenaphthylene (category: PAH)	X	X	D	- -	- -	- -	- -	XX	XX
75-07-0	Acetaldehyde	Y	7.70e-03	2B	125	300	X	X	34.0	9.0

Table K-8. Chemicals in the CDP inventory classified as potentially toxic

Cas #	Material	Chronic							Aquatic ecotoxicity	
		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
64-19-7	Acetic acid	- -	- -	- -	195	X	X	X	XX	XX
67-64-1	Acetone	X	X	D	100	X	X	X	720	180
98-86-2	Acetophenone	- -	- -	- -	423	X	X	X	XX	XX
74-86-2	Acetylene	- -	- -	- -	- -	- -	- -	- -	XX	XX
107-02-8	Acrolein	X	X	C,3	- -	- -	- -	- -	XX	XX
No CAS #	Aluminium (Al3+)	- -	- -	- -	- -	- -	- -	- -	3.6	0.36
7429-90-5	Aluminum (Al)	X	X	SAR0	60	X	X	X	XX	XX
1344-28-1	Aluminum oxide	- -	- -	- -	- -	- -	- -	- -	XX	XX
7664-41-7	Ammonia	- -	- -	- -	34	40	X	X	2.0	9.00e-02
1341-49-7	Ammonium bifluoride	- -	- -	- -	5.10e-02	X	X	X	XX	XX
7789-09-5	Ammonium Dichromate	X	X	A1	- -	- -	- -	- -	XX	XX
12125-01-8	Ammonium Fluoride	- -	- -	- -	- -	- -	- -	- -	XX	XX
1336-21-6	Ammonium hydroxide	- -	- -	- -	- -	- -	- -	- -	XX	XX
1113-38-8	Ammonium Oxalate	- -	- -	- -	- -	- -	- -	- -	XX	XX
6009-70-7	Ammonium Oxalate Monohydrate	- -	- -	- -	- -	- -	- -	- -	XX	XX
628-63-7	Amyl Acetate (mixed isomers)	- -	- -	- -	- -	- -	- -	- -	XX	XX
120-12-7	Anthracene (category: PAH)	X	X	SAR1	1000	X	X	X	0.01	- -
7440-36-0	Antimony (Sb)	- -	- -	- -	X	X	0.35	X	14.4	1.6
7440-38-2	Arsenic (As)	1.5	50	A	8.00e-04	X	X	X	14.4	2.1
"20-01-9"	Arsenic compounds [Arsenic (As3+, As5+)]	1.5	X	A,1	8.00e-04	X	X	X	32.0	2.0
7440-39-3	Barium (Ba)	- -	- -	- -	0.21	X	X	X	580	50.0
513-77-9	Barium carbonate	X	X	D	0.21	X	X	X	XX	XX
"20-02-0"	Barium compounds [Barium (Ba++)]	X	X	D	0.21	X	X	X	200	10.0
7727-43-7	Barium Sulfate	X	X	D	0.21	X	X	X	- -	- -
100-52-7	Benzaldehyde	- -	- -	- -	143	X	X	X	27.0	XX
71-43-2	Benzene	0.055	0.029	A,1	1.0	1.15	10	98	19.0	4.0
56-55-3	Benzo(a)anthracene (category: PAH)	0.73	0.31	B2	- -	- -	- -	- -	XX	XX
50-32-8	Benzo(a)pyrene	7.3	3.1	B2,2A	- -	- -	- -	- -	XX	XX

Table K-8. Chemicals in the CDP inventory classified as potentially toxic

Cas #	Material	Chronic							Aquatic ecotoxicity	
		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
56832-73-6	Benzo(b,j,k)fluoranthene (category: PAH)	X	X	B2	- -	- -	- -	- -	XX	XX
191-24-2	Benzo(g,h,i)perylene (category: PAH)	X	X	D	- -	- -	- -	- -	XX	XX
205-99-2	Benzo[b]fluoranthene	0.73	0.31	B2	- -	- -	- -	- -	XX	XX
100-44-7	Benzyl chloride	0.17	X	B2,3	- -	- -	- -	- -	XX	XX
7440-41-7	Beryllium (Be)	4.3	8.4	X	X	X	X	5.50e-04	XX	XX
92-52-4	Biphenyl (category: PAH)	X	X	SAR0	50	X	X	X	2.0	0.12
68611-71-2 (d)	Blue phosphor (ZnS)	- -	- -	- -	- -	- -	- -	- -	XX	XX
1314-98-3	Blue phosphor (ZnS:Ag:Al)	- -	- -	- -	- -	- -	- -	- -	XX	XX
1303-96-4	borax	- -	- -	- -	- -	- -	- -	- -	XX	XX
11113-50-1	boric acid	- -	- -	- -	67	X	62.5	X	- -	- -
No CAS #	Boron (B III)	- -	- -	- -	8.8	X	X	X	113	27.0
7440-42-8	Boron (B)	- -	- -	- -	8.8	X	X	X	113	27.0
7726-95-6	Bromine	- -	- -	- -	- -	- -	- -	- -	XX	XX
75-25-2	Bromoform	7.90e-03	3.90e-03	B2	17.9	X	X	X	XX	XX
74-83-9	Bromomethane [Methyl bromide]	X	X	C,3	0.4	4.3	X	X	11.0	3.0
7440-43-9	Cadmium (Cd)	X	6.1	B1,1	X	X	4.00e-02	2.20e-02	0.001	0.001
"20-04-2"	Cadmium cmpds (as CdCl2) [Cadmium (Cd++)]	X	X	B1,2A	5.00e-03	X	X	X	0.1	- -
75-15-0	Carbon disulfide	- -	- -	- -	X	10	X	X	694	174
630-08-0	Carbon monoxide (CO)	- -	- -	- -	X	114.5	X	55	XX	XX
56-23-5	Carbon tetrachloride	1.30e-01	5.30e-02	B2,2B	1	34.3	X	X	41.0	5.0
No CAS #	Cerium (Ce++)	- -	- -	- -	- -	- -	- -	- -	- -	- -
1306-38-3	Cerium oxide	- -	- -	- -	X	X	X	5.0	XX	XX
No CAS #	Cesium (Cs++)	- -	- -	- -	- -	- -	- -	- -	- -	- -
75-72-9	CFC 13	- -	- -	- -	- -	- -	- -	- -	XX	XX
7782-50-5	Chlorine (Cl2)	- -	- -	- -	14.0	X	X	X	0.34	0.02
1341-24-8	Chloroacetophenone	- -	- -	- -	- -	- -	- -	- -	XX	XX
108-90-7	Chlorobenzene	X	X	SAR0	12.5	377	X	X	17.0	2.0

Table K-8. Chemicals in the CDP inventory classified as potentially toxic

Cas #	Material	Chronic							Aquatic ecotoxicity	
		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
67-66-3	Chloroform	6.10e-03	8.10e-02	B2,2B	X	X	12.9	X	71.0	18.0
16065-83-1	Chromium (Cr III)	X	X	D	1468	X	X	X	3.3	0.33
7440-47-3	Chromium (Cr)	X	X	1	- -	- -	- -	- -	52.0	5.2
1333-82-0	Chromium oxide (chromium trioxide)	X	X	D	1468	X	X	X	XX	XX
18540-29-9	Chromium, hexavalent	X	41	A,1	2.5	X	X	X	22.6	2.23
218-01-9	Chrysene (category: PAH)	7.30e-03	3.10e-03	X	- -	- -	- -	- -	XX	XX
No CAS #	Cobalt (Co I, Co II, Co III)	- -	- -	- -	- -	- -	- -	- -	- -	- -
7440-48-4	Cobalt (Co)	- -	- -	- -	- -	- -	- -	- -	XX	XX
7440-50-8	Copper (Cu)	X	X	D	5.30e-01	X	X	X	1.40e-02	4.00e-03
No CAS #	Copper (Cu+, Cu++)	- -	- -	- -	5.30e-01	X	X	X	1.40e-02	4.00e-03
9065-82-1	cresol-formaldehyde resins	- -	- -	- -	- -	- -	- -	- -	XX	XX
98-82-8	Cumene	X	X	SAR0	154	537	X	X	6.0	0.49
80-15-9	Cumene hydroperoxide	X	X	SAR1	X	31	X	X	62.0	16.0
57-12-5	Cyanide (CN)	X	X	D	10.8	X	X	X	56.0	5.7
110-82-7	Cyclohexane	X	X	SAR0	X	1500	X	X	5.0	0.39
117-81-7	Di(2-ethylhexyl)phthalate [Bis(2-ethylhexyl)phthalate]	X	X	B2,2B	50	50	X	X	1.0	0.08
53-70-3	Dibenzo(a,h)anthracene	7.3	3.1	B2	- -	- -	- -	- -	XX	XX
25321-22-6	Dichlorobenzene (mixed isomers)	X	X	SAR0	X	610.4	X	X	1.0	0.05
75-71-8	Dichlorodifluoromethane (CFC 12)	- -	- -	- -	15	X	X	X	XX	XX
75-09-2	Dichloromethane (Methylene chloride)	7.50e-03	1.65e-03	B2,2B	155	796	X	X	330	83.0
68334-30-5	Diesel fuel	X	X	C	- -	- -	- -	- -	XX	XX
60-29-7	Diethyl ether (Ethyl ether)	- -	- -	- -	500	X	X	X	XX	XX
111-46-6	Diethylene Glycol	- -	- -	- -	1250	X	X	X	XX	XX
68-12-2	Dimethyl formamide	- -	- -	- -	X	X	X	7.9	XX	XX
77-78-1	Dimethyl sulfate	X	X	B1,2A	- -	- -	- -	- -	XX	XX
57-97-6	Dimethylbenzanthracene	- -	- -	- -	X	X	X	1.40e-02	XX	XX
67-68-5	di-methyl-sulfoxide	- -	- -	- -	X	X	1.0	X	XX	XX
122-62-3	Dioctyl Sebacate	- -	- -	- -	200	X	X	X	XX	XX

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		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
60-00-4	Edetic Acid (EDTA)	- -	- -	- -	- -	- -	- -	- -	473	240
74-84-0	Ethane	- -	- -	- -	- -	- -	- -	- -	XX	XX
75-08-1	Ethanethiol [Mercaptans]	- -	- -	- -	- -	- -	- -	- -	XX	XX
141-43-5	ethanol amine	- -	- -	- -	320	X	X	12.7	XX	XX
75-00-3	Ethyl chloride	X	X	3	X	3600	X	X	16.0	4.0
100-41-4	Ethylbenzene	X	X	SAR0	136	2370	X	X	11.0	1.0
74-85-1	Ethylene	X	X	SAR0	X	11600	X	X	14.0	3.0
106-93-4	Ethylene dibromide	85	7.60e-01	B2	- -	- -	- -	- -	XX	XX
107-06-2	Ethylene dichloride	9.10e-02	9.10e-02	B2,2B	18	221	X	X	136	34.0
unknown	Etoxy Naphtol Sulphonic Acid (ENSA)	- -	- -	- -	- -	- -	- -	- -	XX	XX
No CAS #	Ferromanganese (Fe, Mn, C)	- -	- -	- -	- -	- -	- -	- -	XX	XX
206-44-0	Fluoranthene (category: PAH)	X	X	D	125	X	X	X	XX	XX
86-73-7	Fluorene (category: PAH)	X	X	D	125	X	X	X	XX	XX
16984-48-8	Fluoride	- -	- -	- -	- -	- -	- -	- -	- -	- -
No CAS #	Fluorides (F-)	- -	- -	- -	6.00e-02	X	X	X	- -	- -
7782-41-4	Fluorine (F2)	- -	- -	- -	6.00e-02	X	X	X	XX	XX
9002-84-0	Fluorocarbon resin [Tetrafluoroethylene (C2F4)]	X	X	3	- -	- -	- -	- -	XX	XX
50-00-0	Formaldehyde (CH2O)	X	4.50e-02	B1,2A	15	0.6	X	X	24.0	6.0
No CAS #	Fuel Oil #2 (distillate and diesel)	- -	- -	- -	- -	- -	- -	- -	XX	XX
No CAS #	Fuel Oil #4 (distillate and residual)	- -	- -	- -	- -	- -	- -	- -	XX	XX
No CAS #	Fuel Oil #6 (residual)	- -	- -	- -	- -	- -	- -	- -	XX	XX
111-76-2	glycol ethers [2-butoxy ethanol]	X	X	C,3	203	121	X	X	1,490	373
unknown	Green Phosphor (ZnS.Cu.Al)	- -	- -	- -	- -	- -	- -	- -	XX	XX
68611-68-7 (d)	Green phosphors (ZnS)	- -	- -	- -	- -	- -	- -	- -	XX	XX
75-63-8	Halon 1301	- -	- -	- -	- -	- -	- -		XX	XX
75-45-6	HCFC 22	- -	- -	- -	X	5,260	X	X	XX	XX

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Cas #	Material	Chronic							Aquatic ecotoxicity	
		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
422-56-0	HCFC-225ca	- -	- -	- -	- -	- -	- -	- -	XX	XX
507-55-1	HCFC-225cb	- -	- -	- -	- -	- -	- -	- -	XX	XX
142-82-5	Heptane (n-Heptane)	X	X	D	1,000	X	X	1,630	XX	XX
67-72-1	Hexachloroethane	1.40e-02	1.40e-02	C,3	1.0	X	X	X	1.0	0.35
999-97-3	Hexamethyldisilazane (HMDS)	- -	- -	- -	- -	- -	- -	- -	XX	XX
110-54-3	Hexane	- -	- -	- -	X	X	X	73	2.5	0.25
354-33-6	HFC 125	- -	- -	- -	X	2.45e+05	X	X	XX	XX
302-01-2	Hydrazine	3	17	B2	- -	- -	- -	- -	4.83	0.48
7647-01-0	hydrochloric acid	X	X	3	X	15	X	X	19.0	0.95
7664-39-3	Hydrofluoric acid (hydrogen fluoride)	- -	- -	- -	- -	- -	- -	- -	265	13
74-90-8	Hydrogen Cyanide	X	X	SAR0	10.8	X	30	7.07	1,385	346
7722-84-1	Hydrogen Peroxide	X	X	3	- -	- -	- -	- -	XX	XX
7783-06-4	Hydrogen Sulfide	- -	- -	- -	3.1	X	X	15	XX	XX
7790-92-3	Hypochlorous Acid	- -	- -	- -	- -	- -	- -	- -	- -	- -
193-39-5	Indeno(1,2,3-cd)pyrene (category: PAH)	7.30e-01	3.10e-01	B2	- -	- -	- -	- -	XX	XX
50926-11-9	Indium tin oxide (ITO)	- -	- -	- -	- -	- -	- -	- -	XX	XX
123-92-2	Isopentyl acetate (Amyl Acetate)	- -	- -	- -	- -	- -	- -	- -	XX	XX
78-59-1	Isophorone	9.50e-04	X	C	150	X	X	X	XX	XX
67-63-0	Isopropyl alcohol	X	X	1	230	268.3	X	X	8,623	2,156
637-78-5	Isopropylpropionate	- -	- -	- -	- -	- -	- -	- -	XX	XX
7439-91-0	Lanthanum (La)	- -	- -	- -	- -	- -	- -	- -	XX	XX
7439-92-1	Lead (Pb)	X	X	B2,2B	- -	- -	- -	- -	31.5	0.004
"20-11-1"	Lead compounds (as PbCl2) [Lead (Pb++, Pb4+)]	X	X	B2,2B	- -	- -	- -	- -	5.0	0.26
1317-36-8	Lead oxide	X	X	B2	- -	- -	- -	- -	XX	XX
7446-14-2	Lead sulfate cake	X	X	B2	- -	- -	- -	- -	60.8	6.08
NA	Liquified petroleum gas (LPG)	- -	- -	- -	- -	- -	- -	- -	2600	260
NA	Lithium Salts (Lithine)	- -	- -	- -	- -	- -	- -	- -	- -	- -
NA	LNG (Liquified natural gas)	- -	- -	- -	- -	- -	- -	- -	XX	XX

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Cas #	Material	Chronic							Aquatic ecotoxicity	
		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
7439-96-5	Manganese	X	X	D	0.14	X	X	0.15	- -	- -
"21-12-2"	Manganese cmpds (as MnCl2) [Manganese (Mn II, Mn IV, Mn VII)]	X	X	D	0.14	X	X	0.15	150.0	8.0
7439-97-6	Mercury (Hg)	X	X	D,3	X	6.00e-03	X	9.00e-03	0.155	0.005
no CAS#	Mercury cmpds (as HgCl2) [Mercury (Hg+, Hg++)]	X	X	C	X	X	0.226	X	0.155	0.005
74-82-8	Methane (natural gas)	- -	- -	- -	- -	- -	- -	- -	XX	XX
67-56-1	Methanol	X	X	SAR0	500	130	X	X	29,400	7,350
74-87-3	Methyl chloride	1.30e-02	6.30e-03	C,3	X	1138.4	X	1550	550	138
78-93-3	Methyl ethyl ketone	X	X	D	125	8047	X	X	3,220	805
60-34-4	Methyl hydrazine	3	17.2	A3	- -	- -	- -	- -	XX	XX
80-62-6	Methyl methacrylate	X	X	SAR0	7.5	111.7	X	X	259	65
1634-04-4	Methyl tert butyl ether	X	X	SAR0	100	2880	X	X	786	197
7439-98-7	Molybdenum (Mo)	- -	- -	- -	X	X	0.14	X	157	0.125
no CAS#	Molybdenum cmpds [Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)]	- -	- -	- -	- -	- -	- -	- -	157	0.125
7803-62-5	Monosilane Gas	- -	- -	- -	- -	- -	- -	- -	XX	XX
110-91-8	Morpholine	X	X	3	X	X	X	36		
91-20-3	Naphthalene	X	X	C	71	X	X	9.3	6.0	0.59
79-15-2	N-bromoacetamide (NBA)	- -	- -	- -	- -	- -	- -	- -	XX	XX
123-86-4	N-butyl acetate [Butyl acetate]	- -	- -	- -	X	X	X	210	XX	XX
7440-00-8	Neodymium (Nd)	- -	- -	- -	- -	- -	- -	- -	XX	XX
7440-02-0	Nickel (Ni)	X	X	A	5	X	X	X	2.48	0.09
"20-14-4"	Nickel cmpds (as NiCl2) [Nickel (Ni++, Ni3+)]	X	X	A,1	- -	- -	- -	- -	27	1.0
14797-55-8	Nitrates	- -	- -	- -	1.6	X	X	X	2,213	213
7697-37-2	Nitric Acid	- -	- -	- -	- -	- -	- -	- -	26	1.0
14797-65-0	Nitrites (NO2-)	- -	- -	- -	1.6	X	X	X	225	1.0
10102-44-0	Nitrogen Dioxide	- -	- -	- -	- -	- -	- -	- -	196	19.6

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Cas #	Material	Chronic							Aquatic ecotoxicity	
		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
7783-54-2	Nitrogen fluoride (nitrogen trifluoride)	- -	- -	- -	- -	- -	- -	- -	XX	XX
no CAS#	Nitrogen Oxides (NOx)	- -	- -	- -	- -	- -	- -	- -	XX	XX
10024-97-2	Nitrous oxide	- -	- -	- -	- -	- -	- -	- -	XX	XX
10043-35-3	orthoboric acid	- -	- -	- -	67	X	62.5	X	XX	XX
95-47-6	o-xylene	X	X	D	179	X	X	X	16.0	2.0
608-93-5	Pentachlorobenzene	X	X	D	X	X	8.3	X	XX	XX
87-86-5	Pentachlorophenol	X	X	B2	3	X	X	X	XX	XX
109-66-0	Pentane	X	X	D	- -	- -	- -	- -	XX	XX
7601-90-3	Perchloric acid	- -	- -	- -	- -	- -	- -	- -	XX	XX
76-16-4	Perfluoroethane (Hexafluorocarbon)	- -	- -	- -	X	X	X	1.17e+06	XX	XX
75-73-0	Perfluoromethane (CF4)	- -	- -	- -	- -	- -	- -	- -	XX	XX
10450-60-9	Periodic Acid	- -	- -	- -	- -	- -	- -	- -	XX	XX
No CAS #	Petroleum	- -	- -	- -	- -	- -	- -	- -	XX	XX
85-01-8	Phenanthrene (category: PAH)	X	X	D	- -	- -	- -	- -	XX	XX
108-95-2	Phenol	X	X	D,3	60	X	X	X	34.0	8.0
98-67-9	Phenolsulphonic Acid	- -	- -	- -	- -	- -	- -	- -	XX	XX
57583-54-7 (d)	Phosphate ester, plastic components	- -	- -	- -	1300	X	X	X	XX	XX
7803-51-2	Phosphine gas	- -	- -	- -	0.026	0.25	X	X	XX	XX
7664-38-2	phosphoric acid	- -	- -	- -	X	50	X	180	70.0	4.0
7723-14-0	Phosphorus	X	X	D	1.50e-02	X	X	X	0.02	- -
1314-56-3	Phosphorus Pentoxide	- -	- -	- -	- -	- -	- -	- -	- -	- -
NA	PM [particulates, total]	- -	- -	- -	- -	- -	- -	- -	XX	XX
NA	PM-10 [Particulates < 10 microns]	- -	- -	- -	- -	- -	- -	- -	XX	XX
1336-36-3	Polychloriniated biphenyl (PCB)	X	X	B2,2A	7.00e-03	X	X	X	3.0	0.14
9016-45-9	Polyethylene mono(nonylphenyl)ether glycol [Tergitol NP-33 (glycol ether)]	- -	- -	- -	1000	X	67.5	X	XX	XX
9002-89-5	Polyvinyl alcohol	X	X	3	- -	- -	- -	- -	XX	XX
9003-39-8	Polyvinyl Pyrrolidone (PVP)	X	X	3	550	X	5500	X	XX	XX

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		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
8486041	PPE [Polyphenylene ether]	- -	- -	- -	- -	- -	- -	- -	XX	XX
123-38-6	Propionaldehyde	X	X	SAR3	X	200	X	X	44.0	11.0
115-07-1	Propylene	X	X	SAR0	X	9375	X	X	5.0	1.0
108-32-7	Propylene carbonate	- -	- -	- -	- -	- -	- -	- -	XX	XX
57-55-6	propylene glycol	- -	- -	- -	X	170	X	X	XX	XX
108-65-6	propylene glycol monomethyl ether acetate [1-Methoxy-2-propyl Acetate (glycol ether)]	- -	- -	- -	- -	- -	- -	- -	XX	XX
129-00-0	Pyrene (category: PAH)	X	X	D	75	X	X	X	XX	XX
68784-83-8 (d)	Red phosphors	- -	- -	- -	- -	- -	- -	- -	XX	XX
No CAS#	Red phosphors ($Y_2O_2S.Eu$)	- -	- -	- -	- -	- -	- -	- -	XX	XX
No CAS #	Rubidium (Rb+)	- -	- -	- -	- -	- -	- -	- -	- -	- -
7440-20-2	Scandium (Sc)	- -	- -	- -	- -	- -	- -	- -	XX	XX
7782-49-2	Selenium (Se)	X	X	D	1.50e-02	X	X	X	XX	XX
7440-21-3	Silicon (Si)	- -	- -	- -	- -	- -	- -	- -	XX	XX
7440-22-4	Silver	X	X	D	X	X	1.40e-02	X	4.00e-03	0.001
no CAS#	Silver compounds [Silver (Ag+)]	X	X	D	X	X	1.40e-02	X	12.0	0.001
10588-01-9	Sodium Dichromate	X	X	3	X	X	0.18	0.25	XX	XX
2151247	Sodium Dichromate Dihydrate (VI)	- -	- -	- -	- -	- -	- -	- -	XX	XX
13472-35-0	sodium dihydrogen phosphate dihydrate	- -	- -	- -	- -	- -	- -	- -	XX	XX
7681-52-9	Sodium Hypochlorite	X	X	3	2.1	X	X	X	XX	XX
7681-57-4	Sodium Metabisulfite	X	X	3	- -	- -	- -	- -	XX	XX
7775-27-1	Sodium Persulfate	- -	- -	- -	- -	- -	- -	- -	XX	XX
No CAS #	Strontium (Sr II)	- -	- -	- -	190	X	X	X	- -	- -
7440-24-6	Strontium (Sr)	- -	- -	- -	190	X	X	X	XX	XX
1633-05-2	Strontium carbonate	- -	- -	- -	190	X	X	X	XX	XX
100-42-5	Styrene	X	X	C,2B	100	565	X	X	4.0	0.44
7446-09-5	Sulfur dioxide	X	X	3	X	0.104	X	X	XX	XX
2551-62-4	sulfur hexafluoride	- -	- -	- -	- -	- -	- -	- -	XX	XX

Table K-8. Chemicals in the CDP inventory classified as potentially toxic

Cas #	Material	Chronic							Aquatic ecotoxicity	
		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
no CAS#	sulfur oxides (SOx)	- -	- -	- -	- -	- -	- -	- -	XX	XX
7664-93-9	sulfuric acid	X	X	1	X	0.1	X	X	31.0	2.0
10124-29-5	Sulfuric acid, aluminum salt	- -	- -	- -	X	X	154	X	XX	XX
127-18-4	tetrachloroethylene	5.20e-02	2.00e-03	B2,2B	14	740.2	X	X	17.0	2.0
109-99-9	Tetrahydrofuran (THF)	- -	- -	- -	782	0.2	X	X	XX	XX
75-59-2	Tetramethyl ammonium hydroxide (TMAH)	- -	- -	- -	- -	- -	- -	- -	XX	XX
7440-28-0	Thallium (TI)	- -	- -	- -	- -	- -	- -	- -	XX	XX
7440-29-1	Thorium (Th)	X	X	A	- -	- -	- -	- -	XX	XX
7440-31-5	Tin (Sn)	- -	- -	- -	- -	- -	- -	- -	626.0	62.6
No CAS #	Tin (Sn++, Sn4+)	- -	- -	- -	- -	- -	- -	- -	626.0	62.6
7440-32-6	Titanium	X	X	C	X	0.8	1146	X	- -	- -
7550-45-0	Titanium tetrachloride	- -	- -	- -	X	9.00e-03	X	X	25.0	1.0
108-88-3	Toluene	X	X	D,3	100	411.1	X	X	34.0	4.0
1025-15-6	triallyl isocyanurate	- -	- -	- -	- -	- -	- -	- -	XX	XX
79-01-6	trichloroethylene (TCE)	1.10e-02	6.00e-03	B2,3	24	586.6	X	X	44.0	8.0
75-69-4	Trichlorofluoromethane (CFC 11)	- -	- -	- -	X	X	349	X	XX	XX
1330-78-5	Tricresyl phosphate	- -	- -	- -	- -	- -	- -	- -	XX	XX
112-27-6	Triethylene Glycol	- -	- -	- -	X	X	1200	X	8.81e+04	8,810
115-86-6	Triphenyl phosphate	- -	- -	- -	- -	- -	- -	- -	XX	XX
7440-33-7	Tungsten (W)	- -	- -	- -	- -	- -	- -	- -	XX	XX
1344-59-8	U_3O_8 (yellowcake)	- -	- -	- -	- -	- -	- -	- -	XX	XX
7440-61-1	Uranium (U)	X	X	A1	0.2	X	X	X	XX	XX
7440-62-2	Vanadium (V)	- -	- -	- -	3.00e-03	X	X	X	XX	XX
No CAS #	Vanadium (V3+, V5+)	- -	- -	- -	- -	- -	- -	- -	- -	- -
108-05-4	Vinyl acetate	X	X	SAR0	100	176	X	X	100	25.0
75-01-4	Vinyl chloride	1.4	3.08e-02	A,1	X	6.98e+04	X	X	143	36.0
1330-20-7	Xylene (C24H30) [mixed isomers]	X	X	D	179	X	X	X	13	1.0
7440-66-6	Zinc (Zn)	X	X	D	0.9	X	1	X	9.00e-02	0.036
No CAS #	Zinc (Zn++)	- -	- -	- -	- -	- -	- -	- -	17.0	- -

Table K-8. Chemicals in the CDP inventory classified as potentially toxic

Cas #	Material	Chronic							Aquatic ecotoxicity	
		oral SF (mg/kg-day)$^{-1}$	inhal SF (mg/kg-day)$^{-1}$	WOE (EPA & IARC)(a)	oral NOAEL (b) (mg/kg-day)	inhal NOAEL (b) (mg/m^3)	oral LOAEL (b,c) (mg/kg-day)	inhal LOAEL (b,c) (mg/m^3)	fish LC50 (mg/L)	fish NOAEL (mg/L)
14940-68-2	Zircon sand [Zircon (Zr)]	- -	- -	- -	- -	- -	- -	- -	XX	XX
7440-67-7	Zirconium (Zr)	- -	- -	- -	3,494	X	X	X	XX	XX

Key:
(a)=See Table 3-3 in Section 3.1.2.12 for a description of WOE classifications.
(b)=only lowest value of the NOAEL (or LOAEL/10) is used to calculate chronic, non-cancer effects
(c)=LOAEL only needed if no NOAEL found
(d)=CAS # was provided by a company, but could not be confirmed.
XX=aquatic toxicity data not needed because there are no waterborne releases of this chemical in the CDP LCIs.
X=data not needed because other data are provided to calculate impact score (e.g., LOAEL not needed if NOAEL provided, and WOE used if SF not available).
SAR0=not a probable carcinogen based on structure-activity relationship (SAR) evaluation.
SAR1=possible carcinogen based on SAR evaluation.
- - =no data available, defaulted to mean hazard value (see Section 3.1.2.12 for an explanation of hazard values).
Sources:

- Oral and inhalation slope factors (SF): Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST) (EPA, 1994) as cited in Risk Assessment Information System (RAIS): http://risk.lsd.ornl.gov/rap_hp.shtml.
- Weight of Evidence (WOE): IRIS Web site (http://www.epa.gov/IRIS).
- Oral no observable adverse effect level (NOAEL), inhalation NOAEL, oral lowest obserable adverse effect level (LOAEL) and inhalation LOAEL: IUCLID, 1996; HEAST, 1994; Kincaid and Geibig, 1998; EPA, 2000a; SRC, 2000; EPA, 2000b; Geibig and Swanson, 2000; Sax and Lewis, 1987; NIOSH, 1978; EPA, 1984; and EPA, 1987.
- Fish LC50 and fish NOAEL: EPA, 2001; HSDB; Davis et al. 1994, Appendix E; and Geiger et al., 1984, 1985, 1986, 1988, 1990.

Table K-9. List of Materials Excluded from Toxic Classification

CAS #	Material	Reason for Exclusion [a]
NA	ABS plastic	judgment
21645-51-2	Aluminium Hydroxide (Al(OH)3)	GRAS
10043-01-3	Aluminium Sulfate (Al2(SO4)3)	GRAS
10043-01-3	Aluminum Sulfate (Al2(SO4)3)	GRAS
7440-37-1	Argon (Ar gas)	judgment
1302-78-9	Bentonite (Al2O3.4SiO2.H2O, in ground)	judgment
NA	BOD (Biological Oxygen Demand)	judgment
106-97-8	Butane (n-C4H10)	GRAS
25167-67-3	Butene (1-CH3CH2CHCH2)	judgment
7440-70-2	Calcium (Ca)	judgment
No CAS #	Calcium (Ca++)	judgment
10043-52-4	Calcium Chloride (CaCl2)	judgment
1305-62-0	Calcium hydroxide [Ca(OH)2, hydrated lime]	judgment
7778-18-9	Calcium Sulfate	judgment
124-38-9	Carbon Dioxide (CO2)	judgment
NA	Carbonate ion [Carbonates (CO3--, HCO3-, CO2]	judgment
NA	COD (Chemical Oxygen Demand)	judgment
16887-00-6	Chloride (Cl-)	judgment
1318-74-7	Clay (in ground)	judgment
NA	Dissolved solids	judgment
No CAS #	Dolomite (CaCO3.MgCO3, in ground)	judgment
26265-08-7	Epoxy resin (PC Board-epoxy resin)	judgment
141-78-6	Ethyl acetate (C4H8O2)	GRAS
64-17-5	Ethanol (Ethyl Alcohol)	GRAS
7705-08-0	Ferric chloride (FeCl3)	GRAS
NA	Ferrite	judgment
No CAS #	Glass	judgment
7440-59-7	Helium (He)	GRAS
NA	Nonmethane hydrocarbons	judgment
NA	Hydrocarbons (unspecified)	judgment
1333-74-0	Hydrogen gas (H2)	judgment
14380-61-1	Hypochlorite (ClO-)	judgment
20461-54-5	Iodide (I-)	judgment
7553-56-2	Iodine (I)	judgment
7439-89-6	Iron (Fe)	judgment
No CAS #	Iron (Fe++, Fe3+)	judgment
7720-78-7	Iron Sulfate (FeSO4, ore)	judgment
8008-20-6	Kerosene	judgment

Table K-9. List of Materials Excluded from Toxic Classification

CAS #	Material	Reason for Exclusion [a]
7439-90-9	Krypton Gas	judgment
No CAS #	Lignite (in ground)	judgment
1305-78-8	Lime	judgment
471-34-1	Limestone (CaCO3, in ground)	judgment
7439-95-4	Magnesium (Mg)	judgment
No CAS #	Magnesium cmpds [Magnesium (Mg++)]	judgment
7440-01-9	Neon	judgment
7727-37-9	Nitrogen	GRAS
74-98-6	n-propane [Propane (C3H8)]	GRAS
NA	Oil & grease	judgment
No CAS #	Olivine ((Mg,Fe)2SiO4, ore)	judgment
144-62-7	Oxalic Acid (C2H2O4)	judgment
7782-44-7	Oxygen (O2)	judgment
NA	Phosphates (PO4-3)	judgment
9011-87-4	Poly(methyl methacrylate) [PMMA (Acrylic resin)]	judgment
25971-63-5	Polycarbonate resin	judgment
NA	Polycyclic Aromatic Hydrocarbons (PAH, unspecified)	judgment
9002-88-4	polyethylene (PE) foam, cushion	judgment
No CAS #	Polyimide Resin	judgment
9003-53-6	Polystyrene [Styrene, polymer (C8H8)]	judgment
7440-09-7	Potassium (K)	judgment
No CAS #	Potassium (K+)	judgment
584-08-7	Potassium carbonate (K2CO3)	judgment
7447-40-7	Potassium Chloride (KCl, as K2O, in ground)	judgment
79-09-4	Propionic Acid (CH3CH2COOH)	GRAS
1332-09-8	Pumice	judgment
1309-36-0	Pyrite (FeS2, ore)	judgment
14808-60-7	Silica sand [Silicon dioxide (SiO2)]	GRAS
7440-23-5	Sodium (Na)	judgment
No CAS #	Sodium (Na+)	judgment
497-19-8	Sodium carbonate (Na2CO3, soda ash)	judgment
7647-14-5	Sodium Chloride (NaCl, in ground or in sea)	GRAS
1310-73-2	Sodium hydroxide (NaOH)	judgment
9003-55-8	Styrene-butadiene copolymers (C12H14)	judgment
14808-79-8	Sulfates (SO4--)	judgment
18496-25-8	Sulfides (S--)	judgment
14265-45-3	Sulfites (SO3--)	judgment
7704-34-9	Sulfur	judgment

Table K-9. List of Materials Excluded from Toxic Classification

CAS #	**Material**	**Reason for Exclusion** [a]
NA	Suspended Solids	judgment
14807-96-6	Talcum (4SiO2.3MgO.H2O, ore)	judgment
No CAS #	TOCs (Total organic compounds)	judgment

[a] NOTES:

(1) GRAS = Generally Regarded as Safe by the U.S. Food and Drug Administration.

(2) Some materials were excluded based on judgement if they are nutrients: calcium, chloride, iodine, iron, magnesium, phosphorous, potassium, sodium (per the Risk Assessment Guidance for Superfund [RAGS], EPA/540/1-89/002, December 1989 and the RAGS Region IV update).

(3) This list was reviewed by the U.S. EPA DFE Workgroup (Appendix C, Table C-2).

Table K-10. Chemicals used to calculate mean slope factor values for calculating carcinogenic hazard value

Chemical	CAS #	Oral Slope Factor (mg/kg-day)$^{-1}$	Inhalation Slope Factor (mg/kg-day)$^{-1}$
Acephate	30560-19-1	8.70E-03	
Acetaldehyde	75-07-0		7.70E-03
Acrylamide	79-06-1	4.50E+00	4.50E+00
Acrylonitrile	107-13-1	5.40E-01	2.40E-01
Alachlor	15972-60-8	8.00E-02	
Aldrin	309-00-2	1.70E+01	1.70E+01
Aniline	62-53-3	5.70E-03	
Aramite	140-57-8	2.50E-02	2.50E-02
Aroclor 1016	12674-11-2	4.00E-01	4.00E-01
Aroclor 1016	12674-11-2	2.00E+00	2.00E+00
Aroclor 1221	11104-28-2	4.00E-01	4.00E-01
Aroclor 1221	11104-28-2	2.00E+00	2.00E+00
Aroclor 1232	11141-16-5	4.00E-01	4.00E-01
Aroclor 1232	11141-16-5	2.00E+00	2.00E+00
Aroclor 1242	53469-21-9	4.00E-01	4.00E-01
Aroclor 1242	53469-21-9	2.00E+00	2.00E+00
Aroclor 1248	12672-29-6	4.00E-01	4.00E-01
Aroclor 1248	12672-29-6	2.00E+00	2.00E+00
Aroclor 1254	11097-69-1	4.00E-01	4.00E-01
Aroclor 1254	11097-69-1		2.00E+00
Aroclor 1260	11096-82-5	4.00E-01	4.00E-01
Aroclor 1260	11096-82-5	2.00E+00	2.00E+00
Arsenic, Inorganic	7440-38-2	1.50E+00	5.00E+01
Atrazine	1912-24-9	2.22E-01	
Azobenzene	103-33-3	1.10E-01	1.10E-01
Benz[a]anthracene	56-55-3	7.30E-01	3.10E-01
Benzene	71-43-2	5.50E-02	2.90E-02
Benzidine	92-87-5	2.30E+02	2.30E+02
Benzo[a]pyrene	50-32-8	7.30E+00	3.10E+00
Benzo[b]fluoranthene	205-99-2	7.30E-01	3.10E-01
Benzo[k]fluoranthene	207-08-9	7.30E-02	3.10E-02
Benzotrichloride	98-07-7	1.30E+01	
Benzyl Chloride	100-44-7	1.70E-01	
Beryllium and compounds	7440-41-7	4.30E+00	8.40E+00
Bis(2-chloro-1-methylethyl)ether (Technical)	108-60-1	7.00E-02	3.50E-02
Bis(2-chloroethyl)ether	111-44-4	1.10E+00	1.10E+00
Bis(2-ethylhexyl)phthalate	117-81-7	1.40E-02	

Table K-10. Chemicals used to calculate mean slope factor values for calculating carcinogenic hazard value

Chemical	CAS #	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Slope Factor $(mg/kg\text{-}day)^{-1}$
Bis(chloromethyl)ether	542-88-1	2.20E+02	2.20E+02
Bromodichloromethane	75-27-4	6.20E-02	
Bromoform	75-25-2	7.90E-03	3.90E-03
Butadiene, 1,3-	106-99-0		1.80E+00
Cadmium (Diet)	7440-43-9		6.10E+00
Cadmium (Water)	7440-43-9		6.10E+00
Captafol	2425-06-1	8.60E-03	
Captan	133-06-2	3.50E-03	
Carbazole	86-74-8	2.00E-02	
Carbon Tetrachloride	56-23-5	1.30E-01	5.30E-02
Chloranil	118-75-2	4.03E-01	
Chlordane	057-74-9	3.50E-01	1.30E+00
Chloro-2-methylaniline HCl, 4-	3165-93-3	4.60E-01	
Chloro-2-methylaniline, 4-	95-69-2	5.80E-01	
Chlorobenzilate	510-15-6	2.70E-01	2.70E-01
Chlorodibromoethane	73506-94-2	8.40E-02	
Chloroform	67-66-3	6.10E-03	8.10E-02
Chloromethane	74-87-3	1.30E-02	6.30E-03
Chloronitrobenzene, o-	88-73-3	2.50E-02	
Chloronitrobenzene, p-	121-73-3	1.80E-02	
Chlorothalonil	1897-45-6	1.10E-02	
Chromium VI (chromic acid mists)	18540-29-9		4.10E+01
Chromium VI (particulates)	18540-29-9		4.10E+01
Chrysene	218-01-9	7.30E-03	3.10E-03
Coke Oven Emissions	8007-45-2		2.20E+00
Crotonaldehyde, trans-	123-73-9	1.90E+00	
Cyanazine	21725-46-2	8.40E-01	
Cyclohexane, 1,2,3,4,5-pentabromo-6-chloro-	87-84-3	2.30E-02	
DDD	72-54-8	2.40E-01	
DDE	72-55-9	3.40E-01	
DDT	50-29-3	3.40E-01	3.40E-01
Di(2-ethylhexyl)adipate	103-23-1	1.20E-03	
Diallate	2303-16-4	6.10E-02	
Dibenz[a,h]anthracene	53-70-3	7.30E+00	3.10E+00
Dibromo-3-chloropropane, 1,2-	96-12-8	1.40E+00	2.40E-03
Dibromochloromethane	124-48-1	8.40E-02	
Dibromoethane, 1,2-	106-93-4	8.50E+01	7.60E-01

Table K-10. Chemicals used to calculate mean slope factor values for calculating carcinogenic hazard value

Chemical	CAS #	Oral Slope Factor (mg/kg-day)$^{-1}$	Inhalation Slope Factor (mg/kg-day)$^{-1}$
Dichloro-2-butene, 1,4-	764-41-0		9.30E+00
Dichlorobenzene, 1,4-	106-46-7	2.40E-02	
Dichlorobenzidine, 3,3'-	91-94-1	4.50E-01	
Dichloroethane, 1,2-	107-06-2	9.10E-02	9.10E-02
Dichloroethylene, 1,1-	75-35-4	6.00E-01	1.20E+00
Dichloropropane, 1,2-	78-87-5	6.80E-02	
Dichloropropene, 1,3-	542-75-6	1.00E-01	1.40E-02
Dichlorvos	62-73-7	2.90E-01	
Dieldrin	60-57-1	1.60E+01	1.60E+01
Diethylstilbesterol	56-53-1	4.70E+03	4.90E+02
Dimethoxybenzidine, 3,3'-	119-90-4	1.40E-02	
Dimethylaniline HCl, 2,4-	21436-96-4	5.80E-01	
Dimethylaniline, 2,4-	095-68-1	7.50E-01	
Dimethylbenzidine, 3,3'-	119-93-7	9.20E+00	
Dimethylhydrazine, 1,1-	57-14-7	3.00E+00	1.72E+01
Dinitrotoluene Mixture, 2,4/2,6-	25321-14-6	6.80E-01	
Dinitrotoluene, 2,4-	121-14-2	6.80E-01	
Dinitrotoluene, 2,6-	606-20-2	6.80E-01	
Dioxane, 1,4-	123-91-1	1.10E-02	
Diphenylhydrazine, 1,2-	122-66-7	8.00E-01	8.00E-01
Direct Black 38	1937-37-7	8.60E+00	
Direct Blue 6	2602-46-2	8.10E+00	
Direct Brown 95	16071-86-6	9.30E+00	
Epichlorohydrin	106-89-8	9.90E-03	4.20E-03
Ethyl Acrylate	140-88-5	4.80E-02	
Ethylbenzene	100-41-4		3.85E-03
Ethylene Oxide	75-21-8	1.02E+00	3.50E-01
Ethylene Thiourea	96-45-7	1.10E-01	
Folpet	133-07-3	3.50E-03	
Fomesafen	72178-02-0	1.90E-01	
Formaldehyde	50-00-0		4.50E-02
Furazolidone	67-45-8	3.80E+00	
Furium	531-82-8	5.00E+01	
Furmecyclox	60568-05-0	3.00E-02	
Heptachlor	76-44-8	4.50E+00	4.50E+00
Heptachlor Epoxide	1024-57-3	9.10E+00	9.10E+00
Hexachlorobenzene	118-74-1	1.60E+00	1.60E+00

Table K-10. Chemicals used to calculate mean slope factor values for calculating carcinogenic hazard value

Chemical	CAS #	Oral Slope Factor (mg/kg-day)$^{-1}$	Inhalation Slope Factor (mg/kg-day)$^{-1}$
Hexachlorobutadiene	87-68-3	7.80E-02	7.80E-02
Hexachlorocyclohexane, Alpha-	319-84-6	6.30E+00	6.30E+00
Hexachlorocyclohexane, Beta-	319-85-7	1.80E+00	1.80E+00
Hexachlorocyclohexane, Gamma-	58-89-9	1.30E+00	
Hexachlorocyclohexane, Technical	608-73-1	1.80E+00	1.80E+00
Hexachlorodibenzo-p-dioxin, Mixture	19408-74-3	6.20E+03	4.55E+03
Hexachloroethane	67-72-1	1.40E-02	1.40E-02
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	1.10E-01	
HpCDD, 2,3,7,8-	37871-00-4	1.50E+03	1.50E+03
HpCDF, 2,3,7,8-	38998-75-3	1.50E+03	1.50E+03
HxCDD, 2,3,7,8-	34465-46-8	1.50E+04	1.50E+04
HxCDF, 2,3,7,8-	55684-94-1	1.50E+04	1.50E+04
Hydrazine	302-01-2	3.00E+00	1.70E+01
Hydrazine Sulfate	10034-93-2	3.00E+00	1.70E+01
Indeno[1,2,3-cd]pyrene	193-39-5	7.30E-01	3.10E-01
Isophorone	78-59-1	9.50E-04	
Methoxy-5-nitroaniline, 2-	99-59-2	4.60E-02	
Methyl Hydrazine	60-34-4	3.00E+00	1.72E+01
Methyl-5-Nitroaniline, 2-	99-55-8	3.30E-02	
Methylaniline Hydrochloride, 2-	636-21-5	1.80E-01	
Methylene Chloride	75-09-2	7.50E-03	1.65E-03
Methylene-bis(2-chloroaniline), 4,4'-	101-14-4	1.30E-01	1.30E-01
Methylene-bis(N,N-dimethyl) Aniline, 4,4'-	101-61-1	4.60E-02	
Methylenebisbenzenamine, 4,4'-	101-77-9	2.50E-01	
Mirex	2385-85-5	1.80E+00	
Nickel Refinery Dust	NA		8.40E-01
Nickel Subsulfide	12035-72-2		1.70E+00
Nitrofurazone	59-87-0	1.50E+00	
Nitropropane, 2-	79-46-9	9.50E+00	9.40E+00
Nitrosodiethanolamine, N-	1116-54-7	2.80E+00	
Nitrosodiethylamine, N-	55-18-5	1.50E+02	1.50E+02
Nitrosodimethylamine, N-	62-75-9	5.10E+01	5.10E+01
Nitroso-di-N-butylamine, N-	924-16-3	5.40E+00	5.40E+00
Nitroso-di-N-propylamine, N-	621-64-7	7.00E+00	
Nitrosodiphenylamine, N-	86-30-6	4.90E-03	
Nitrosomethylethylamine, N-	10595-95-6	2.20E+01	
Nitroso-N-ethylurea, N-	759-73-9	1.40E+02	

Table K-10. Chemicals used to calculate mean slope factor values for calculating carcinogenic hazard value

Chemical	CAS #	Oral Slope Factor (mg/kg-day)$^{-1}$	Inhalation Slope Factor (mg/kg-day)$^{-1}$
Nitrosopyrrolidine, N-	930-55-2	2.10E+00	2.10E+00
OCDD	3268-87-9	1.50E+02	1.50E+02
OCDF	39001-02-0	1.50E+02	1.50E+02
PeCDD, 2,3,7,8-	36088-22-9	7.50E+04	7.50E+04
PeCDF, 1,2,3,7,8-	57117-41-6	7.50E+04	7.50E+04
PeCDF, 2,3,4,7,8-	57117-31-4	7.50E+03	7.50E+03
Pentachloronitrobenzene	82-68-8	2.60E-01	
Pentachlorophenol	87-86-5	1.20E-01	
Phenylenediamine, o-	95-54-5	4.70E-02	
Phenylphenol, 2-	90-43-7	1.94E-03	
Polybrominated Biphenyls	59536-65-1	8.90E+00	
Polychlorinated Biphenyls (high risk)	1336-36-3	2.00E+00	2.00E+00
Polychlorinated Biphenyls (low risk)	1336-36-3	4.00E-01	4.00E-01
Polychlorinated Biphenyls (lowest risk)	1336-36-3	7.00E-02	
Prochloraz	67747-09-5	1.50E-01	
Propylene Oxide	75-56-9	2.40E-01	1.30E-02
Quinoline	91-22-5	1.20E+01	
Simazine	122-34-9	1.20E-01	
Sodium Diethyldithiocarbamate	148-18-5	2.70E-01	
Stirofos (Tetrachlorovinphos)	961-11-5	2.40E-02	
TCDD, 2,3,7,8-	1746-01-6	1.50E+05	1.50E+05
TCDF, 2,3,7,8-	51207-31-9	1.50E+04	1.50E+04
Tetrachloroethane, 1,1,1,2-	630-20-6	2.60E-02	2.60E-02
Tetrachloroethane, 1,1,2,2-	79-34-5	2.00E-01	2.00E-01
Tetrachloroethylene	127-18-4	5.20E-02	2.00E-03
Tetrachlorotoluene, p- alpha, alpha, alpha-	5216-25-1	2.00E+01	
Toluene-2,4-diamine	95-80-7	3.20E+00	
Toluidine, o- (Methylaniline, 2-)	95-53-4	2.40E-01	
Toluidine, p-	106-49-0	1.90E-01	
Toxaphene	8001-35-2	1.10E+00	1.10E+00
Trichloroaniline HCl, 2,4,6-	33663-50-2	2.90E-02	
Trichloroaniline, 2,4,6-	634-93-5	3.40E-02	
Trichloroethane, 1,1,2-	79-00-5	5.70E-02	5.70E-02
Trichloroethylene	79-01-6	1.10E-02	6.00E-03
Trichlorophenol, 2,4,6-	88-06-2	1.10E-02	1.00E-02
Trichloropropane, 1,2,3-	96-18-4	7.00E+00	
Trifluralin	1582-09-8	7.70E-03	

Table K-10. Chemicals used to calculate mean slope factor values for calculating carcinogenic hazard value

Chemical	**CAS #**	**Oral Slope Factor (mg/kg-day)$^{-1}$**	**Inhalation Slope Factor (mg/kg-day)$^{-1}$**
Trimethyl Phosphate	512-56-1	3.70E-02	
Trinitrotoluene, 2,4,6-	118-96-7	3.00E-02	
Vinyl Bromide	593-60-2		1.10E-01
Vinyl Chloride	75-01-4	1.40E+00	3.08E-02
geometric mean		0.71	1.70
count (n)		175	105

blank=no data

Source: Risk Assessment Information System (RAIS), http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_9801 (downloaded 11/00): IRIS/HEAST Slope Factors.

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APPENDIX L

SECONDARY ISSUES TO THE USE LIFE-CYCLE STAGE OF COMPUTER DISPLAYS

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APPENDIX L

SECONDARY ISSUES TO THE USE LIFE-CYCLE STAGE OF COMPUTER DISPLAYS

1. ELECTRIC AND MAGNETIC FIELDS (EMFs)

Electric and magnetic fields (EMFs) are invisible lines of force that surround any electrical device, including power lines, electrical wiring, and electrical equipment. Electric fields are produced by voltage and increase in strength as the voltage increases. Magnetic fields result from the flow of current through wires and or electrical devices and increase in strength as the current increases. Most electrical equipment has to be turned on for a magnetic field to be produced, but electric fields are present even when equipment is switched off as long as it is connected to an electric power source. Electric fields are weakened or shielded by materials that conduct electricity (including human skin). Magnetic fields, on the other hand, pass through most materials and are therefore more difficult to shield and of greater concern. Both electric and magnetic fields decrease with distance from the source (NIOSH, et al 1996).

Most information on EMFs from video display units (VDUs) pertains to CRT monitors. The following is excerpted from the World Health Organization fact sheet, “Video Display Units (VDUs) and Human Health (1998):”

> *“The typical VDU creates images in a large evacuated cathode-ray-tube (CRT) by directing a beam of high-energy electrons from the cathode onto a special phosphor-coated glass screen. This coating emits light when struck by the fast-moving electrons. The electron beam creates the image from computer signals that control coils, at the back of the CRT, that sweep the electrons in the vertical and horizontal directions. These coils are called vertical and horizontal deflection coils. The electronic circuitry used to create the image gives rise to static electric and magnetic fields, as well as low and high frequency electromagnetic fields...*
>
> *Electric and magnetic fields are emitted in three different frequency ranges. The horizontal deflection coils emit fields operating predominantly in the frequency range 15-35kHz. Extremely low frequency (ELF) fields at 50 to 60 Hz come from the power supply, transformers and the vertical deflection coils. Finally, weak signals at higher radio frequencies (RF) come from the VDU’s interior electronic circuitry and signals received from the computer.”*

Very little information was found on the relative magnitude of EMFs emitted by CRTs and LCDs. However, typical household power operates at 50-60 Hz and 120 volts – these remain relatively constant no matter how much power in watts a piece of electrical equipment needs or draws. What fluctuates with power demand is current (in amperes, or amps). CRTs consume a greater quantity of power in watts, and therefore require a larger amount of electrical current in amps. Since magnetic fields increase in strength with increased current, it is assumed a CRT will generate a larger magnetic field than an LCD. Additionally, some of the components discussed above, such as the horizontal and vertical deflection coils, are found in CRTs but not in LCDs. Thus, due to their power handling needs and capabilities, CRTs also generate EMFs that are not generated by LCDs. However, according to NoRad Corporation, a manufacturer and marketer of EMF shielding products for monitors, it is a common misconception that LCDs do not emit EMFs because of their smaller current draw; backlit LCD displays can emit significant levels of both magnetic fields and electric fields (NoRad, undated).

To address concerns about potential health effects from EMF exposure, in 1992 the U.S. Congress authorized the Electric and Magnetic Fields Research and Public Information Program (EMF-RAPID Program) and directed the National Institute of Environmental Health Sciences (NIEHS) and the Department of Energy (DOE) to direct and manage a program of research and analysis aimed at providing scientific evidence to clarify the potential for health risks from exposure to ELF-EMF (NIEHS, 1999). After several years of research, in 1999 NIEHS issued a report to Congress on the health effects from exposure to power-line frequency EMFs, which concluded the following (NIEHS, 1999):

> *"The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic finding of biological effects (including increased cancers in animals) have been reported. No indication of increased leukemia in experimental animals has been observed.*
>
> *The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real-life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given the weak magnitude of these increased risks, some other factor or common source of error could explain these findings. However, no consistent explanation other than exposure to ELF-EMF has been identified.*
>
> *Epidemiological studies have serious limitations in their ability to demonstrate a cause and effect relationship whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to ELF-EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but it cannot completely discount the epidemiological findings.*
>
> *The NIEHS concludes that ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our*

> *opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers on non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern."*

More recently, an expert scientific working group of the Monographs Programme of the International Agency for Research on Cancer (IARC) released its findings from a review of health effects of static and ELF EMFs. IARC concluded that ELF magnetic fields are possibly carcinogenic to humans, based on consistent statistical associations of high level residential magnetic fields with a doubling of risk of childhood leukemia. However, IARC also concluded that children who are exposed to residential ELF magnetic fields less than 0.4 microTesla (4 milligauss)[1] have no increased risk of leukemia (IARC, 2001). To help put this in perspective, Table L-1 presents the average magnetic field exposures for clerical workers with and without computers.[2] As shown in the table, clerical workers with computers have increased average daily exposures of about 0.07 μT (0.7 mG) over clerical workers without computers. The average daily median for workers with computers is 0.12 μT (1.2 mG) and the exposure range is 0.05 to 0.45 μT (0.5 to 4.5 mG). Only the upper end of the exposure range exceeds the exposure level that IARC concluded has an increased risk of childhood leukemia (0.4 μT).

Table L-1. Average magnetic field exposures for clerical workers*

Type of worker	Average daily median (μT)	Exposure range (μT)
Clerical workers with computers	0.12	0.05 to 0.45
Clerical workers without computers	0.05	0.02 to 0.2

Source: NIOSH Fact Sheet: EMFs in the Workplace
* The source does not give the distance at which measurements were taken. Monitor EMF emission measurements are often taken at a distance of 30 cm (approximately 12 inches) or 50 cm (approximately 20 inches).

In summary, no data were found on EMF measurements from LCDs. However, because of the lesser current requirements of LCDs compared to CRTs, it is assumed that LCDs also generate a lesser magnetic field. NIEHS has concluded that the evidence that ELF-EMF exposures pose any health risk is weak. However, since publication of the NIEHS report, IARC has classified ELF-EMFs as possibly carcinogenic to humans. Based on the data in Table L-3, it

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[1] Magnetic field intensity is measured in units of tesla (T) or gauss (G). One tesla equals 10,000 gauss. Since most environmental EMF exposure involve magnetic field intensities that are only a fraction of a tesla or a gauss, they are commonly measured in units of microteslas (μT) or milligauss (mG). One μT is equal to 10 mG.

[2] Given the fact that desktop LCD monitors were only recently introduced into the marketplace, it is assumed that the computers used by clerical workers for whom measurements were taken were equipped with CRT monitors, although the data could also include clerical workers who used laptops with LCD displays.

appears most exposures to ELFs-EMFs from computer displays may be below the carcinogenicity concern level determined by IARC (0.4 μT).

2. ERGONOMIC ISSUES

Merriam-Webster's Online Dictionary defines ergonomics as "an applied science concerned with designing and arranging things people use so that the people and things interact most efficiently and safely – also called human engineering." While CRT and LCD desktop monitors are both usable in the same environments (in most cases), there are differences in their sizes and the way they present information to the user in their working environment. Thus the potential exists for there to be differences in the way a user might physically interact with their CRT or LCD monitor. (Note that Eye Strain is addressed as a separate issue in this Appendix [see L.3], and issues related to image generation on the monitor surface are addressed there.)

In reviewing several documents on ergonomics and the placement of computer monitors in or around a user's working area, some sources discuss the differences in using a CRT versus an LCD monitor. It is assumed in most discussions that the user is able to move/adjust the monitor to within a recommended operating position for use (e.g., eye-to-screen distance, vertical monitor location [with respect to horizontal eye level]). Thus, with unlimited resources within which to setup a computing environment, it is expected that only viewing angle would potentially favor a CRT over an LCD. CRTs provide a horizontal viewing angle of 180˚ whereas early-model LCD monitors were limited to an almost straight on view. The most recent LCDs on the market have a 120˚ capability (EIZO 1999). Although less than the CRT horizontal viewing angle, these current viewing angles significantly diminish the differences in viewing ability between the two monitor types. The reduced viewing angle of the LCD appears to mainly be a factor when presenting information to users who are viewing the screen from the side, such as during presentations to multiple users.

However, the user's environment is often limited by physical constraints on where the monitor can be placed and user seated. With this in mind, the physical size and footprint of the monitor becomes more of an ergonomics issue. In cases where the footprint of a monitor dictates that the monitor not go directly in-front of the user, but to either the left or right side, an increased level of ergonomic stress may be realized (typically neck twist) if the user is unable to adjust his or her seated position accordingly. Even the smaller footprint CRTs being manufactured today have a much larger footprint than those of closely-equivalent LCD monitors, typically occupying almost six times the depth of LCDs (IBM 1999). Additionally, some LCD monitors can be wall-mounted, almost completely removing the monitor from the desktop. Thus, it appears that the smaller footprint of the LCD may offer benefits in more easily positioning the monitor for optimum user use.

3. EYE STRAIN

There are numerous sensations that can be interpreted to be eye strain in the use of monitors, including but not limited to burning, tightness, sharp pains, dull pains, watering, blurring, double vision and headaches. Many of the principal factors that cause eye strain can be corrected or improved by adequately setting up the computing environment (e.g., controlling the distance between the eyes and the screen, wearing corrective lenses, if needed, etc.). Others can be improved by adjusting the controls on the monitor (e.g., setting brightness or contrast). Of the factors identified in this study, glare and screen flicker are the two that appear to be most affected by the technology choice (e.g., CRT or LCD).

The distance between your eyes and the monitor should be at least 25" (Ankrum 1996), and using a CRT versus an LCD should have no effect on the necessary distance needed to clearly see the monitor screen, as long as the user is using an appropriately sized resolution for his or her monitor size. Both CRTs and LCDs should be equally readable, not considering the viewing of an LCD from outside its particular viewing angle. If the brightness levels of a CRT and LCD are set appropriately, then the contrast between what is being looked at and its immediate environment should be no different for the two monitor types. Lastly, a user has to have good or corrected vision before either monitor will be useful.

The only notable difference between CRTs and LCDs with respect to glare is their flatness. As LCDs have completely flat monitor surfaces or screens, versus most CRTs which have rounded screens, they significantly reduce the probability of reflected glare from overhead or nearby lights. There are two main types of CRT tube technology, shadow mask and aperture grill. Shadow masks are utilized in older, less flat monitors, and aperture grills are utilized in the more current variations that have flatter outside faces (IBM 1999). Flatter screens provide less opportunity for the occurrence of reflected glare.

CRTs, especially older models, may be prone to screen flicker, which contributes significantly to eye strain. CRT's use phosphor that has been excited by an electron beam to create light. After the phosphor is excited, it begins to decay. The electron beam needs to return to the phosphor in a specific amount of time to keep the phosphor from decaying to the point that the human eye can perceive it. The rate at which the electron beam returns to any given phosphor is called the refresh rate. If the refresh rate is too low, the decaying of the phosphor may be perceptible to the human eye as a flickering screen image. Because LCDs do not use phosphors to create the image they do not have a refresh rate and do not flicker.

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APPENDIX M

LIFE-CYCLE IMPACT ASSESSMENT RESULTS

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APPENDIX M

LIFE-CYCLE IMPACT ASSESSMENT RESULTS

Table M-1. CRT LCIA Results for the Renewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Renewable Resource Use (kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Water	secondary	4.69e+02	3.57e+00
Invar	Water	secondary	3.96e+01	3.02e-01
Lead	Water	secondary	1.40e+01	1.07e-01
Polycarbonate Production	Water	secondary	1.30e+01	9.93e-02
Ferrite mfg.	Water	secondary	1.11e+01	8.46e-02
ABS Production	Water	secondary	3.94e+00	3.00e-02
Styrene-butadiene Copolymer Prod.	Water	secondary	2.58e+00	1.97e-02
Polystyrene Prod., high-impact	Water	secondary	8.16e-01	6.22e-03
Polycarbonate Production	Sodium chloride (NaCl, in ground or in sea)	secondary	7.30e-01	5.56e-03
Steel Prod., cold-rolled, semi-finished	Limestone (CaCO3, in ground)	secondary	6.72e-01	5.12e-03
Aluminum Prod.	Limestone (CaCO3, in ground)	secondary	9.25e-02	7.05e-04
Lead	Limestone (CaCO3, in ground)	secondary	6.63e-02	5.05e-04
Lead	Sand (in ground)	secondary	4.79e-02	3.65e-04
Aluminum Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	2.56e-02	1.95e-04
Invar	Limestone (CaCO3, in ground)	secondary	9.08e-03	6.91e-05
ABS Production	Limestone (CaCO3, in ground)	secondary	7.62e-03	5.80e-05
Polycarbonate Production	Limestone (CaCO3, in ground)	secondary	6.00e-03	4.57e-05
Aluminum Prod.	Sand (in ground)	secondary	5.26e-03	4.00e-05
Polystyrene Prod., high-impact	Limestone (CaCO3, in ground)	secondary	3.78e-03	2.88e-05
Invar	Sand (in ground)	secondary	3.67e-03	2.80e-05
ABS Production	Gravel/Sand	secondary	3.60e-03	2.74e-05
Aluminum Prod.	Clay (in ground)	secondary	2.79e-03	2.13e-05
ABS Production	Sodium chloride (NaCl, in ground or in sea)	secondary	2.63e-03	2.00e-05
Steel Prod., cold-rolled, semi-finished	Gravel/Sand	secondary	2.05e-03	1.56e-05
Ferrite mfg.	Limestone (CaCO3, in ground)	secondary	1.58e-03	1.21e-05
Styrene-butadiene Copolymer Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	1.16e-03	8.82e-06
Styrene-butadiene Copolymer Prod.	Limestone (CaCO3, in ground)	secondary	1.13e-03	8.63e-06
Steel Prod., cold-rolled, semi-finished	Sodium chloride (NaCl, in ground or in sea)	secondary	1.02e-03	7.74e-06
Ferrite mfg.	Sand (in ground)	secondary	9.35e-04	7.12e-06
Invar	Clay (in ground)	secondary	8.67e-04	6.60e-06
Invar	Sodium chloride (NaCl, in ground or in sea)	secondary	6.95e-04	5.29e-06
Invar	Gravel/Sand	secondary	5.91e-04	4.50e-06
Ferrite mfg.	Gravel/Sand	secondary	5.77e-04	4.39e-06
Steel Prod., cold-rolled, semi-finished	Clay (in ground)	secondary	4.45e-04	3.39e-06
Polycarbonate Production	Sand (in ground)	secondary	3.79e-04	2.88e-06
Polystyrene Prod., high-impact	Sodium chloride (NaCl, in ground or in sea)	secondary	3.17e-04	2.42e-06
Ferrite mfg.	Sodium chloride (NaCl, in ground or in sea)	secondary	2.65e-04	2.02e-06
ABS Production	Sand (in ground)	secondary	2.54e-04	1.93e-06
Ferrite mfg.	Clay (in ground)	secondary	1.91e-04	1.45e-06
ABS Production	Clay (in ground)	secondary	1.25e-04	9.55e-07
Styrene-butadiene Copolymer Prod.	Sand (in ground)	secondary	6.21e-05	4.73e-07
Invar	Maize	secondary	5.75e-05	4.38e-07

Table M-1. CRT LCIA Results for the Renewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Renewable Resource Use (kg)	% of Total
Ferrite mfg.	Maize	secondary	5.62e-05	4.28e-07
Steel Prod., cold-rolled, semi-finished	Sand (in ground)	secondary	5.34e-05	4.07e-07
Polycarbonate Production	Clay (in ground)	secondary	4.62e-05	3.52e-07
Styrene-butadiene Copolymer Prod.	Clay (in ground)	secondary	2.44e-05	1.86e-07
Polystyrene Prod., high-impact	Sand (in ground)	secondary	2.42e-05	1.84e-07
Invar	Potatoes	secondary	1.55e-05	1.18e-07
Ferrite mfg.	Potatoes	secondary	1.51e-05	1.15e-07
Polycarbonate Production	Gravel/Sand	secondary	2.77e-06	2.11e-08
Styrene-butadiene Copolymer Prod.	Gravel/Sand	secondary	8.27e-07	6.30e-09
Total Materials Processing			**5.56e+02**	**4.23e+00**
Manufacturing Life-cycle Stage				
LPG Production	Water, unspecified	secondary	1.04e+04	7.94e+01
CRT tube mfg.	Water	primary	8.11e+02	6.18e+00
Japanese Electric Grid	Water	model/secondary	4.43e+01	3.37e-01
PWB Mfg.	Water	model/secondary	4.22e+01	3.21e-01
Fuel Oil #6 Prod.	Water, unspecified	secondary	3.56e+01	2.71e-01
Glass/frit	Water	primary	3.51e+01	2.67e-01
Fuel Oil #2 Prod.	Water, unspecified	secondary	2.93e+01	2.23e-01
US electric grid	Water	model/secondary	1.82e+01	1.38e-01
Glass/frit	Sand	primary	2.40e+00	1.83e-02
Fuel Oil #4 Prod.	Water, unspecified	secondary	2.39e+00	1.82e-02
LPG Production	Limestone (CaCO3, in ground)	secondary	1.06e+00	8.10e-03
Natural Gas Prod.	Water	secondary	2.12e-01	1.61e-03
US electric grid	Limestone	model/secondary	3.85e-02	2.93e-04
Japanese Electric Grid	Limestone	model/secondary	3.06e-02	2.33e-04
LPG Production	Sand (in ground)	secondary	2.72e-02	2.08e-04
LPG Production	Sodium chloride (NaCl, in ground or in sea)	secondary	1.25e-02	9.52e-05
Fuel Oil #6 Prod.	Limestone (CaCO3, in ground)	secondary	8.56e-03	6.52e-05
Fuel Oil #2 Prod.	Limestone (CaCO3, in ground)	secondary	3.34e-03	2.54e-05
Natural Gas Prod.	Limestone (CaCO3, in ground)	secondary	1.84e-03	1.40e-05
Fuel Oil #4 Prod.	Limestone (CaCO3, in ground)	secondary	3.55e-04	2.71e-06
Fuel Oil #6 Prod.	Sand (in ground)	secondary	9.22e-05	7.02e-07
Fuel Oil #2 Prod.	Sand (in ground)	secondary	7.65e-05	5.82e-07
Fuel Oil #6 Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	4.23e-05	3.22e-07
Fuel Oil #2 Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	3.51e-05	2.67e-07
Fuel Oil #4 Prod.	Sand (in ground)	secondary	6.21e-06	4.73e-08
Fuel Oil #4 Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	2.85e-06	2.17e-08
Natural Gas Prod.	Sand (in ground)	secondary	5.51e-07	4.19e-09
Natural Gas Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	2.53e-07	1.92e-09
Total Manufacturing			**1.15e+04**	**8.72e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Water	model/secondary	1.14e+03	8.67e+00
US electric grid	Limestone	model/secondary	2.41e+00	1.83e-02
Total Use, Maintenance and Repair			**1.14e+03**	**8.69e+00**
End-of-life Life-cycle Stage				
CRT Incineration	Clay (in ground)	secondary	4.24e+00	3.23e-02
CRT landfilling	Clay (in ground)	primary	3.95e+00	3.01e-02
CRT Incineration	Sand (in ground)	secondary	1.40e+00	1.07e-02
CRT landfilling	Sand (in ground)	primary	1.31e+00	9.97e-03
US electric grid	Water	model/secondary	1.14e-01	8.67e-04

Table M-1. CRT LCIA Results for the Renewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Renewable Resource Use (kg)	% of Total
LPG Production	Water, unspecified	secondary	9.00e-02	6.86e-04
CRT landfilling	Limestone (CaCO3, in ground)	primary	6.32e-04	4.81e-06
US electric grid	Limestone	model/secondary	2.41e-04	1.84e-06
LPG Production	Limestone (CaCO3, in ground)	secondary	9.18e-06	6.99e-08
LPG Production	Sand (in ground)	secondary	2.35e-07	1.79e-09
LPG Production	Sodium chloride (NaCl, in ground or in sea)	secondary	1.08e-07	8.22e-10
Natural Gas Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	-1.27e-07	-9.65e-10
Natural Gas Prod.	Sand (in ground)	secondary	-2.76e-07	-2.10e-09
Fuel Oil #4 Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	-3.06e-05	-2.33e-07
Fuel Oil #4 Prod.	Sand (in ground)	secondary	-6.68e-05	-5.09e-07
Natural Gas Prod.	Limestone (CaCO3, in ground)	secondary	-9.22e-04	-7.02e-06
Fuel Oil #4 Prod.	Limestone (CaCO3, in ground)	secondary	-3.82e-03	-2.91e-05
Natural Gas Prod.	Water	secondary	-1.06e-01	-8.09e-04
CRT Incineration	Limestone (CaCO3, in ground)	secondary	-2.35e-01	-1.79e-03
CRT Incineration	Water	secondary	-1.73e+00	-1.32e-02
Fuel Oil #4 Prod.	Water, unspecified	secondary	-2.57e+01	-1.95e-01
Total End-of-Life			**-1.66e+01**	**-1.27e-01**
Total All Life-cycle Stages			**1.31e+04**	**1.00e+02**

Table M-2. LCD LCIA Results for the Renewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Renewable Resource Use (kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Water	secondary	2.30e+02	8.21e+00
Natural Gas Prod.	Water	secondary	1.48e+01	5.29e-01
PMMA Sheet Prod.	Water	secondary	8.86e+00	3.17e-01
Polycarbonate Production	Water	secondary	7.28e+00	2.60e-01
Styrene-butadiene Copolymer Prod.	Water	secondary	1.13e+00	4.03e-02
PET Resin Production	Water	secondary	8.19e-01	2.92e-02
Polycarbonate Production	Sodium chloride (NaCl, in ground or in sea)	secondary	4.07e-01	1.46e-02
Steel Prod., cold-rolled, semi-finished	Limestone (CaCO3, in ground)	secondary	3.29e-01	1.18e-02
Natural Gas Prod.	Limestone (CaCO3, in ground)	secondary	1.28e-01	4.59e-03
Aluminum Prod.	Limestone (CaCO3, in ground)	secondary	3.44e-02	1.23e-03
PMMA Sheet Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	1.92e-02	6.85e-04
Aluminum Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	9.54e-03	3.41e-04
PMMA Sheet Prod.	Limestone (CaCO3, in ground)	secondary	8.44e-03	3.01e-04
PMMA Sheet Prod.	Sand (in ground)	secondary	7.29e-03	2.60e-04
Polycarbonate Production	Limestone (CaCO3, in ground)	secondary	3.35e-03	1.20e-04
Aluminum Prod.	Sand (in ground)	secondary	1.96e-03	6.99e-05
PET Resin Production	Limestone (CaCO3, in ground)	secondary	1.91e-03	6.81e-05
Aluminum Prod.	Clay (in ground)	secondary	1.04e-03	3.71e-05
Steel Prod., cold-rolled, semi-finished	Gravel/Sand	secondary	1.01e-03	3.60e-05
Styrene-butadiene Copolymer Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	5.06e-04	1.81e-05
Steel Prod., cold-rolled, semi-finished	Sodium chloride (NaCl, in ground or in sea)	secondary	4.98e-04	1.78e-05
Styrene-butadiene Copolymer Prod.	Limestone (CaCO3, in ground)	secondary	4.96e-04	1.77e-05
Steel Prod., cold-rolled, semi-finished	Clay (in ground)	secondary	2.18e-04	7.78e-06
Polycarbonate Production	Sand (in ground)	secondary	2.11e-04	7.55e-06
PET Resin Production	Sodium chloride (NaCl, in ground or in sea)	secondary	1.27e-04	4.54e-06
Natural Gas Prod.	Sand (in ground)	secondary	3.85e-05	1.37e-06
Styrene-butadiene Copolymer Prod.	Sand (in ground)	secondary	2.71e-05	9.69e-07
Steel Prod., cold-rolled, semi-finished	Sand (in ground)	secondary	2.62e-05	9.35e-07
Polycarbonate Production	Clay (in ground)	secondary	2.58e-05	9.21e-07
Natural Gas Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	1.77e-05	6.30e-07
Styrene-butadiene Copolymer Prod.	Clay (in ground)	secondary	1.07e-05	3.81e-07
PET Resin Production	Sand (in ground)	secondary	5.81e-06	2.07e-07
PMMA Sheet Prod.	Clay (in ground)	secondary	4.60e-06	1.64e-07
Polycarbonate Production	Gravel/Sand	secondary	1.55e-06	5.53e-08
PMMA Sheet Prod.	Gravel/Sand	secondary	1.15e-06	4.11e-08
Styrene-butadiene Copolymer Prod.	Gravel/Sand	secondary	3.62e-07	1.29e-08
PET Resin Production	Clay (in ground)	secondary	9.08e-08	3.24e-09
PET Resin Production	Gravel	secondary	9.08e-08	3.24e-09
Total Materials Processing			**2.64e+02**	**9.42e+00**
Manufacturing Life-cycle Stage				
Monitor/module	Water	primary	1.08e+03	3.85e+01
LPG Production	Water, unspecified	secondary	5.00e+02	1.79e+01
Panel components	Water	primary	1.79e+02	6.38e+00
Backlight	Water	primary	1.67e+02	5.95e+00
Japanese Electric Grid	Water	model/secondary	1.49e+02	5.32e+00
Backlight	Water	primary	2.16e+01	7.70e-01
PWB Mfg.	Water	model/secondary	1.86e+01	6.64e-01
Backlight	Water	primary	3.76e+00	1.34e-01
Fuel Oil #4 Prod.	Water, unspecified	secondary	3.68e+00	1.31e-01

Table M-2. LCD LCIA Results for the Renewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Renewable Resource Use (kg)	% of Total
US electric grid	Water	model/secondary	2.20e+00	7.87e-02
LCD glass mfg.	Water	primary	1.62e+00	5.80e-02
Fuel Oil #2 Prod.	Water, unspecified	secondary	1.37e+00	4.88e-02
Fuel Oil #6 Prod.	Water, unspecified	secondary	1.21e+00	4.33e-02
Natural Gas Prod.	Water	secondary	3.34e-01	1.19e-02
Panel components	Water	primary	3.03e-01	1.08e-02
Panel components	Water	primary	2.01e-01	7.19e-03
LCD glass mfg.	Sand	primary	1.11e-01	3.97e-03
Japanese Electric Grid	Limestone	model/secondary	1.03e-01	3.68e-03
LPG Production	Limestone (CaCO3, in ground)	secondary	5.10e-02	1.82e-03
US electric grid	Limestone	model/secondary	4.66e-03	1.67e-04
Natural Gas Prod.	Limestone (CaCO3, in ground)	secondary	2.90e-03	1.04e-04
LPG Production	Sand (in ground)	secondary	1.31e-03	4.67e-05
LPG Production	Sodium chloride (NaCl, in ground or in sea)	secondary	6.00e-04	2.14e-05
Fuel Oil #4 Prod.	Limestone (CaCO3, in ground)	secondary	5.48e-04	1.96e-05
Fuel Oil #6 Prod.	Limestone (CaCO3, in ground)	secondary	2.92e-04	1.04e-05
Fuel Oil #2 Prod.	Limestone (CaCO3, in ground)	secondary	1.56e-04	5.56e-06
Fuel Oil #4 Prod.	Sand (in ground)	secondary	9.58e-06	3.42e-07
Fuel Oil #4 Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	4.39e-06	1.57e-07
Fuel Oil #2 Prod.	Sand (in ground)	secondary	3.57e-06	1.27e-07
Fuel Oil #6 Prod.	Sand (in ground)	secondary	3.14e-06	1.12e-07
Fuel Oil #2 Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	1.64e-06	5.85e-08
Fuel Oil #6 Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	1.44e-06	5.14e-08
Natural Gas Prod.	Sand (in ground)	secondary	8.68e-07	3.10e-08
Natural Gas Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	3.98e-07	1.42e-08
Total Manufacturing			**2.13e+03**	**7.59e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Water	model/secondary	4.25e+02	1.52e+01
US electric grid	Limestone	model/secondary	8.99e-01	3.21e-02
Total Use, Maintenance, and Repair			**4.26e+02**	**1.52e+01**
End-of-life Life-cycle Stage				
LCD landfilling	Clay (in ground)	primary	9.52e-01	3.40e-02
LCD incineration	Clay (in ground)	secondary	7.38e-01	2.64e-02
LCD landfilling	Sand (in ground)	primary	3.15e-01	1.13e-02
LCD incineration	Sand (in ground)	secondary	2.45e-01	8.73e-03
US electric grid	Water	model/secondary	8.06e-02	2.88e-03
LPG Production	Water, unspecified	secondary	4.11e-02	1.47e-03
US electric grid	Limestone	model/secondary	1.71e-04	6.09e-06
LCD landfilling	Limestone (CaCO3, in ground)	primary	1.52e-04	5.44e-06
LCD landfilling	Sodium chloride (NaCl, in ground or in sea)	primary	1.82e-05	6.50e-07
LCD incineration	Sodium chloride (NaCl, in ground or in sea)	secondary	1.28e-05	4.59e-07
LPG Production	Limestone (CaCO3, in ground)	secondary	4.19e-06	1.50e-07
LPG Production	Sand (in ground)	secondary	1.07e-07	3.83e-09
LPG Production	Sodium chloride (NaCl, in ground or in sea)	secondary	4.92e-08	1.76e-09
Natural Gas Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	-8.37e-08	-2.99e-09
Natural Gas Prod.	Sand (in ground)	secondary	-1.82e-07	-6.51e-09
Fuel Oil #4 Prod.	Sodium chloride (NaCl, in ground or in sea)	secondary	-2.02e-05	-7.23e-07
Fuel Oil #4 Prod.	Sand (in ground)	secondary	-4.41e-05	-1.58e-06
Natural Gas Prod.	Limestone (CaCO3, in ground)	secondary	-6.09e-04	-2.17e-05

Table M-2. LCD LCIA Results for the Renewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Renewable Resource Use (kg)	% of Total
Fuel Oil #4 Prod.	Limestone (CaCO3, in ground)	secondary	-2.52e-03	-9.01e-05
Natural Gas Prod.	Water	secondary	-7.02e-02	-2.51e-03
LCD incineration	Limestone (CaCO3, in ground)	secondary	-1.52e-01	-5.44e-03
LCD incineration	Water	secondary	-1.12e+00	-4.01e-02
Fuel Oil #4 Prod.	Water, unspecified	secondary	-1.69e+01	-6.05e-01
Total End-of-life			**-1.59e+01**	**-5.68e-01**
Total All Life-cycle Stages			**2.80e+03**	**1.00e+02**

Table M-3. CRT LCIA Results for the Nonrenewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Nonrenewable Resource Use (kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Iron (Fe, ore)	secondary	6.65e+00	9.95e-01
Steel Prod., cold-rolled, semi-finished	Coal, average (in ground)	secondary	3.98e+00	5.96e-01
Aluminum Prod.	Bauxite (Al2O3, ore)	secondary	1.37e+00	2.05e-01
Polycarbonate Production	Natural gas (in ground)	secondary	1.29e+00	1.92e-01
Styrene-butadiene Copolymer Prod.	Petroleum (in ground)	secondary	1.03e+00	1.54e-01
Aluminum Prod.	Coal, average (in ground)	secondary	9.83e-01	1.47e-01
Lead	Lead (Pb, ore)	secondary	4.96e-01	7.42e-02
Steel Prod., cold-rolled, semi-finished	Petroleum (in ground)	secondary	4.89e-01	7.32e-02
Aluminum Prod.	Petroleum (in ground)	secondary	4.64e-01	6.95e-02
Steel Prod., cold-rolled, semi-finished	Natural gas (in ground)	secondary	4.58e-01	6.86e-02
ABS Production	Natural gas (in ground)	secondary	4.42e-01	6.62e-02
Polycarbonate Production	Petroleum (in ground)	secondary	4.34e-01	6.49e-02
Styrene-butadiene Copolymer Prod.	Natural gas (in ground)	secondary	4.30e-01	6.44e-02
Steel Prod., cold-rolled, semi-finished	Coal, lignite (in ground)	secondary	4.16e-01	6.23e-02
Polycarbonate Production	Coal, average (in ground)	secondary	3.90e-01	5.85e-02
Invar	Petroleum (in ground)	secondary	3.70e-01	5.55e-02
Invar	Natural gas (in ground)	secondary	3.51e-01	5.25e-02
ABS Production	Petroleum (in ground)	secondary	2.98e-01	4.45e-02
Lead	Coal, average (in ground)	secondary	2.88e-01	4.30e-02
Invar	Iron (Fe, ore)	secondary	2.52e-01	3.77e-02
Polycarbonate Production	Coal, lignite (in ground)	secondary	2.46e-01	3.69e-02
Ferrite mfg.	Iron ore	secondary	2.37e-01	3.55e-02
Aluminum Prod.	Natural gas (in ground)	secondary	2.14e-01	3.20e-02
Aluminum Prod.	Coal, lignite (in ground)	secondary	1.83e-01	2.73e-02
Ferrite mfg.	Coal, average (in ground)	secondary	1.74e-01	2.60e-02
Lead	Natural gas (in ground)	secondary	1.56e-01	2.34e-02
Polystyrene Prod., high-impact	Natural gas (in ground)	secondary	1.39e-01	2.08e-02
Ferrite mfg.	Coal, lignite (in ground)	secondary	1.28e-01	1.92e-02
Ferrite mfg.	Natural gas (in ground)	secondary	1.24e-01	1.85e-02
Polystyrene Prod., high-impact	Petroleum (in ground)	secondary	1.18e-01	1.76e-02
Aluminum Prod.	Pyrite (FeS2, ore)	secondary	1.01e-01	1.51e-02
Invar	Nickel (Ni, ore)	secondary	9.80e-02	1.47e-02
Lead	Petroleum (in ground)	secondary	8.74e-02	1.31e-02
Lead	Iron (Fe, ore)	secondary	5.30e-02	7.93e-03
Lead	Pyrite (FeS2, ore)	secondary	5.09e-02	7.62e-03
Ferrite mfg.	Petroleum (in ground)	secondary	4.90e-02	7.34e-03
Invar	Pyrite (FeS2, ore)	secondary	3.94e-02	5.89e-03
Steel Prod., cold-rolled, semi-finished	Tin (Sn, ore)	secondary	2.43e-02	3.64e-03
Invar	Zinc (Zn, ore)	secondary	1.92e-02	2.87e-03
Ferrite mfg.	Zinc (Zn, ore)	secondary	1.87e-02	2.80e-03
Aluminum Prod.	Iron (Fe, ore)	secondary	1.75e-02	2.62e-03
ABS Production	Talcum (ore)	secondary	8.89e-03	1.33e-03
Steel Prod., cold-rolled, semi-finished	Raw materials (unspecified)	secondary	7.11e-03	1.06e-03
Polycarbonate Production	Sulfur (S, in ground)	secondary	5.31e-03	7.95e-04
Ferrite mfg.	Pyrite (FeS2, ore)	secondary	2.19e-03	3.27e-04
ABS Production	Potassium chloride (KCl, as K2O, in ground)	secondary	1.91e-03	2.85e-04
Polycarbonate Production	Bentonite (in ground)	secondary	1.29e-03	1.94e-04
Invar	Barium sulfate (BaSO4, in ground)	secondary	1.10e-03	1.65e-04

Table M-3. CRT LCIA Results for the Nonrenewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Nonrenewable Resource Use (kg)	% of Total
Polycarbonate Production	Iron (Fe, ore)	secondary	8.68e-04	1.30e-04
Aluminum Prod.	Copper (Cu, ore)	secondary	7.06e-04	1.06e-04
Aluminum Prod.	Bentonite (in ground)	secondary	6.62e-04	9.92e-05
Styrene-butadiene Copolymer Prod.	Iron (Fe, ore)	secondary	5.83e-04	8.73e-05
Invar	Raw materials (unspecified)	secondary	5.29e-04	7.91e-05
Invar	Bauxite (Al2O3, ore)	secondary	5.27e-04	7.90e-05
Ferrite mfg.	Raw materials (unspecified)	secondary	5.16e-04	7.72e-05
Styrene-butadiene Copolymer Prod.	Bauxite	secondary	4.80e-04	7.19e-05
ABS Production	Iron (Fe, ore)	secondary	3.81e-04	5.71e-05
Invar	Bentonite (in ground)	secondary	3.24e-04	4.85e-05
Steel Prod., cold-rolled, semi-finished	Pyrite (FeS2, ore)	secondary	3.04e-04	4.55e-05
Polycarbonate Production	Bauxite (Al2O3, ore)	secondary	2.77e-04	4.15e-05
ABS Production	Bauxite (Al2O3, ore)	secondary	2.54e-04	3.80e-05
Invar	Copper (Cu, ore)	secondary	1.61e-04	2.41e-05
Polystyrene Prod., high-impact	Bauxite	secondary	1.51e-04	2.26e-05
Polystyrene Prod., high-impact	Iron ore	secondary	1.27e-04	1.90e-05
ABS Production	Bentonite (in ground)	secondary	8.47e-05	1.27e-05
Styrene-butadiene Copolymer Prod.	Sulfur (S, in ground)	secondary	8.15e-05	1.22e-05
Aluminum Prod.	Lead (Pb, ore)	secondary	6.30e-05	9.43e-06
Styrene-butadiene Copolymer Prod.	Bentonite (in ground)	secondary	5.79e-05	8.67e-06
Steel Prod., cold-rolled, semi-finished	Uranium (U, ore)	secondary	4.27e-05	6.39e-06
Ferrite mfg.	Bentonite (in ground)	secondary	3.82e-05	5.72e-06
Ferrite mfg.	Bauxite (Al2O3, ore)	secondary	3.37e-05	5.05e-06
Polycarbonate Production	Uranium (U, ore)	secondary	3.13e-05	4.68e-06
Aluminum Prod.	Uranium (U, ore)	secondary	2.86e-05	4.28e-06
Steel Prod., cold-rolled, semi-finished	Bentonite (in ground)	secondary	1.79e-05	2.68e-06
Steel Prod., cold-rolled, semi-finished	Iron sulfate (FeSO4, ore)	secondary	1.63e-05	2.44e-06
Polycarbonate Production	Calcium sulfate (CaSO4, ore)	secondary	1.29e-05	1.94e-06
Ferrite mfg.	Uranium (U, ore)	secondary	1.23e-05	1.85e-06
Steel Prod., cold-rolled, semi-finished	Bauxite (Al2O3, ore)	secondary	1.18e-05	1.77e-06
Polycarbonate Production	Dolomite (in ground)	secondary	9.23e-06	1.38e-06
Styrene-butadiene Copolymer Prod.	Potassium chloride (KCl, as K2O, in ground)	secondary	8.69e-06	1.30e-06
Polycarbonate Production	Olivine ore	secondary	7.39e-06	1.11e-06
Lead	Uranium (U, ore)	secondary	6.08e-06	9.10e-07
Styrene-butadiene Copolymer Prod.	Calcium sulfate (CaSO4, ore)	secondary	5.79e-06	8.67e-07
Polycarbonate Production	Potassium chloride (KCl, as K2O, in ground)	secondary	5.54e-06	8.29e-07
Invar	Iron sulfate (FeSO4, ore)	secondary	4.68e-06	7.01e-07
Ferrite mfg.	Iron sulfate (FeSO4, ore)	secondary	4.57e-06	6.84e-07
Invar	Calcium sulfate (CaSO4, ore)	secondary	4.32e-06	6.47e-07
ABS Production	Dolomite (in ground)	secondary	4.24e-06	6.34e-07
ABS Production	Olivine ore	secondary	3.39e-06	5.07e-07
Styrene-butadiene Copolymer Prod.	Dolomite (in ground)	secondary	2.48e-06	3.72e-07
Polycarbonate Production	Lead (Pb, ore)	secondary	1.85e-06	2.76e-07
ABS Production	Fluorspar (CaF2, ore)	secondary	1.69e-06	2.54e-07
Styrene-butadiene Copolymer Prod.	Olivine ore	secondary	1.65e-06	2.48e-07
Invar	Sulfur (S, in ground)	secondary	1.62e-06	2.42e-07
Ferrite mfg.	Sulfur (S, in ground)	secondary	1.58e-06	2.37e-07
Invar	Borax	secondary	2.63e-07	3.94e-08
Ferrite mfg.	Borax	secondary	2.57e-07	3.85e-08
Steel Prod., cold-rolled, semi-finished	Copper (Cu, ore)	secondary	1.86e-07	2.78e-08
Ferrite mfg.	Copper (Cu, ore)	secondary	1.82e-07	2.73e-08

Table M-3. CRT LCIA Results for the Nonrenewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Nonrenewable Resource Use (kg)	% of Total
Invar	Lead (Pb, ore)	secondary	5.84e-08	8.74e-09
Steel Prod., cold-rolled, semi-finished	Lead (Pb, ore)	secondary	5.79e-08	8.67e-09
Ferrite mfg.	Lead (Pb, ore)	secondary	5.70e-08	8.53e-09
Invar	Chromium ore	secondary	3.67e-08	5.50e-09
Steel Prod., cold-rolled, semi-finished	Chromium ore	secondary	3.65e-08	5.46e-09
Ferrite mfg.	Chromium ore	secondary	3.59e-08	5.37e-09
Invar	Manganese (Mn, ore)	secondary	2.14e-08	3.20e-09
Steel Prod., cold-rolled, semi-finished	Manganese (Mn, ore)	secondary	2.13e-08	3.18e-09
Ferrite mfg.	Manganese (Mn, ore)	secondary	2.09e-08	3.13e-09
Steel Prod., cold-rolled, semi-finished	Nickel (Ni, ore)	secondary	1.24e-08	1.85e-09
Ferrite mfg.	Nickel (Ni, ore)	secondary	1.21e-08	1.82e-09
Steel Prod., cold-rolled, semi-finished	Zinc (Zn, ore)	secondary	1.35e-09	2.02e-10
Invar	Silver (Ag, ore)	secondary	9.27e-10	1.39e-10
Steel Prod., cold-rolled, semi-finished	Silver (Ag, ore)	secondary	9.20e-10	1.38e-10
Ferrite mfg.	Silver (Ag, ore)	secondary	9.05e-10	1.35e-10
Invar	Dolomite	secondary	7.26e-11	1.09e-11
Ferrite mfg.	Dolomite	secondary	7.08e-11	1.06e-11
Invar	Olivine	secondary	5.44e-11	8.15e-12
Ferrite mfg.	Olivine	secondary	5.31e-11	7.95e-12
Total Materials Processing			**2.32e+01**	**3.47e+00**
Manufacturing Life-cycle Stage				
LPG Production	Petroleum (in ground)	secondary	3.75e+02	5.61e+01
LPG Production	Natural gas (in ground)	secondary	4.51e+01	6.75e+00
LPG Production	Coal, average (in ground)	secondary	1.34e+01	2.01e+00
Fuel Oil #6 Prod.	Petroleum (in ground)	secondary	3.88e+00	5.81e-01
Natural Gas Prod.	Natural gas (in ground)	secondary	3.40e+00	5.09e-01
US electric grid	Coal, average (in ground)	model/secondary	2.86e+00	4.29e-01
Japanese Electric Grid	Coal, average (in ground)	model/secondary	2.28e+00	3.42e-01
Japanese Electric Grid	Petroleum (in ground)	model/secondary	1.29e+00	1.93e-01
Japanese Electric Grid	Natural gas	model/secondary	1.25e+00	1.87e-01
Fuel Oil #2 Prod.	Petroleum (in ground)	secondary	1.24e+00	1.85e-01
Glass/frit	Lead	primary	4.47e-01	6.70e-02
Fuel Oil #6 Prod.	Natural gas (in ground)	secondary	2.88e-01	4.31e-02
US electric grid	Natural gas	model/secondary	2.23e-01	3.34e-02
Fuel Oil #4 Prod.	Petroleum (in ground)	secondary	1.47e-01	2.19e-02
Fuel Oil #2 Prod.	Natural gas (in ground)	secondary	1.36e-01	2.04e-02
Fuel Oil #6 Prod.	Coal, average (in ground)	secondary	1.08e-01	1.62e-02
US electric grid	Petroleum (in ground)	model/secondary	6.07e-02	9.08e-03
Glass/frit	Lead	primary	4.67e-02	6.99e-03
LPG Production	Bauxite (Al2O3, ore)	secondary	4.45e-02	6.66e-03
Fuel Oil #2 Prod.	Coal, average (in ground)	secondary	4.21e-02	6.30e-03
Natural Gas Prod.	Coal, average (in ground)	secondary	2.33e-02	3.49e-03
Fuel Oil #4 Prod.	Natural gas (in ground)	secondary	1.34e-02	2.00e-03
Natural Gas Prod.	Petroleum (in ground)	secondary	8.39e-03	1.26e-03
Glass/frit	Borax	primary	8.00e-03	1.20e-03
Glass/frit	Silica	primary	5.33e-03	7.98e-04
Japanese Electric Grid	Uranium, yellowcake	model/secondary	3.04e-04	4.55e-05
LPG Production	Uranium (U, ore)	secondary	2.26e-04	3.38e-05
Fuel Oil #6 Prod.	Bauxite (Al2O3, ore)	secondary	1.50e-04	2.25e-05

Table M-3. CRT LCIA Results for the Nonrenewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Nonrenewable Resource Use (kg)	% of Total
Fuel Oil #2 Prod.	Bauxite (Al2O3, ore)	secondary	1.25e-04	1.87e-05
US electric grid	Uranium, yellowcake	model/secondary	7.74e-05	1.16e-05
Fuel Oil #4 Prod.	Bauxite (Al2O3, ore)	secondary	1.01e-05	1.52e-06
Fuel Oil #6 Prod.	Uranium (U, ore)	secondary	1.82e-06	2.73e-07
Natural Gas Prod.	Bauxite (Al2O3, ore)	secondary	8.99e-07	1.35e-07
Fuel Oil #2 Prod.	Uranium (U, ore)	secondary	7.08e-07	1.06e-07
Natural Gas Prod.	Uranium (U, ore)	secondary	4.00e-07	5.99e-08
Total Manufacturing			**4.51e+02**	**6.75e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Coal, average (in ground)	model/secondary	1.79e+02	2.69e+01
US electric grid	Natural gas	model/secondary	1.40e+01	2.09e+00
US electric grid	Petroleum (in ground)	model/secondary	3.80e+00	5.69e-01
US electric grid	Uranium, yellowcake	model/secondary	4.85e-03	7.26e-04
Total Use, Maintenance and Repair			**1.97e+02**	**2.95e+01**
End-of-life Life-cycle Stage				
CRT landfilling	Oil (in ground)	primary	3.35e-02	5.01e-03
US electric grid	Coal, average (in ground)	model/secondary	1.79e-02	2.69e-03
CRT landfilling	Natural gas (in ground)	primary	4.52e-03	6.76e-04
LPG Production	Petroleum (in ground)	secondary	3.24e-03	4.84e-04
CRT landfilling	Coal, average (in ground)	primary	3.06e-03	4.59e-04
CRT Incineration	Iron (Fe, ore)	secondary	1.76e-03	2.64e-04
CRT landfilling	Iron (Fe, ore)	primary	1.65e-03	2.46e-04
US electric grid	Natural gas	model/secondary	1.40e-03	2.10e-04
LPG Production	Natural gas (in ground)	secondary	3.89e-04	5.82e-05
US electric grid	Petroleum (in ground)	model/secondary	3.80e-04	5.69e-05
LPG Production	Coal, average (in ground)	secondary	1.16e-04	1.73e-05
CRT landfilling	Bauxite (Al2O3, ore)	primary	8.81e-07	1.32e-07
US electric grid	Uranium, yellowcake	model/secondary	4.85e-07	7.27e-08
LPG Production	Bauxite (Al2O3, ore)	secondary	3.84e-07	5.75e-08
CRT landfilling	Uranium (U, ore)	primary	4.16e-08	6.23e-09
LPG Production	Uranium (U, ore)	secondary	1.95e-09	2.91e-10
Natural Gas Prod.	Uranium (U, ore)	secondary	-2.01e-07	-3.00e-08
Natural Gas Prod.	Bauxite (Al2O3, ore)	secondary	-4.51e-07	-6.75e-08
CRT Incineration	Bauxite (Al2O3, ore)	secondary	-6.05e-06	-9.06e-07
Fuel Oil #4 Prod.	Bauxite (Al2O3, ore)	secondary	-1.09e-04	-1.63e-05
Natural Gas Prod.	Petroleum (in ground)	secondary	-4.21e-03	-6.30e-04
Natural Gas Prod.	Coal, average (in ground)	secondary	-1.17e-02	-1.75e-03
CRT Incineration	Natural gas	secondary	-9.02e-02	-1.35e-02
Fuel Oil #4 Prod.	Natural gas (in ground)	secondary	-1.44e-01	-2.15e-02
Fuel Oil #4 Prod.	Petroleum (in ground)	secondary	-1.58e+00	-2.36e-01
Natural Gas Prod.	Natural gas (in ground)	secondary	-1.71e+00	-2.55e-01
Total End-of-life			**-3.46e+00**	**-5.18e-01**
Total All Life-cycle Stages			**6.68e+02**	**1.00e+02**

Table M-4. LCD LCIA Results for the Nonrenewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Nonrenewable Resource Use (kg)	% of Total
Materials Processing Life-cycle Stage				
Natural Gas Prod.	Natural gas (in ground)	secondary	2.38e+02	6.52e+01
Steel Prod., cold-rolled, semi-finished	Iron (Fe, ore)	secondary	3.26e+00	8.94e-01
Steel Prod., cold-rolled, semi-finished	Coal, average (in ground)	secondary	1.95e+00	5.36e-01
Natural Gas Prod.	Coal, average (in ground)	secondary	1.63e+00	4.47e-01
Polycarbonate Production	Natural gas (in ground)	secondary	7.18e-01	1.97e-01
Natural Gas Prod.	Petroleum (in ground)	secondary	5.86e-01	1.61e-01
Aluminum Prod.	Bauxite (Al2O3, ore)	secondary	5.09e-01	1.40e-01
Styrene-butadiene Copolymer Prod.	Petroleum (in ground)	secondary	4.48e-01	1.23e-01
PMMA Sheet Prod.	Petroleum (in ground)	secondary	4.43e-01	1.21e-01
PMMA Sheet Prod.	Natural gas (in ground)	secondary	4.19e-01	1.15e-01
Aluminum Prod.	Coal, average (in ground)	secondary	3.66e-01	1.00e-01
Polycarbonate Production	Petroleum (in ground)	secondary	2.42e-01	6.65e-02
Steel Prod., cold-rolled, semi-finished	Petroleum (in ground)	secondary	2.40e-01	6.58e-02
Steel Prod., cold-rolled, semi-finished	Natural gas (in ground)	secondary	2.24e-01	6.16e-02
Polycarbonate Production	Coal, average (in ground)	secondary	2.18e-01	5.98e-02
Steel Prod., cold-rolled, semi-finished	Coal, lignite (in ground)	secondary	2.04e-01	5.60e-02
Styrene-butadiene Copolymer Prod.	Natural gas (in ground)	secondary	1.88e-01	5.16e-02
Aluminum Prod.	Petroleum (in ground)	secondary	1.73e-01	4.74e-02
Polycarbonate Production	Coal, lignite (in ground)	secondary	1.38e-01	3.77e-02
PET Resin Production	Petroleum (in ground)	secondary	9.30e-02	2.55e-02
Aluminum Prod.	Natural gas (in ground)	secondary	7.95e-02	2.18e-02
Aluminum Prod.	Coal, lignite (in ground)	secondary	6.80e-02	1.86e-02
PET Resin Production	Coal, average (in ground)	secondary	3.84e-02	1.05e-02
Aluminum Prod.	Pyrite (FeS2, ore)	secondary	3.75e-02	1.03e-02
PET Resin Production	Natural gas (in ground)	secondary	2.78e-02	7.64e-03
PMMA Sheet Prod.	Sulfur (S, in ground)	secondary	1.23e-02	3.37e-03
Steel Prod., cold-rolled, semi-finished	Tin (Sn, ore)	secondary	1.19e-02	3.27e-03
Aluminum Prod.	Iron (Fe, ore)	secondary	6.53e-03	1.79e-03
Steel Prod., cold-rolled, semi-finished	Raw materials (unspecified)	secondary	3.49e-03	9.56e-04
Polycarbonate Production	Sulfur (S, in ground)	secondary	2.97e-03	8.14e-04
PMMA Sheet Prod.	Dolomite (in ground)	secondary	2.07e-03	5.68e-04
Polycarbonate Production	Bentonite (in ground)	secondary	7.22e-04	1.98e-04
PMMA Sheet Prod.	Raw materials (unspecified)	secondary	5.75e-04	1.58e-04
Polycarbonate Production	Iron (Fe, ore)	secondary	4.85e-04	1.33e-04
PMMA Sheet Prod.	Iron (Fe, ore)	secondary	3.53e-04	9.68e-05
PMMA Sheet Prod.	Bauxite (Al2O3, ore)	secondary	3.07e-04	8.42e-05
Aluminum Prod.	Copper (Cu, ore)	secondary	2.63e-04	7.21e-05
Styrene-butadiene Copolymer Prod.	Iron (Fe, ore)	secondary	2.55e-04	7.00e-05
Aluminum Prod.	Bentonite (in ground)	secondary	2.47e-04	6.77e-05
Styrene-butadiene Copolymer Prod.	Bauxite	secondary	2.10e-04	5.76e-05
Polycarbonate Production	Bauxite (Al2O3, ore)	secondary	1.55e-04	4.25e-05
Steel Prod., cold-rolled, semi-finished	Pyrite (FeS2, ore)	secondary	1.49e-04	4.09e-05
PET Resin Production	Coal, lignite (in ground)	secondary	1.21e-04	3.32e-05
Natural Gas Prod.	Bauxite (Al2O3, ore)	secondary	6.28e-05	1.72e-05
Styrene-butadiene Copolymer Prod.	Sulfur (S, in ground)	secondary	3.56e-05	9.78e-06
PET Resin Production	Bauxite (Al2O3, ore)	secondary	2.90e-05	7.97e-06
Natural Gas Prod.	Uranium (U, ore)	secondary	2.79e-05	7.67e-06
PET Resin Production	Iron (Fe, ore)	secondary	2.63e-05	7.22e-06

Table M-4. LCD LCIA Results for the Nonrenewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Nonrenewable Resource Use (kg)	% of Total
Styrene-butadiene Copolymer Prod.	Bentonite (in ground)	secondary	2.53e-05	6.95e-06
Aluminum Prod.	Lead (Pb, ore)	secondary	2.35e-05	6.44e-06
PMMA Sheet Prod.	Potassium chloride (KCl, as K2O, in ground)	secondary	2.34e-05	6.42e-06
Steel Prod., cold-rolled, semi-finished	Uranium (U, ore)	secondary	2.09e-05	5.74e-06
Polycarbonate Production	Uranium (U, ore)	secondary	1.75e-05	4.79e-06
Aluminum Prod.	Uranium (U, ore)	secondary	1.07e-05	2.92e-06
Steel Prod., cold-rolled, semi-finished	Bentonite (in ground)	secondary	8.78e-06	2.41e-06
Steel Prod., cold-rolled, semi-finished	Iron sulfate (FeSO4, ore)	secondary	7.99e-06	2.19e-06
Polycarbonate Production	Calcium sulfate (CaSO4, ore)	secondary	7.22e-06	1.98e-06
Steel Prod., cold-rolled, semi-finished	Bauxite (Al2O3, ore)	secondary	5.79e-06	1.59e-06
PMMA Sheet Prod.	Fluorspar (CaF2, ore)	secondary	5.37e-06	1.47e-06
Polycarbonate Production	Dolomite (in ground)	secondary	5.16e-06	1.42e-06
Polycarbonate Production	Olivine ore	secondary	4.13e-06	1.13e-06
Styrene-butadiene Copolymer Prod.	Potassium chloride (KCl, as K2O, in ground)	secondary	3.80e-06	1.04e-06
Polycarbonate Production	Potassium chloride (KCl, as K2O, in ground)	secondary	3.09e-06	8.49e-07
PMMA Sheet Prod.	Olivine ore	secondary	3.07e-06	8.42e-07
PET Resin Production	Sulfur (S, in ground)	secondary	2.81e-06	7.72e-07
Styrene-butadiene Copolymer Prod.	Calcium sulfate (CaSO4, ore)	secondary	2.53e-06	6.95e-07
PET Resin Production	Uranium (U, ore)	secondary	1.66e-06	4.56e-07
Styrene-butadiene Copolymer Prod.	Dolomite (in ground)	secondary	1.09e-06	2.98e-07
Polycarbonate Production	Lead (Pb, ore)	secondary	1.03e-06	2.83e-07
PMMA Sheet Prod.	Bentonite (in ground)	secondary	7.67e-07	2.10e-07
Styrene-butadiene Copolymer Prod.	Olivine ore	secondary	7.23e-07	1.98e-07
PET Resin Production	Bentonite (in ground)	secondary	3.63e-07	9.96e-08
PET Resin Production	Dolomite (in ground)	secondary	3.63e-07	9.96e-08
PET Resin Production	Olivine	secondary	2.72e-07	7.47e-08
PET Resin Production	Lead (Pb, ore)	secondary	1.82e-07	4.98e-08
Steel Prod., cold-rolled, semi-finished	Copper (Cu, ore)	secondary	9.10e-08	2.50e-08
Steel Prod., cold-rolled, semi-finished	Lead (Pb, ore)	secondary	2.84e-08	7.79e-09
Steel Prod., cold-rolled, semi-finished	Chromium ore	secondary	1.79e-08	4.91e-09
Steel Prod., cold-rolled, semi-finished	Manganese (Mn, ore)	secondary	1.04e-08	2.86e-09
Steel Prod., cold-rolled, semi-finished	Nickel (Ni, ore)	secondary	6.05e-09	1.66e-09
Steel Prod., cold-rolled, semi-finished	Zinc (Zn, ore)	secondary	6.61e-10	1.81e-10
Steel Prod., cold-rolled, semi-finished	Silver (Ag, ore)	secondary	4.51e-10	1.24e-10
Total Materials Processing			**2.50e+02**	**6.86e+01**
Manufacturing Life-cycle Stage				
LPG Production	Petroleum (in ground)	secondary	1.80e+01	4.93e+00
Japanese Electric Grid	Coal, average (in ground)	model/secondary	7.68e+00	2.11e+00
Natural Gas Prod.	Natural gas (in ground)	secondary	5.36e+00	1.47e+00
Japanese Electric Grid	Petroleum (in ground)	model/secondary	4.33e+00	1.19e+00
Japanese Electric Grid	Natural gas	model/secondary	4.20e+00	1.15e+00
LPG Production	Natural gas (in ground)	secondary	2.16e+00	5.93e-01
LPG Production	Coal, average (in ground)	secondary	6.44e-01	1.77e-01
US electric grid	Coal, average (in ground)	model/secondary	3.47e-01	9.53e-02
Fuel Oil #4 Prod.	Petroleum (in ground)	secondary	2.26e-01	6.20e-02
Fuel Oil #6 Prod.	Petroleum (in ground)	secondary	1.32e-01	3.63e-02
Fuel Oil #2 Prod.	Petroleum (in ground)	secondary	5.77e-02	1.58e-02
Natural Gas Prod.	Coal, average (in ground)	secondary	3.67e-02	1.01e-02
US electric grid	Natural gas	model/secondary	2.71e-02	7.43e-03
Fuel Oil #4 Prod.	Natural gas (in ground)	secondary	2.06e-02	5.64e-03
Natural Gas Prod.	Petroleum (in ground)	secondary	1.32e-02	3.63e-03

Table M-4. LCD LCIA Results for the Nonrenewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Nonrenewable Resource Use (kg)	% of Total
Fuel Oil #6 Prod.	Natural gas (in ground)	secondary	9.80e-03	2.69e-03
US electric grid	Petroleum (in ground)	model/secondary	7.36e-03	2.02e-03
Fuel Oil #2 Prod.	Natural gas (in ground)	secondary	6.35e-03	1.74e-03
Fuel Oil #6 Prod.	Coal, average (in ground)	secondary	3.69e-03	1.01e-03
LPG Production	Bauxite (Al2O3, ore)	secondary	2.13e-03	5.85e-04
Fuel Oil #2 Prod.	Coal, average (in ground)	secondary	1.96e-03	5.39e-04
Japanese Electric Grid	Uranium, yellowcake	model/secondary	1.02e-03	2.80e-04
Panel components	Borax	primary	9.13e-05	2.51e-05
Fuel Oil #4 Prod.	Bauxite (Al2O3, ore)	secondary	1.56e-05	4.29e-06
LPG Production	Uranium (U, ore)	secondary	1.08e-05	2.97e-06
US electric grid	Uranium, yellowcake	model/secondary	9.39e-06	2.58e-06
Fuel Oil #2 Prod.	Bauxite (Al2O3, ore)	secondary	5.82e-06	1.60e-06
Fuel Oil #6 Prod.	Bauxite (Al2O3, ore)	secondary	5.12e-06	1.41e-06
Natural Gas Prod.	Bauxite (Al2O3, ore)	secondary	1.42e-06	3.89e-07
Natural Gas Prod.	Uranium (U, ore)	secondary	6.31e-07	1.73e-07
Fuel Oil #6 Prod.	Uranium (U, ore)	secondary	6.21e-08	1.70e-08
Fuel Oil #2 Prod.	Uranium (U, ore)	secondary	3.31e-08	9.07e-09
Total Manufacturing			**4.33e+01**	**1.19e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Coal, average (in ground)	model/secondary	6.69e+01	1.84e+01
US electric grid	Natural gas	model/secondary	5.22e+00	1.43e+00
US electric grid	Petroleum (in ground)	model/secondary	1.42e+00	3.89e-01
US electric grid	Uranium, yellowcake	model/secondary	1.81e-03	4.97e-04
Total Use, Maintenance and Repair			**7.36e+01**	**2.02e+01**
End-of-life Life-cycle Stage				
US electric grid	Coal, average (in ground)	model/secondary	1.27e-02	3.49e-03
LCD landfilling	Oil (in ground)	primary	8.06e-03	2.21e-03
LPG Production	Petroleum (in ground)	secondary	1.48e-03	4.05e-04
LCD landfilling	Natural gas (in ground)	primary	1.09e-03	2.98e-04
US electric grid	Natural gas	model/secondary	9.91e-04	2.72e-04
LCD landfilling	Coal, average (in ground)	primary	7.38e-04	2.02e-04
LCD landfilling	Iron (Fe, ore)	primary	3.96e-04	1.09e-04
LCD incineration	Iron (Fe, ore)	secondary	3.07e-04	8.43e-05
US electric grid	Petroleum (in ground)	model/secondary	2.69e-04	7.39e-05
LPG Production	Natural gas (in ground)	secondary	1.78e-04	4.87e-05
LPG Production	Coal, average (in ground)	secondary	5.28e-05	1.45e-05
US electric grid	Uranium, yellowcake	model/secondary	3.44e-07	9.43e-08
LCD landfilling	Bauxite (Al2O3, ore)	primary	2.12e-07	5.82e-08
LPG Production	Bauxite (Al2O3, ore)	secondary	1.75e-07	4.81e-08
LCD landfilling	Uranium (U, ore)	primary	1.00e-08	2.75e-09
LPG Production	Uranium (U, ore)	secondary	8.88e-10	2.44e-10
Natural Gas Prod.	Uranium (U, ore)	secondary	-1.32e-07	-3.63e-08
Natural Gas Prod.	Bauxite (Al2O3, ore)	secondary	-2.98e-07	-8.16e-08
LCD incineration	Bauxite (Al2O3, ore)	secondary	-4.37e-06	-1.20e-06
Fuel Oil #4 Prod.	Bauxite (Al2O3, ore)	secondary	-7.20e-05	-1.98e-05
Natural Gas Prod.	Petroleum (in ground)	secondary	-2.78e-03	-7.62e-04
Natural Gas Prod.	Coal, average (in ground)	secondary	-7.71e-03	-2.12e-03
LCD incineration	Natural gas	secondary	-5.85e-02	-1.60e-02
Fuel Oil #4 Prod.	Natural gas (in ground)	secondary	-9.48e-02	-2.60e-02
Fuel Oil #4 Prod.	Petroleum (in ground)	secondary	-1.04e+00	-2.86e-01

Table M-4. LCD LCIA Results for the Nonrenewable Resource Use Impact Category

Process Group	Material	LCI Data Type	Nonrenewable Resource Use (kg)	% of Total
Natural Gas Prod.	Natural gas (in ground)	secondary	-1.13e+00	-3.09e-01
Total End-of-Life			**-2.30e+00**	**-6.32e-01**
Total All Life-cycle Stages			**3.64e+02**	**1.00e+02**

Table M-5. CRT LCIA Results for the Energy Use Impact Category

Process Group	Material	LCI Data Type	Energy Use (MJ)	% of Total
Materials Processing Life-cycle Stage				
Polycarbonate Production	Natural gas (in ground)	secondary	3.42e+01	1.64e-01
Aluminum Prod.	Coal, average (in ground)	secondary	2.20e+01	1.05e-01
Steel Prod., cold-rolled, semi-finished	Petroleum (in ground)	secondary	2.10e+01	1.01e-01
Steel Prod., cold-rolled, semi-finished	Natural gas (in ground)	secondary	2.04e+01	9.79e-02
Aluminum Prod.	Electricity	secondary	2.03e+01	9.76e-02
Aluminum Prod.	Petroleum (in ground)	secondary	1.99e+01	9.54e-02
Styrene-butadiene Copolymer Prod.	Natural gas (in ground)	secondary	1.91e+01	9.19e-02
Steel Prod., cold-rolled, semi-finished	Electricity	secondary	1.81e+01	8.71e-02
Invar	Petroleum (in ground)	secondary	1.59e+01	7.64e-02
Invar	Natural gas (in ground)	secondary	1.56e+01	7.50e-02
Polycarbonate Production	Electricity	secondary	1.39e+01	6.68e-02
Steel Prod., cold-rolled, semi-finished	Coal, average (in ground)	secondary	1.08e+01	5.19e-02
Aluminum Prod.	Natural gas (in ground)	secondary	9.51e+00	4.57e-02
Polycarbonate Production	Petroleum (in ground)	secondary	9.49e+00	4.56e-02
Polycarbonate Production	Coal, average (in ground)	secondary	8.73e+00	4.19e-02
ABS Production	Natural gas (in ground)	secondary	8.71e+00	4.18e-02
Invar	Electricity	secondary	8.06e+00	3.87e-02
Styrene-butadiene Copolymer Prod.	Petroleum (in ground)	secondary	8.04e+00	3.86e-02
Lead	Natural gas (in ground)	secondary	6.96e+00	3.34e-02
Steel Prod., cold-rolled, semi-finished	Uranium (U, ore)	secondary	6.44e+00	3.09e-02
Lead	Coal, average (in ground)	secondary	6.43e+00	3.08e-02
Steel Prod., cold-rolled, semi-finished	Coal, lignite (in ground)	secondary	6.17e+00	2.96e-02
ABS Production	Petroleum (in ground)	secondary	5.91e+00	2.84e-02
Ferrite mfg.	Natural gas (in ground)	secondary	5.51e+00	2.64e-02
Polycarbonate Production	Uranium (U, ore)	secondary	4.72e+00	2.27e-02
Ferrite mfg.	Electricity	secondary	4.43e+00	2.13e-02
Aluminum Prod.	Uranium (U, ore)	secondary	4.32e+00	2.07e-02
Polycarbonate Production	Coal, lignite (in ground)	secondary	3.65e+00	1.75e-02
Lead	Electricity	secondary	3.14e+00	1.51e-02
ABS Production	Electricity	secondary	3.00e+00	1.44e-02
Polystyrene Prod., high-impact	Natural gas (in ground)	secondary	2.81e+00	1.35e-02
Aluminum Prod.	Coal, lignite (in ground)	secondary	2.71e+00	1.30e-02
Lead	Petroleum (in ground)	secondary	2.69e+00	1.29e-02
Ferrite mfg.	Coal, average (in ground)	secondary	2.39e+00	1.15e-02
Ferrite mfg.	Petroleum (in ground)	secondary	2.10e+00	1.01e-02
Ferrite mfg.	Coal, lignite (in ground)	secondary	1.90e+00	9.12e-03
Ferrite mfg.	Uranium (U, ore)	secondary	1.86e+00	8.93e-03
Polystyrene Prod., high-impact	Petroleum (in ground)	secondary	1.61e+00	7.72e-03
Styrene-butadiene Copolymer Prod.	Electricity	secondary	1.39e+00	6.67e-03
Lead	Uranium (U, ore)	secondary	9.17e-01	4.40e-03
Polystyrene Prod., high-impact	Electricity	secondary	7.29e-01	3.50e-03
Total Materials Processing			**3.66e+02**	**1.75e+00**
Manufacturing Life-cycle Stage				
Glass/frit	Liquified petroleum gas ("propane")	primary	1.51e+04	7.23e+01
LPG Production	Natural gas (in ground)	secondary	2.01e+03	9.63e+00
LPG Production	Petroleum (in ground)	secondary	4.10e+02	1.97e+00
LPG Production	Coal, average (in ground)	secondary	3.00e+02	1.44e+00
CRT tube mfg.	Fuel oil #6	primary	1.51e+02	7.23e-01
Glass/frit	Natural gas	primary	5.41e+01	2.60e-01
Glass/frit	Fuel oil #2	primary	5.06e+01	2.43e-01

Table M-5. CRT LCIA Results for the Energy Use Impact Category

Process Group	Material	LCI Data Type	Energy Use (MJ)	% of Total
Glass/frit	Elec-nonlink	primary	4.75e+01	2.28e-01
CRT tube mfg.	Natural gas	primary	3.73e+01	1.79e-01
LPG Production	Uranium (U, ore)	secondary	3.40e+01	1.63e-01
CRT tube mfg.	Elec-nonlink	primary	3.19e+01	1.53e-01
Glass/frit	Elec-nonlink	primary	2.65e+01	1.27e-01
PWB Mfg.	Natural gas	model/secondary	1.74e+01	8.34e-02
CRT tube mfg.	LNG	primary	1.72e+01	8.26e-02
CRT monitor assembly	Elec-nonlink	primary	1.33e+01	6.37e-02
Fuel Oil #6 Prod.	Natural gas (in ground)	secondary	1.28e+01	6.15e-02
PWB Mfg.	Elec-nonlink	model/secondary	1.00e+01	4.82e-02
Fuel Oil #2 Prod.	Natural gas (in ground)	secondary	6.06e+00	2.91e-02
Natural Gas Prod.	Natural gas (in ground)	secondary	5.83e+00	2.80e-02
Fuel Oil #6 Prod.	Petroleum (in ground)	secondary	5.78e+00	2.78e-02
Monitor/module	Fuel oil #4	primary	5.76e+00	2.77e-02
Fuel Oil #6 Prod.	Coal, average (in ground)	secondary	2.42e+00	1.16e-02
Fuel Oil #2 Prod.	Coal, average (in ground)	secondary	9.41e-01	4.51e-03
Fuel Oil #4 Prod.	Natural gas (in ground)	secondary	5.95e-01	2.85e-03
Fuel Oil #2 Prod.	Petroleum (in ground)	secondary	5.78e-01	2.77e-03
Natural Gas Prod.	Coal, average (in ground)	secondary	5.21e-01	2.50e-03
Natural Gas Prod.	Petroleum (in ground)	secondary	3.60e-01	1.73e-03
Fuel Oil #6 Prod.	Uranium (U, ore)	secondary	2.75e-01	1.32e-03
Fuel Oil #4 Prod.	Petroleum (in ground)	secondary	2.14e-01	1.03e-03
Fuel Oil #2 Prod.	Uranium (U, ore)	secondary	1.07e-01	5.13e-04
Natural Gas Prod.	Uranium (U, ore)	secondary	6.04e-02	2.90e-04
Total Manufacturing			**1.83e+04**	**8.79e+01**
Use, Maintenance and Repair Life-cycle Stage				
CRT monitor use	Elec-nonlink	primary	2.29e+03	1.10e+01
Total Use, Maintenance and Repair			**2.29e+03**	**1.10e+01**
End-of-life Manufacturing Stage				
CRT landfilling	Fuel oil #4	primary	8.13e-01	3.90e-03
CRT landfilling	Natural gas	primary	7.71e-01	3.70e-03
CRT Recycling	Elec-nonlink	primary	2.29e-01	1.10e-03
CRT Recycling	Liquified petroleum gas ("propane")	primary	1.30e-01	6.24e-04
LPG Production	Natural gas (in ground)	secondary	1.73e-02	8.32e-05
LPG Production	Petroleum (in ground)	secondary	3.54e-03	1.70e-05
LPG Production	Coal, average (in ground)	secondary	2.59e-03	1.24e-05
LPG Production	Uranium (U, ore)	secondary	2.94e-04	1.41e-06
Natural Gas Prod.	Uranium (U, ore)	secondary	-3.03e-02	-1.45e-04
Natural Gas Prod.	Petroleum (in ground)	secondary	-1.81e-01	-8.67e-04
Natural Gas Prod.	Coal, average (in ground)	secondary	-2.61e-01	-1.25e-03
Fuel Oil #4 Prod.	Petroleum (in ground)	secondary	-2.30e+00	-1.10e-02
Natural Gas Prod.	Natural gas (in ground)	secondary	-2.92e+00	-1.40e-02
Fuel Oil #4 Prod.	Natural gas (in ground)	secondary	-6.39e+00	-3.07e-02
CRT Incineration	Natural gas	secondary	-5.88e+01	-2.82e-01
CRT Incineration	Fuel oil #4	secondary	-5.88e+01	-2.82e-01
Total End-of-life			**-1.28e+02**	**-6.13e-01**
Total All Life-cycle Stages			**2.08e+04**	**1.00e+02**

Table M-6. LCD LCIA Results for the Energy Use Impact Category

Process Group	Material	LCI Data Type	Energy Use (MJ)	% of Total
Materials processing Life-cycle Stage				
Natural Gas Prod.	Natural gas (in ground)	secondary	4.07e+02	1.43e+01
Natural Gas Prod.	Coal, average (in ground)	secondary	3.64e+01	1.28e+00
Natural Gas Prod.	Petroleum (in ground)	secondary	2.52e+01	8.86e-01
Polycarbonate Production	Natural gas (in ground)	secondary	1.91e+01	6.72e-01
PMMA Sheet Prod.	Petroleum (in ground)	secondary	1.18e+01	4.17e-01
PMMA Sheet Prod.	Natural gas (in ground)	secondary	1.16e+01	4.09e-01
Steel Prod., cold-rolled, semi-finished	Petroleum (in ground)	secondary	1.03e+01	3.63e-01
Steel Prod., cold-rolled, semi-finished	Natural gas (in ground)	secondary	9.99e+00	3.52e-01
PMMA Sheet Prod.	Electricity	secondary	8.96e+00	3.16e-01
Steel Prod., cold-rolled, semi-finished	Electricity	secondary	8.89e+00	3.13e-01
Styrene-butadiene Copolymer Prod.	Natural gas (in ground)	secondary	8.37e+00	2.95e-01
Aluminum Prod.	Coal, average (in ground)	secondary	8.18e+00	2.88e-01
Polycarbonate Production	Electricity	secondary	7.77e+00	2.74e-01
Aluminum Prod.	Electricity	secondary	7.57e+00	2.67e-01
Aluminum Prod.	Petroleum (in ground)	secondary	7.40e+00	2.61e-01
Polycarbonate Production	Petroleum (in ground)	secondary	5.30e+00	1.87e-01
Steel Prod., cold-rolled, semi-finished	Coal, average (in ground)	secondary	5.30e+00	1.87e-01
Polycarbonate Production	Coal, average (in ground)	secondary	4.87e+00	1.72e-01
Natural Gas Prod.	Uranium (U, ore)	secondary	4.22e+00	1.48e-01
Aluminum Prod.	Natural gas (in ground)	secondary	3.54e+00	1.25e-01
Styrene-butadiene Copolymer Prod.	Petroleum (in ground)	secondary	3.51e+00	1.24e-01
Steel Prod., cold-rolled, semi-finished	Uranium (U, ore)	secondary	3.16e+00	1.11e-01
Steel Prod., cold-rolled, semi-finished	Coal, lignite (in ground)	secondary	3.02e+00	1.07e-01
Polycarbonate Production	Uranium (U, ore)	secondary	2.64e+00	9.28e-02
Polycarbonate Production	Coal, lignite (in ground)	secondary	2.04e+00	7.18e-02
Aluminum Prod.	Uranium (U, ore)	secondary	1.61e+00	5.66e-02
PET Resin Production	Petroleum (in ground)	secondary	1.57e+00	5.54e-02
Aluminum Prod.	Coal, lignite (in ground)	secondary	1.01e+00	3.55e-02
PET Resin Production	Coal, average (in ground)	secondary	8.58e-01	3.02e-02
PET Resin Production	Electricity	secondary	7.72e-01	2.72e-02
Styrene-butadiene Copolymer Prod.	Electricity	secondary	6.07e-01	2.14e-02
PET Resin Production	Natural gas (in ground)	secondary	3.16e-01	1.11e-02
PET Resin Production	Uranium (U, ore)	secondary	2.51e-01	8.82e-03
PET Resin Production	Coal, lignite (in ground)	secondary	1.79e-03	6.32e-05
Total Materials Processing			**6.33e+02**	**2.23e+01**
Manufacturing Life-cycle Stage				
LCD glass mfg.	Liquified petroleum gas ("propane")	primary	6.98e+02	2.46e+01
Monitor/module	Elec-nonlink	primary	2.54e+02	8.93e+00
Monitor/module	LNG	primary	1.65e+02	5.81e+00
LPG Production	Natural gas (in ground)	secondary	9.63e+01	3.39e+00
Panel components	Elec-nonlink	primary	4.08e+01	1.44e+00
Monitor/module	Natural gas	primary	3.77e+01	1.33e+00
Monitor/module	Liquified petroleum gas ("propane")	primary	2.50e+01	8.81e-01
LPG Production	Petroleum (in ground)	secondary	1.97e+01	6.93e-01
LPG Production	Coal, average (in ground)	secondary	1.44e+01	5.07e-01
Monitor/module	Kerosene	primary	1.31e+01	4.60e-01
Natural Gas Prod.	Natural gas (in ground)	secondary	9.19e+00	3.24e-01
Monitor/module	Fuel oil #4	primary	8.88e+00	3.13e-01
PWB Mfg.	Natural gas	model/secondary	7.67e+00	2.70e-01

Table M-6. LCD LCIA Results for the Energy Use Impact Category

Process Group	Material	LCI Data Type	Energy Use (MJ)	% of Total
Panel components	Kerosene	primary	7.36e+00	2.59e-01
Panel components	Elec-nonlink	primary	5.13e+00	1.81e-01
Panel components	Fuel oil #6	primary	5.13e+00	1.81e-01
Monitor/module	Elec-nonlink	primary	4.92e+00	1.73e-01
PWB Mfg.	Elec-nonlink	model/secondary	4.43e+00	1.56e-01
Panel components	Natural gas	primary	3.85e+00	1.35e-01
Backlight	Elec-nonlink	primary	2.62e+00	9.23e-02
LCD glass mfg.	Natural gas	primary	2.50e+00	8.82e-02
LCD glass mfg.	Fuel oil #2	primary	2.34e+00	8.26e-02
LCD glass mfg.	Elec-nonlink	primary	2.20e+00	7.75e-02
LPG Production	Uranium (U, ore)	secondary	1.63e+00	5.75e-02
Backlight	Elec-nonlink	primary	1.24e+00	4.36e-02
Fuel Oil #4 Prod.	Natural gas (in ground)	secondary	9.16e-01	3.23e-02
Natural Gas Prod.	Coal, average (in ground)	secondary	8.21e-01	2.89e-02
Backlight	Elec-nonlink	primary	6.01e-01	2.12e-02
Natural Gas Prod.	Petroleum (in ground)	secondary	5.68e-01	2.00e-02
Panel components	Elec-nonlink	primary	5.04e-01	1.77e-02
Fuel Oil #6 Prod.	Natural gas (in ground)	secondary	4.36e-01	1.54e-02
Fuel Oil #4 Prod.	Petroleum (in ground)	secondary	3.30e-01	1.16e-02
Fuel Oil #2 Prod.	Natural gas (in ground)	secondary	2.83e-01	9.96e-03
Fuel Oil #6 Prod.	Petroleum (in ground)	secondary	1.97e-01	6.93e-03
Panel components	Steam (100 psig)	primary	1.04e-01	3.66e-03
Natural Gas Prod.	Uranium (U, ore)	secondary	9.51e-02	3.35e-03
Fuel Oil #6 Prod.	Coal, average (in ground)	secondary	8.24e-02	2.90e-03
Fuel Oil #2 Prod.	Coal, average (in ground)	secondary	4.39e-02	1.55e-03
Fuel Oil #2 Prod.	Petroleum (in ground)	secondary	2.70e-02	9.50e-04
Panel components	Fuel oil #2	primary	1.78e-02	6.25e-04
Fuel Oil #6 Prod.	Uranium (U, ore)	secondary	9.37e-03	3.30e-04
Fuel Oil #2 Prod.	Uranium (U, ore)	secondary	4.99e-03	1.76e-04
Backlight	LNG	primary	2.14e-04	7.53e-06
Backlight	Natural gas	primary	1.85e-04	6.53e-06
Panel components	Natural gas	primary	5.24e-06	1.85e-07
Total Manufacturing			**1.44e+03**	**5.06e+01**
Use, Maintenance and Repair Life-cycle Stage				
LCD monitor use	Elec-nonlink	primary	8.53e+02	3.00e+01
Total use, Maintenance and Repair			**8.53e+02**	**3.00e+01**
End-of-life Life-cycle Stage				
LCD landfilling	Fuel oil #4	primary	1.96e-01	6.90e-03
LCD landfilling	Natural gas	primary	1.86e-01	6.54e-03
LCD recycling	Elec-nonlink	primary	1.62e-01	5.70e-03
LCD recycling	Liquified petroleum gas ("propane")	primary	5.93e-02	2.09e-03
LPG Production	Natural gas (in ground)	secondary	7.91e-03	2.78e-04
LPG Production	Petroleum (in ground)	secondary	1.61e-03	5.69e-05
LPG Production	Coal, average (in ground)	secondary	1.18e-03	4.16e-05
LPG Production	Uranium (U, ore)	secondary	1.34e-04	4.72e-06
Natural Gas Prod.	Uranium (U, ore)	secondary	-2.00e-02	-7.04e-04
Natural Gas Prod.	Petroleum (in ground)	secondary	-1.19e-01	-4.20e-03
Natural Gas Prod.	Coal, average (in ground)	secondary	-1.72e-01	-6.07e-03
Fuel Oil #4 Prod.	Petroleum (in ground)	secondary	-1.52e+00	-5.35e-02
Natural Gas Prod.	Natural gas (in ground)	secondary	-1.93e+00	-6.80e-02
Fuel Oil #4 Prod.	Natural gas (in ground)	secondary	-4.22e+00	-1.49e-01

Table M-6. LCD LCIA Results for the Energy Use Impact Category

Process Group	Material	LCI Data Type	Energy Use (MJ)	% of Total
LCD incineration	Natural gas	secondary	-3.85e+01	-1.36e+00
LCD incineration	Fuel oil #4	secondary	-3.85e+01	-1.36e+00
Total End-of-life			**-8.44e+01**	**-2.97e+00**
Total All Life-cycle Stages			**2.84e+03**	**1.00e+02**

Table M-7. CRT LCIA Results for the Solid Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Solid Waste Landfill Use (m3)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Unspecified solid waste	secondary	1.09e-02	6.56e+00
Steel Prod., cold-rolled, semi-finished	Mining waste	secondary	6.41e-04	3.85e-01
Invar	Mining waste	secondary	1.82e-04	1.09e-01
Ferrite mfg.	Mining waste	secondary	1.77e-04	1.06e-01
Steel Prod., cold-rolled, semi-finished	Mineral waste	secondary	6.34e-05	3.81e-02
Polycarbonate Production	Mineral waste	secondary	5.41e-05	3.25e-02
Steel Prod., cold-rolled, semi-finished	Mixed industrial (waste)	secondary	4.50e-05	2.70e-02
Invar	Unspecified solid waste	secondary	3.53e-05	2.12e-02
Ferrite mfg.	Unspecified solid waste	secondary	3.45e-05	2.07e-02
Steel Prod., cold-rolled, semi-finished	Slag and ash	secondary	1.83e-05	1.10e-02
Invar	Mineral waste	secondary	1.82e-05	1.09e-02
Polycarbonate Production	Slag and ash	secondary	1.80e-05	1.08e-02
Ferrite mfg.	Mineral waste	secondary	1.78e-05	1.07e-02
ABS Production	Mineral waste	secondary	1.27e-05	7.64e-03
ABS Production	Unspecified solid waste	secondary	1.09e-05	6.57e-03
Polycarbonate Production	Mixed industrial (waste)	secondary	9.93e-06	5.96e-03
Invar	Slag and ash	secondary	5.24e-06	3.15e-03
Ferrite mfg.	Slag and ash	secondary	5.12e-06	3.07e-03
Styrene-butadiene Copolymer Prod.	Mineral waste	secondary	4.52e-06	2.72e-03
ABS Production	Non toxic chemical waste (unspecified)	secondary	3.21e-06	1.93e-03
ABS Production	Slag and ash	secondary	2.68e-06	1.61e-03
ABS Production	Mixed industrial (waste)	secondary	2.22e-06	1.34e-03
Steel Prod., cold-rolled, semi-finished	Non toxic chemical waste (unspecified)	secondary	2.02e-06	1.21e-03
Polycarbonate Production	Non toxic chemical waste (unspecified)	secondary	1.79e-06	1.08e-03
Polystyrene Prod., high-impact	Mineral waste	secondary	1.59e-06	9.56e-04
Styrene-butadiene Copolymer Prod.	Non toxic chemical waste (unspecified)	secondary	1.35e-06	8.09e-04
Invar	Mixed industrial (waste)	secondary	1.16e-06	6.96e-04
Ferrite mfg.	Mixed industrial (waste)	secondary	1.13e-06	6.80e-04
Styrene-butadiene Copolymer Prod.	Slag and ash	secondary	1.09e-06	6.54e-04
Styrene-butadiene Copolymer Prod.	Mixed industrial (waste)	secondary	1.00e-06	6.03e-04
Polystyrene Prod., high-impact	Non toxic chemical waste (unspecified)	secondary	6.74e-07	4.05e-04
Polystyrene Prod., high-impact	Mixed industrial (waste)	secondary	4.16e-07	2.50e-04
Aluminum Prod.	Calcium	secondary	3.72e-07	2.23e-04
Polystyrene Prod., high-impact	Slag and ash	secondary	3.66e-07	2.20e-04
Styrene-butadiene Copolymer Prod.	Unspecified solid waste	secondary	2.62e-07	1.57e-04
Invar	Calcium	secondary	1.79e-07	1.07e-04
Polycarbonate Production	Unspecified solid waste	secondary	1.09e-07	6.55e-05
Lead	Calcium	secondary	9.31e-08	5.59e-05
Steel Prod., cold-rolled, semi-finished	Sewage sludge (unspecified)	secondary	6.64e-08	3.99e-05
Aluminum Prod.	Carbon	secondary	5.48e-08	3.29e-05
Steel Prod., cold-rolled, semi-finished	Waste oil	secondary	5.37e-08	3.23e-05
Steel Prod., cold-rolled, semi-finished	Non mineral waste (inert)	secondary	4.46e-08	2.68e-05
Ferrite mfg.	Calcium	secondary	3.41e-08	2.05e-05
Steel Prod., cold-rolled, semi-finished	Calcium	secondary	3.02e-08	1.81e-05
Invar	Carbon	secondary	2.62e-08	1.57e-05

Table M-7. CRT LCIA Results for the Solid Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Solid Waste Landfill Use (m3)	% of Total
Aluminum Prod.	Waste oil	secondary	2.25e-08	1.35e-05
Polystyrene Prod., high-impact	Unspecified solid waste	secondary	2.02e-08	1.21e-05
Invar	Non toxic chemical waste (unspecified)	secondary	1.54e-08	9.25e-06
Ferrite mfg.	Non toxic chemical waste (unspecified)	secondary	1.50e-08	9.03e-06
Lead	Carbon	secondary	1.36e-08	8.19e-06
Invar	Non mineral waste (inert)	secondary	1.08e-08	6.46e-06
Ferrite mfg.	Non mineral waste (inert)	secondary	1.05e-08	6.30e-06
Invar	Waste oil	secondary	8.51e-09	5.11e-06
Ferrite mfg.	Carbon	secondary	4.90e-09	2.94e-06
Steel Prod., cold-rolled, semi-finished	Carbon	secondary	4.32e-09	2.59e-06
Lead	Waste oil	secondary	4.30e-09	2.58e-06
Ferrite mfg.	Waste oil	secondary	2.72e-10	1.63e-07
Total Materials Processing			**1.23e-02**	**7.39e+00**
Manufacturing Life-cycle Stage				
LPG Production	Slag and ash	secondary	3.46e-02	2.08e+01
LPG Production	Unspecified waste	secondary	7.44e-03	4.47e+00
Glass/frit	Waste water treatment (WWT) sludge	primary	7.28e-03	4.37e+00
CRT tube mfg.	Waste water treatment (WWT) sludge	primary	2.37e-03	1.42e+00
LPG Production	Mixed industrial (waste)	secondary	1.24e-03	7.47e-01
US electric grid	Coal waste	model/secondary	1.01e-03	6.09e-01
Japanese Electric Grid	Coal waste	model/secondary	8.10e-04	4.86e-01
US electric grid	Dust/sludge	model/secondary	3.14e-04	1.89e-01
Fuel Oil #6 Prod.	Slag and ash	secondary	2.79e-04	1.68e-01
US electric grid	Fly/bottom ash	model/secondary	2.54e-04	1.52e-01
Japanese Electric Grid	Dust/sludge	model/secondary	2.51e-04	1.50e-01
Japanese Electric Grid	Fly/bottom ash	model/secondary	2.02e-04	1.22e-01
Fuel Oil #2 Prod.	Slag and ash	secondary	1.09e-04	6.52e-02
Natural Gas Prod.	Slag and ash	secondary	6.01e-05	3.61e-02
Fuel Oil #6 Prod.	Unspecified waste	secondary	6.00e-05	3.60e-02
Fuel Oil #2 Prod.	Unspecified waste	secondary	2.33e-05	1.40e-02
Natural Gas Prod.	Unspecified waste	secondary	1.29e-05	7.76e-03
Fuel Oil #4 Prod.	Slag and ash	secondary	1.16e-05	6.96e+00
Glass/frit	Potassium Carbonate	primary	1.08e-05	6.48e-03
CRT tube mfg.	Wood, average	primary	9.89e-06	5.94e-03
Glass/frit	Sodium Carbonate	primary	9.74e-06	5.85e-03
Glass/frit	CRT glass, faceplate	primary	9.73e-06	5.84e-03
Glass/frit	Unspecified sludge	primary	7.69e-06	4.62e-03
CRT tube mfg.	Sludge (phosphor)	primary	4.31e-06	2.59e-03
Fuel Oil #6 Prod.	Mixed industrial (waste)	secondary	4.23e-06	2.54e-03
Fuel Oil #2 Prod.	Mixed industrial (waste)	secondary	3.49e-06	2.10e-03
Fuel Oil #4 Prod.	Unspecified waste	secondary	2.49e-06	1.49e-03
CRT tube mfg.	Sludge (aquadag)	primary	2.22e-06	1.34e-03
LPG Production	Non toxic chemical waste (unspecified)	secondary	1.35e-06	8.13e-04
LPG Production	Mineral waste	secondary	1.01e-06	6.07e-04
Glass/frit	Waste refractory	primary	9.52e-07	5.72e-04
Glass/frit	blasting media	primary	8.16e-07	4.90e-04
Glass/frit	Oily rags & filter media	primary	7.25e-07	4.36e-04

Table M-7. CRT LCIA Results for the Solid Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Solid Waste Landfill Use (m3)	% of Total
Glass/frit	Plating process sludge	primary	2.98e-07	1.79e-04
Fuel Oil #4 Prod.	Mixed industrial (waste)	secondary	2.84e-07	1.71e-04
Glass/frit	acid absorbent	primary	1.02e-07	6.11e-05
Natural Gas Prod.	Mixed industrial (waste)	secondary	2.51e-08	1.51e-05
Fuel Oil #6 Prod.	Non toxic chemical waste (unspecified)	secondary	4.58e-09	2.75e-06
Fuel Oil #2 Prod.	Non toxic chemical waste (unspecified)	secondary	3.80e-09	2.28e-06
Fuel Oil #6 Prod.	Mineral waste	secondary	3.42e-09	2.05e-06
Fuel Oil #2 Prod.	Mineral waste	secondary	2.84e-09	1.70e-06
Fuel Oil #4 Prod.	Non toxic chemical waste (unspecified)	secondary	3.09e-10	1.85e-07
Fuel Oil #4 Prod.	Mineral waste	secondary	2.30e-10	1.38e-07
Natural Gas Prod.	Non toxic chemical waste (unspecified)	secondary	2.74e-11	1.64e-08
Natural Gas Prod.	Mineral waste	secondary	2.04e-11	1.23e-08
Total Manufacturing			**5.64e-02**	**3.39e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Coal waste	model/secondary	6.35e-02	3.82e+01
US electric grid	Dust/sludge	model/secondary	1.97e-02	1.18e+01
US electric grid	Fly/bottom ash	model/secondary	1.59e-02	9.54e+00
Total Use, Maintenance and Repair			**9.91e-02**	**5.95e+01**
End-of-life Life-cycle Stage				
CRT landfilling	EOL CRT Monitor, landfilled	primary	8.31e-03	4.99e+00
US electric grid	Coal waste	model/secondary	6.36e-06	3.82e-03
CRT landfilling	Unspecified solid waste	primary	4.34e-06	2.61e-03
CRT Incineration	Mixed industrial (waste)	secondary	2.41e-06	1.45e-03
US electric grid	Dust/sludge	model/secondary	1.97e-06	1.18e-03
US electric grid	Fly/bottom ash	model/secondary	1.59e-06	9.54e-04
LPG Production	Slag and ash	secondary	2.99e-07	1.79e-04
LPG Production	Unspecified waste	secondary	6.42e-08	3.85e-05
LPG Production	Mixed industrial (waste)	secondary	1.07e-08	6.44e-06
LPG Production	Non toxic chemical waste (unspecified)	secondary	1.17e-11	7.01e-09
LPG Production	Mineral waste	secondary	8.72e-12	5.24e-09
Natural Gas Prod.	Mineral waste	secondary	-1.02e-11	-6.15e-09
Natural Gas Prod.	Non toxic chemical waste (unspecified)	secondary	-1.37e-11	-8.24e-09
CRT Incineration	Mineral waste	secondary	-1.59e-10	-9.55e-08
CRT Incineration	Non toxic chemical waste (unspecified)	secondary	-2.13e-10	-1.28e-07
Fuel Oil #4 Prod.	Mineral waste	secondary	-2.48e-09	-1.49e-06
Fuel Oil #4 Prod.	Non toxic chemical waste (unspecified)	secondary	-3.32e-09	-1.99e-06
CRT Incineration	Mining waste	secondary	-4.23e-09	-2.54e-06
Natural Gas Prod.	Mixed industrial (waste)	secondary	-1.26e-08	-7.57e-06
Fuel Oil #4 Prod.	Mixed industrial (waste)	secondary	-3.05e-06	-1.83e-03
Natural Gas Prod.	Unspecified waste	secondary	-6.48e-06	-3.89e-03
Fuel Oil #4 Prod.	Unspecified waste	secondary	-2.67e-05	-1.61e-02
Natural Gas Prod.	Slag and ash	secondary	-3.01e-05	-1.81e-02
Fuel Oil #4 Prod.	Slag and ash	secondary	-1.25e-04	-7.48e-02

Table M-7. CRT LCIA Results for the Solid Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Solid Waste Landfill Use (m3)	% of Total
CRT Incineration	Unspecified solid waste	secondary	-1.76e-03	-1.06e+00
CRT Incineration	Slag and ash	secondary	-7.70e-03	-4.62e+00
Total End-of-life			**-1.32e-03**	**-7.95e-01**
Total All Life-cycle Stages	Total		**1.67e-01**	**1.00e+02**

Table M-8. LCD LCIA Results for the Solid Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Solid Waste landfill Use (m3)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Unspecified solid waste	secondary	5.36e-03	9.87e+00
Natural Gas Prod.	Slag and ash	secondary	4.20e-03	7.74e+00
Natural Gas Prod.	Unspecified waste	secondary	9.03e-04	1.66e+00
Steel Prod., cold-rolled, semi-finished	Mining waste	secondary	3.14e-04	5.79e-01
Steel Prod., cold-rolled, semi-finished	Mineral waste	secondary	3.11e-05	5.73e-02
Polycarbonate Production	Mineral waste	secondary	3.02e-05	5.56e-02
PMMA Sheet Prod.	Mixed industrial (waste)	secondary	2.45e-05	4.51e-02
Steel Prod., cold-rolled, semi-finished	Mixed industrial (waste)	secondary	2.21e-05	4.06e-02
PMMA Sheet Prod.	Mineral waste	secondary	1.99e-05	3.67e-02
Polycarbonate Production	Slag and ash	secondary	1.00e-05	1.85e-02
PMMA Sheet Prod.	Non toxic chemical waste (unspecified)	secondary	9.41e-06	1.73e-02
Steel Prod., cold-rolled, semi-finished	Slag and ash	secondary	8.99e-06	1.66e-02
PMMA Sheet Prod.	Slag and ash	secondary	6.26e-06	1.15e-02
Polycarbonate Production	Mixed industrial (waste)	secondary	5.55e-06	1.02e-02
PET Resin Production	Mineral waste	secondary	2.87e-06	5.29e-03
Styrene-butadiene Copolymer Prod.	Mineral waste	secondary	1.98e-06	3.64e-03
Natural Gas Prod.	Mixed industrial (waste)	secondary	1.76e-06	3.24e-03
PET Resin Production	Slag and ash	secondary	1.24e-06	2.29e-03
Polycarbonate Production	Non toxic chemical waste (unspecified)	secondary	1.00e-06	1.84e-03
Steel Prod., cold-rolled, semi-finished	Non toxic chemical waste (unspecified)	secondary	9.88e-07	1.82e-03
PET Resin Production	Non toxic chemical waste (unspecified)	secondary	7.69e-07	1.42e-03
Styrene-butadiene Copolymer Prod.	Non toxic chemical waste (unspecified)	secondary	5.89e-07	1.09e-03
Styrene-butadiene Copolymer Prod.	Slag and ash	secondary	4.76e-07	8.77e-04
Styrene-butadiene Copolymer Prod.	Mixed industrial (waste)	secondary	4.39e-07	8.08e-04
PET Resin Production	Unspecified solid waste	secondary	3.65e-07	6.73e-04
Aluminum Prod.	Calcium	secondary	1.38e-07	2.55e-04
Styrene-butadiene Copolymer Prod.	Unspecified solid waste	secondary	1.15e-07	2.11e-04
PMMA Sheet Prod.	Unspecified solid waste	secondary	7.91e-08	1.46e-04
Polycarbonate Production	Unspecified solid waste	secondary	6.10e-08	1.12e-04
Steel Prod., cold-rolled, semi-finished	Sewage sludge (unspecified)	secondary	3.25e-08	6.00e-05
Steel Prod., cold-rolled, semi-finished	Waste oil	secondary	2.63e-08	4.85e-05
Steel Prod., cold-rolled, semi-finished	Non mineral waste (inert)	secondary	2.19e-08	4.03e-05
Aluminum Prod.	Carbon	secondary	2.04e-08	3.76e-05
Steel Prod., cold-rolled, semi-finished	Calcium	secondary	1.48e-08	2.73e-05
Aluminum Prod.	Waste oil	secondary	8.38e-09	1.54e-05
Steel Prod., cold-rolled, semi-finished	Carbon	secondary	2.12e-09	3.90e-06
Natural Gas Prod.	Non toxic chemical waste (unspecified)	secondary	1.91e-09	3.52e-06
Natural Gas Prod.	Mineral waste	secondary	1.43e-09	2.63e-06
Total Materials Processing			**1.10e-02**	**2.02e+01**
Manufacturing Life-cycle Stage				
Monitor/module	Waste water treatment (WWT) sludge	primary	3.06e-03	5.65e+00
Japanese Electric Grid	Coal waste	model/secondary	2.72e-03	5.02e+00
LPG Production	Slag and ash	secondary	1.66e-03	3.06e+00
Japanese Electric Grid	Dust/sludge	model/secondary	8.43e-04	1.55e+00
Japanese Electric Grid	Fly/bottom ash	model/secondary	6.81e-04	1.25e+00
LPG Production	Unspecified waste	secondary	3.57e-04	6.57e-01
LCD glass mfg.	Waste water treatment (WWT) sludge	primary	3.39e-04	6.25e-01
Monitor/module	Waste plastics from LCD monitor	primary	2.89e-04	5.33e-01
Monitor/module	Waste acid (containing F and detergents)	primary	1.80e-04	3.31e-01

Table M-8. LCD LCIA Results for the Solid Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Solid Waste landfill Use (m3)	% of Total
US electric grid	Coal waste	model/secondary	1.23e-04	2.27e-01
Natural Gas Prod.	Slag and ash	secondary	9.47e-05	1.75e-01
Monitor/module	Waste LCD glass	primary	8.23e-05	1.52e-01
LPG Production	Mixed industrial (waste)	secondary	5.97e-05	1.10e-01
US electric grid	Dust/sludge	model/secondary	3.81e-05	7.03e-02
US electric grid	Fly/bottom ash	model/secondary	3.08e-05	5.67e-02
Panel components	Waste LCD glass	primary	2.30e-05	4.23e-02
Natural Gas Prod.	Unspecified waste	secondary	2.04e-05	3.75e-02
Fuel Oil #4 Prod.	Slag and ash	secondary	1.78e-05	3.29e-02
Fuel Oil #6 Prod.	Slag and ash	secondary	9.52e-06	1.75e-02
Monitor/module	Printed wiring board (PWB)	primary	9.38e-06	1.73e-02
Fuel Oil #2 Prod.	Slag and ash	secondary	5.07e-06	9.34e-03
Fuel Oil #4 Prod.	Unspecified waste	secondary	3.83e-06	7.07e-03
Monitor/module	LCD panel waste	primary	3.79e-06	6.98e-03
Panel components	Used silica gel	primary	2.14e-06	3.94e-03
Fuel Oil #6 Prod.	Unspecified waste	secondary	2.04e-06	3.77e-03
Backlight	Waste backlight light guide (PMMA)	primary	1.28e-06	2.35e-03
Fuel Oil #2 Prod.	Unspecified waste	secondary	1.09e-06	2.01e-03
LCD glass mfg.	Potassium Carbonate	primary	4.99e-07	9.19e-04
LCD glass mfg.	Sodium Carbonate	primary	4.51e-07	8.31e-04
Fuel Oil #4 Prod.	Mixed industrial (waste)	secondary	4.38e-07	8.07e-04
LCD glass mfg.	Unspecified sludge	primary	3.56e-07	6.56e-04
LCD glass mfg.	Cinders from LCD glass mfg	primary	3.19e-07	5.87e-04
Fuel Oil #2 Prod.	Mixed industrial (waste)	secondary	1.63e-07	3.00e-04
Fuel Oil #6 Prod.	Mixed industrial (waste)	secondary	1.44e-07	2.65e-04
LCD glass mfg.	LCD glass EP dust	primary	9.94e-08	1.83e-04
LPG Production	Non toxic chemical waste (unspecified)	secondary	6.49e-08	1.20e-04
LPG Production	Mineral waste	secondary	4.85e-08	8.94e-05
LCD glass mfg.	Waste refractory	primary	4.41e-08	8.13e-05
Natural Gas Prod.	Mixed industrial (waste)	secondary	3.96e-08	7.30e-05
LCD glass mfg.	blasting media	primary	3.78e-08	6.97e-05
LCD glass mfg.	Waste LCD glass	primary	3.48e-08	6.41e-05
LCD glass mfg.	Oily rags & filter media	primary	3.36e-08	6.19e-05
LCD glass mfg.	Sludge from LCD glass mfg	primary	2.99e-08	5.51e-05
LCD glass mfg.	Plating process sludge	primary	1.38e-08	2.54e-05
Backlight	Waste backlight casing (PC)	primary	5.41e-09	9.97e-06
LCD glass mfg.	acid absorbent	primary	4.71e-09	8.68e-06
Fuel Oil #4 Prod.	Non toxic chemical waste (unspecified)	secondary	4.76e-10	8.76e-07
Fuel Oil #4 Prod.	Mineral waste	secondary	3.55e-10	6.54e-07
Fuel Oil #2 Prod.	Non toxic chemical waste (unspecified)	secondary	1.77e-10	3.27e-07
Fuel Oil #6 Prod.	Non toxic chemical waste (unspecified)	secondary	1.56e-10	2.87e-07
Fuel Oil #2 Prod.	Mineral waste	secondary	1.32e-10	2.44e-07
Fuel Oil #6 Prod.	Mineral waste	secondary	1.16e-10	2.14e-07
Natural Gas Prod.	Non toxic chemical waste (unspecified)	secondary	4.31e-11	7.95e-08
Natural Gas Prod.	Mineral waste	secondary	3.22e-11	5.93e-08
Backlight	Broken CCFL	primary	1.98e-11	3.65e-08
Total Manufacturing			**1.07e-02**	**1.97e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Coal waste	model/secondary	2.37e-02	4.37e+01
US electric grid	Dust/sludge	model/secondary	7.35e-03	1.35e+01

Table M-8. LCD LCIA Results for the Solid Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Solid Waste landfill Use (m3)	% of Total
US electric grid	Fly/bottom ash	model/secondary	5.93e-03	1.09e+01
Total Use, Maintenance and Repair			**3.70e-02**	**6.82e+01**
End-of-life Life-cycle Stage				
LCD landfilling	EOL LCD Monitor, landfilled	primary	1.90e-03	3.50e+00
US electric grid	Coal waste	model/secondary	4.50e-06	8.29e-03
US electric grid	Dust/sludge	model/secondary	1.39e-06	2.57e-03
US electric grid	Fly/bottom ash	model/secondary	1.12e-06	2.07e-03
LCD landfilling	Unspecified solid waste	primary	1.05e-06	1.93e-03
LCD incineration	Mixed industrial (waste)	secondary	3.28e-07	6.04e-04
LPG Production	Slag and ash	secondary	1.36e-07	2.51e-04
LPG Production	Unspecified waste	secondary	2.93e-08	5.40e-05
LPG Production	Mixed industrial (waste)	secondary	4.90e-09	9.02e-06
LPG Production	Non toxic chemical waste (unspecified)	secondary	5.33e-12	9.82e-09
LPG Production	Mineral waste	secondary	3.98e-12	7.34e-09
Natural Gas Prod.	Mineral waste	secondary	-6.76e-12	-1.25e-08
Natural Gas Prod.	Non toxic chemical waste (unspecified)	secondary	-9.06e-12	-1.67e-08
LCD incineration	Mineral waste	secondary	-1.03e-10	-1.90e-07
LCD incineration	Non toxic chemical waste (unspecified)	secondary	-1.38e-10	-2.54e-07
Fuel Oil #4 Prod.	Mineral waste	secondary	-1.64e-09	-3.02e-06
Fuel Oil #4 Prod.	Non toxic chemical waste (unspecified)	secondary	-2.19e-09	-4.04e-06
LCD incineration	Mining waste	secondary	-2.74e-09	-5.06e-06
Natural Gas Prod.	Mixed industrial (waste)	secondary	-8.32e-09	-1.53e-05
Fuel Oil #4 Prod.	Mixed industrial (waste)	secondary	-2.02e-06	-3.72e-03
Natural Gas Prod.	Unspecified waste	secondary	-4.28e-06	-7.88e-03
Fuel Oil #4 Prod.	Unspecified waste	secondary	-1.77e-05	-3.26e-02
Natural Gas Prod.	Slag and ash	secondary	-1.99e-05	-3.67e-02
Fuel Oil #4 Prod.	Slag and ash	secondary	-8.22e-05	-1.52e-01
LCD incineration	Unspecified solid waste	secondary	-1.14e-03	-2.10e+00
LCD incineration	Slag and ash	secondary	-4.99e-03	-9.19e+00
Total End-of-life			**-4.35e-03**	**-8.01e+00**
Total All Life-cycle Stages			**5.43e-02**	**1.00e+02**

Table M-9. CRT LCIA Results for the Hazardous Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Hazardous Waste Landfill Use (m3)	% of Total
Materials Processing Life-cycle Stage				
Invar	General Hazardous Waste	secondary	3.92e-05	2.33e-01
Ferrite mfg.	General Hazardous Waste	secondary	3.82e-05	2.28e-01
Polycarbonate Production	General Hazardous Waste	secondary	2.06e-05	1.23e-01
ABS Production	General Hazardous Waste	secondary	9.45e-06	5.62e-02
Styrene-butadiene Copolymer Prod.	Hazardous waste	secondary	8.58e-07	5.11e-03
Steel Prod., cold-rolled, semi-finished	General Hazardous Waste	secondary	4.35e-07	2.59e-03
Polystyrene Prod., high-impact	General Hazardous Waste	secondary	2.70e-07	1.60e-03
Total Materials Processing			**1.09e-04**	**6.49e-01**
Manufacturing Life-cycle Stage				
LPG Production	Hazardous waste	secondary	1.36e-03	8.11e+00
Glass/frit	Hydrofluoric acid	primary	1.34e-05	7.98e-02
Glass/frit	cinders from CRT glass mfg (70% PbO)	primary	6.88e-06	4.09e-02
CRT tube mfg.	Unspecified sludge	primary	5.22e-06	3.11e-02
Fuel Oil #6 Prod.	Hazardous waste	secondary	4.61e-06	2.74e-02
Fuel Oil #2 Prod.	Hazardous waste	secondary	3.82e-06	2.27e-02
CRT tube mfg.	Frit	primary	3.04e-06	1.81e-02
CRT tube mfg.	Carbon and filmer waste	primary	2.30e-06	1.37e-02
Glass/frit	CRT glass faceplate EP dust (Pb) (D008 waste)	primary	2.15e-06	1.28e-02
CRT tube mfg.	Slurry scrap (chromium-based)	primary	1.60e-06	9.52e-03
Glass/frit	Hazardous sludge (Pb) (D008)	primary	1.38e-06	8.21e-03
CRT tube mfg.	Slag and ash	primary	1.30e-06	7.74e-03
CRT tube mfg.	Waste water treatment (WWT) filters	primary	7.59e-07	4.52e-03
Glass/frit	sludge from CRT glass mfg (1% PbO)	primary	6.45e-07	3.84e-03
Glass/frit	Broken CRT glass	primary	6.22e-07	3.70e-03
Glass/frit	Barium debris (D008 waste)	primary	4.58e-07	2.72e-03
Fuel Oil #4 Prod.	Hazardous waste	secondary	3.11e-07	1.85e-03
Glass/frit	Waste finishing sludge (Pb) (D008 waste)	primary	2.32e-07	1.38e-03
Glass/frit	Waste Batch (Ba, Pb) (D008 waste)	primary	1.22e-07	7.28e-04
CRT tube mfg.	Lead sulfate cake	primary	3.03e-08	1.80e-04
Natural Gas Prod.	Hazardous waste	secondary	2.75e-08	1.64e-04
Glass/frit	Lead debris (D008 waste)	primary	1.85e-08	1.10e-04
Glass/frit	Lead contaminated grit (D008 waste)	primary	2.99e-09	1.78e-05
Total Manufacturing			**1.41e-03**	**8.40e+00**
Use, Maintenance and Repair Life-cycle Stage				
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
CRT landfilling	EOL CRT Monitor, landfilled	primary	1.53e-02	9.10e+01
LPG Production	Hazardous waste	secondary	1.18e-08	7.00e-05
Natural Gas Prod.	Hazardous waste	secondary	-1.38e-08	-8.22e-05
CRT Incineration	General Hazardous Waste	secondary	-2.14e-07	-1.28e-03
Fuel Oil #4 Prod.	Hazardous waste	secondary	-3.34e-06	-1.99e-02
Total End-of-life			**1.53e-02**	**9.10e+01**
Total All Life-cycle Stages			**1.68e-02**	**1.00e+02**

Table M-10. LCD LCIA Results for the Hazardous Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Hazardous Waste Landfill Use (m3)	% of Total
Materials Processing Life-cycle Stage				
Polycarbonate Production	General Hazardous Waste	secondary	1.15e-05	3.18e-01
Natural Gas Prod.	Hazardous waste	secondary	1.92e-06	5.33e-02
PMMA Sheet Prod.	General Hazardous Waste	secondary	9.41e-07	2.60e-02
Styrene-butadiene Copolymer Prod.	Hazardous waste	secondary	3.75e-07	1.04e-02
Steel Prod., cold-rolled, semi-finished	General Hazardous Waste	secondary	2.13e-07	5.90e-03
PET Resin Production	Unspecified hazardous waste	secondary	3.24e-08	8.96e-04
Total Materials Processing			**1.50e-05**	**4.15e-01**
Manufacturing Life-cycle Stage				
LPG Production	Hazardous waste	secondary	6.54e-05	1.81e+00
Monitor/module	Acetic acid	primary	3.18e-05	8.80e-01
Monitor/module	Phosphoric acid	primary	8.55e-06	2.37e-01
LCD glass mfg.	Hydrofluoric acid	primary	6.21e-07	1.72e-02
Fuel Oil #4 Prod.	Hazardous waste	secondary	4.79e-07	1.33e-02
Monitor/module	Nitric acid	primary	2.48e-07	6.87e-03
Fuel Oil #2 Prod.	Hazardous waste	secondary	1.78e-07	4.94e-03
Fuel Oil #6 Prod.	Hazardous waste	secondary	1.57e-07	4.34e-03
Natural Gas Prod.	Hazardous waste	secondary	4.34e-08	1.20e-03
LCD glass mfg.	Barium debris (D008 waste)	primary	2.12e-08	5.87e-04
LCD glass mfg.	Waste Batch (Ba, Pb) (D008 waste)	primary	5.67e-09	1.57e-04
Backlight	Waste glass, with mercury	primary	7.73e-15	2.14e-10
Total Manufacturing			**1.07e-04**	**2.98e+00**
Use, Maintenance and Repair Life-cycle Stage				
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
LCD landfilling	EOL LCD Monitor, landfilled	primary	3.49e-03	9.67e+01
LPG Production	Hazardous waste	secondary	5.37e-09	1.49e-04
Natural Gas Prod.	Hazardous waste	secondary	-9.12e-09	-2.52e-04
LCD incineration	General Hazardous Waste	secondary	-1.39e-07	-3.84e-03
Fuel Oil #4 Prod.	Hazardous waste	secondary	-2.21e-06	-6.11e-02
Total End-of-life			**3.49e-03**	**9.66e+01**
Total All Life-cycle Stages			**3.61e-03**	**1.00e+02**

Table M-11. CRT LCIA Results for the Radioactive Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Radioactive Waste Landfill Use (m3)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Low-level radioactive waste	secondary	1.64e-05	9.03e+00
Invar	Low-level radioactive waste	secondary	4.72e-06	2.60e+00
Ferrite mfg.	Low-level radioactive waste	secondary	4.61e-06	2.54e+00
Steel Prod., cold-rolled, semi-finished	Radioactive waste (unspecified)	secondary	7.36e-07	4.06e-01
Steel Prod., cold-rolled, semi-finished	Highly radioactive waste (Class C)	secondary	3.46e-07	1.91e-01
Invar	Radioactive waste (unspecified)	secondary	2.20e-07	1.22e-01
Ferrite mfg.	Radioactive waste (unspecified)	secondary	2.15e-07	1.19e-01
Invar	Highly radioactive waste (Class C)	secondary	9.80e-08	5.41e-02
Ferrite mfg.	Highly radioactive waste (Class C)	secondary	9.57e-08	5.28e-02
Total Materials Processing			**2.74e-05**	**1.51e+01**
Manufacturing Life-cycle Stage				
Japanese Electric Grid	Low-level radioactive waste	model/secondary	6.89e-06	3.80e+00
Japanese Electric Grid	Uranium, depleted	model/secondary	2.07e-06	1.14e+00
US electric grid	Low-level radioactive waste	model/secondary	1.75e-06	9.66e-01
US electric grid	Uranium, depleted	model/secondary	5.25e-07	2.90e-01
Total Manufacturing			**1.12e-05**	**6.19e+00**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Low-level radioactive waste	model/secondary	1.10e-04	6.05e+01
US electric grid	Uranium, depleted	model/secondary	3.29e-05	1.82e+01
Total use, Maintenance and Repair			**1.43e-04**	**7.87e+01**
End-of-life Life-cycle Stage				
US electric grid	Low-level radioactive waste	model/secondary	1.10e-08	6.06e-03
US electric grid	Uranium, depleted	model/secondary	3.29e-09	1.82e-03
Total End-of-life			**1.43e-08**	**7.87e-03**
Total All Life-cycle Stages			**1.81e-04**	**1.00e+02**

Table M-12. LCD LCIA Results for the Radioactive Waste Landfill Use Impact Category

Process Group	Material	LCI Data Type	Radioactive Waste Landfill Use (m3)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Low-level radioactive waste	secondary	8.02e-06	8.70e+00
Steel Prod., cold-rolled, semi-finished	Radioactive waste (unspecified)	secondary	3.61e-07	3.91e-01
Steel Prod., cold-rolled, semi-finished	Highly radioactive waste (Class C)	secondary	1.70e-07	1.84e-01
Total Materials Processing			**8.55e-06**	**9.28e+00**
Manufacturing Life-cycle Stage				
Japanese Electric Grid	Low-level radioactive waste	model/secondary	2.32e-05	2.51e+01
Japanese Electric Grid	Uranium, depleted	model/secondary	6.95e-06	7.54e+00
US electric grid	Low-level radioactive waste	model/secondary	2.12e-07	2.30e-01
US electric grid	Uranium, depleted	model/secondary	6.37e-08	6.91e-02
Total Manufacturing			**3.04e-05**	**3.30e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Low-level radioactive waste	model/secondary	4.10e-05	4.44e+01
US electric grid	Uranium, depleted	model/secondary	1.23e-05	1.33e+01
Total use, Maintenance and Repair			**5.32e-05**	**5.77e+01**
End-of-life Life-cycle Stage				
US electric grid	Low-level radioactive waste	model/secondary	7.77e-09	8.43e-03
US electric grid	Uranium, depleted	model/secondary	2.33e-09	2.53e-03
Total End-of-life			**1.01e-08**	**1.10e-02**
Total All Life-cycle Stages			**9.22e-05**	**1.00e+02**

Table M-13. CRT LCIA Results for the Global Warming Impact Category

Process Group	Material	LCI Data Type	Global Warming Potential (kg-Co2 Equivalents)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Carbon dioxide	secondary	1.34e+01	1.93e+00
Polycarbonate Production	Carbon dioxide	secondary	4.62e+00	6.64e-01
Aluminum Prod.	Carbon dioxide	secondary	3.59e+00	5.16e-01
Invar	Carbon dioxide	secondary	2.26e+00	3.25e-01
Styrene-butadiene Copolymer Prod.	Carbon dioxide	secondary	1.65e+00	2.38e-01
ABS Production	Carbon dioxide	secondary	1.31e+00	1.89e-01
Lead	Carbon dioxide	secondary	1.07e+00	1.54e-01
Aluminum Prod.	Perfluoromethane	secondary	8.42e-01	1.21e-01
Ferrite mfg.	Carbon dioxide	secondary	8.32e-01	1.20e-01
Polycarbonate Production	Methane	secondary	4.27e-01	6.13e-02
Polystyrene Prod., high-impact	Carbon dioxide	secondary	4.23e-01	6.09e-02
Steel Prod., cold-rolled, semi-finished	Nitrous oxide	secondary	2.41e-01	3.46e-02
Steel Prod., cold-rolled, semi-finished	Methane	secondary	2.29e-01	3.29e-02
Aluminum Prod.	Methane	secondary	1.69e-01	2.43e-02
Styrene-butadiene Copolymer Prod.	Methane	secondary	1.44e-01	2.07e-02
Aluminum Prod.	Perfluoroethane	secondary	1.32e-01	1.90e-02
Invar	Methane	secondary	1.21e-01	1.74e-02
ABS Production	Methane	secondary	1.07e-01	1.53e-02
Ferrite mfg.	Methane	secondary	5.99e-02	8.62e-03
Lead	Methane	secondary	5.29e-02	7.61e-03
Aluminum Prod.	Nitrous oxide	secondary	4.28e-02	6.16e-03
Polystyrene Prod., high-impact	Methane	secondary	3.49e-02	5.02e-03
Lead	Nitrous oxide	secondary	6.29e-03	9.05e-04
Ferrite mfg.	Nitrous oxide	secondary	3.29e-03	4.73e-04
Polycarbonate Production	Nitrous oxide	secondary	1.43e-04	2.06e-03
ABS Production	Nitrous oxide	secondary	6.56e-05	9.44e-06
Styrene-butadiene Copolymer Prod.	Nitrous oxide	secondary	6.41e-05	9.22e-06
Invar	Perfluoromethane	secondary	1.85e-05	2.67e-06
Ferrite mfg.	Perfluoromethane	secondary	1.81e-05	2.60e-06
Invar	Nitrous oxide	secondary	1.50e-05	2.16e-06
Invar	HFC-125	secondary	6.43e-06	9.25e-07
Ferrite mfg.	HFC-125	secondary	6.28e-06	9.03e-07
Steel Prod., cold-rolled, semi-finished	Perfluoromethane	secondary	2.92e-07	4.20e-08
Invar	Perfluoroethane	secondary	4.92e-08	7.08e-09
Total Materials Processing			**3.18e+01**	**4.57e+00**
Manufacturing Life-cycle Stage				
LPG Production	Carbon dioxide	secondary	1.51e+02	2.17e+01
LPG Production	Methane	secondary	1.76e+01	2.53e+00
Japanese Electric Grid	Carbon dioxide	model/secondary	1.54e+01	2.21e+00
US electric grid	Carbon dioxide	model/secondary	7.10e+00	1.02e+00
LPG Production	Nitrous oxide	secondary	5.03e+00	7.23e-01
Glass/frit	Carbon dioxide	primary	2.81e+00	4.04e-01
Natural Gas Prod.	Carbon dioxide	secondary	1.32e+00	1.90e-01
Natural Gas Prod.	Methane	secondary	1.05e+00	1.51e-01
Fuel Oil #6 Prod.	Carbon dioxide	secondary	8.51e-01	1.22e-01
Fuel Oil #2 Prod.	Carbon dioxide	secondary	4.48e-01	6.44e-02
US electric grid	Methane	model/secondary	2.16e-01	3.11e-02
Fuel Oil #6 Prod.	Methane	secondary	1.24e-01	1.78e-02
Fuel Oil #2 Prod.	Methane	secondary	5.40e-02	7.76e-03

Table M-13. CRT LCIA Results for the Global Warming Impact Category

Process Group	Material	LCI Data Type	Global Warming Potential (kg-Co2 Equivalents)	% of Total
Fuel Oil #6 Prod.	Nitrous oxide	secondary	4.50e-02	6.47e-03
Glass/frit	Carbon dioxide	primary	4.33e-02	6.23e-03
Fuel Oil #4 Prod.	Carbon dioxide	secondary	4.22e-02	6.06e-03
Japanese Electric Grid	Nitrous oxide	model/secondary	3.46e-02	4.98e-03
US electric grid	Nitrous oxide	model/secondary	1.68e-02	2.42e-03
Fuel Oil #2 Prod.	Nitrous oxide	secondary	1.61e-02	2.31e-03
Fuel Oil #4 Prod.	Methane	secondary	5.47e-03	7.87e-04
Natural Gas Prod.	Nitrous oxide	secondary	3.58e-03	5.15e-04
Fuel Oil #4 Prod.	Nitrous oxide	secondary	1.78e-03	2.56e-04
Japanese Electric Grid	Methane	model/secondary	1.71e-03	2.46e-04
Total Manufacturing			**2.03e+02**	**2.92e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Carbon dioxide	model/secondary	4.45e+02	6.39e+01
US electric grid	Methane	model/secondary	1.35e+01	1.95e+00
US electric grid	Nitrous oxide	model/secondary	1.05e+00	1.51e-01
Total Use, Maintenance and Repair			**4.59e+02**	**6.60e+01**
End-of-life Life-cycle Stage				
CRT Incineration	Carbon dioxide	secondary	3.55e+00	5.11e-01
CRT landfilling	Carbon dioxide	primary	1.03e-01	1.49e-02
US electric grid	Carbon dioxide	model/secondary	4.45e-02	6.40e-03
US electric grid	Methane	model/secondary	1.35e-03	1.95e-04
LPG Production	Carbon dioxide	secondary	1.30e-03	1.87e-04
CRT landfilling	Methane	primary	1.14e-03	1.64e-04
LPG Production	Methane	secondary	1.52e-04	2.19e-05
US electric grid	Nitrous oxide	model/secondary	1.05e-04	1.52e-05
LPG Production	Nitrous oxide	secondary	4.34e-05	6.24e-06
Natural Gas Prod.	Nitrous oxide	secondary	-1.80e-03	-2.58e-04
Fuel Oil #4 Prod.	Nitrous oxide	secondary	-1.92e-02	-2.75e-03
Fuel Oil #4 Prod.	Methane	secondary	-5.88e-02	-8.46e-03
CRT Incineration	Methane	secondary	-3.18e-01	-4.57e-02
CRT Incineration	Nitrous oxide	secondary	-3.23e-01	-4.64e-02
Fuel Oil #4 Prod.	Carbon dioxide	secondary	-4.53e-01	-6.52e-02
Natural Gas Prod.	Methane	secondary	-5.28e-01	-7.60e-02
Natural Gas Prod.	Carbon dioxide	secondary	-6.63e-01	-9.54e-02
Total End-of-life			**1.34e+00**	**1.93e-01**
Total All Life-cycle Stages			**6.95e+02**	**1.00e+02**

Table M-14. LCD LCIA Results for the Global Warming Impact Category

Process Group	Material	LCI Data Type	Global Warming Potential (kg-Co2 Equivalents)	% of Total
Materials Processing Life-cycle Stage				
Natural Gas Prod.	Carbon dioxide	secondary	9.24e+01	1.56e+01
Natural Gas Prod.	Methane	secondary	7.36e+01	1.24e+01
Steel Prod., cold-rolled, semi-finished	Carbon dioxide	secondary	6.58e+00	1.11e+00
PMMA Sheet Prod.	Carbon dioxide	secondary	2.65e+00	4.46e-01
Polycarbonate Production	Carbon dioxide	secondary	2.58e+00	4.35e-01
Aluminum Prod.	Carbon dioxide	secondary	1.34e+00	2.25e-01
Styrene-butadiene Copolymer Prod.	Carbon dioxide	secondary	7.23e-01	1.22e-01
PET Resin Production	Carbon dioxide	secondary	3.90e-01	6.58e-02
Aluminum Prod.	Perfluoromethane	secondary	3.14e-01	5.29e-02
Natural Gas Prod.	Nitrous oxide	secondary	2.50e-01	4.22e-02
PMMA Sheet Prod.	Methane	secondary	2.42e-01	4.07e-02
Polycarbonate Production	Methane	secondary	2.38e-01	4.02e-02
Steel Prod., cold-rolled, semi-finished	Nitrous oxide	secondary	1.18e-01	1.99e-02
Steel Prod., cold-rolled, semi-finished	Methane	secondary	1.12e-01	1.89e-02
Styrene-butadiene Copolymer Prod.	Methane	secondary	6.30e-02	1.06e-02
Aluminum Prod.	Methane	secondary	6.29e-02	1.06e-02
Aluminum Prod.	Perfluoroethane	secondary	4.93e-02	8.31e-03
PET Resin Production	Methane	secondary	2.10e-02	3.53e-03
Aluminum Prod.	Nitrous oxide	secondary	1.59e-02	2.69e-03
Polycarbonate Production	Nitrous oxide	secondary	7.99e-05	1.35e-05
PMMA Sheet Prod.	Nitrous oxide	secondary	5.94e-05	1.00e-05
PET Resin Production	Nitrous oxide	secondary	2.81e-05	4.74e-06
Styrene-butadiene Copolymer Prod.	Nitrous oxide	secondary	2.80e-05	4.73e-06
Steel Prod., cold-rolled, semi-finished	Perfluoromethane	secondary	1.43e-07	2.41e-08
Total Materials Processing			**1.82e+02**	**3.06e+01**
Manufacturing Life-cycle Stage				
Monitor/module	Sulfur hexafluoride	primary	1.74e+02	2.94e+01
Japanese Electric Grid	Carbon dioxide	model/secondary	5.18e+01	8.72e+00
LPG Production	Carbon dioxide	secondary	7.24e+00	1.22e+00
Natural Gas Prod.	Carbon dioxide	secondary	2.09e+00	3.51e-01
Natural Gas Prod.	Methane	secondary	1.66e+00	2.80e-01
US electric grid	Carbon dioxide	model/secondary	8.61e-01	1.45e-01
LPG Production	Methane	secondary	8.45e-01	1.42e-01
LPG Production	Nitrous oxide	secondary	2.41e-01	4.07e-02
LCD glass mfg.	Carbon dioxide	primary	1.30e-01	2.19e-02
Japanese Electric Grid	Nitrous oxide	model/secondary	1.17e-01	1.96e-02
Fuel Oil #4 Prod.	Carbon dioxide	secondary	6.50e-02	1.10e-02
Fuel Oil #6 Prod.	Carbon dioxide	secondary	2.90e-02	4.88e-03
US electric grid	Methane	model/secondary	2.62e-02	4.42e-03
Fuel Oil #2 Prod.	Carbon dioxide	secondary	2.09e-02	3.52e-03
Fuel Oil #4 Prod.	Methane	secondary	8.43e-03	1.42e-03
Japanese Electric Grid	Methane	model/secondary	5.74e-03	9.68e-04
Natural Gas Prod.	Nitrous oxide	secondary	5.64e-03	9.51e-04
Panel components	Carbon dioxide	primary	4.82e-03	8.12e-04
Fuel Oil #6 Prod.	Methane	secondary	4.21e-03	7.10e-04
Fuel Oil #4 Prod.	Nitrous oxide	secondary	2.75e-03	4.63e-04
Fuel Oil #2 Prod.	Methane	secondary	2.52e-03	4.24e-04
Monitor/module	Carbon dioxide	primary	2.16e-03	3.64e-04

Table M-14. LCD LCIA Results for the Global Warming Impact Category

Process Group	Material	LCI Data Type	Global Warming Potential (kg-Co2 Equivalents)	% of Total
US electric grid	Nitrous oxide	model/secondary	2.04e-03	3.44e-04
Fuel Oil #6 Prod.	Nitrous oxide	secondary	1.53e-03	2.58e-04
Fuel Oil #2 Prod.	Nitrous oxide	secondary	7.50e-04	1.26e-04
Total Manufacturing			**2.40e+02**	**4.04e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Carbon dioxide	model/secondary	1.66e+02	2.80e+01
US electric grid	Methane	model/secondary	5.05e+00	8.52e-01
US electric grid	Nitrous oxide	model/secondary	3.93e-01	6.63e-02
Total Use, Maintenance and Repair			**1.71e+02**	**2.89e+01**
End-of-life Life-cycle Stage				
LCD incineration	Carbon dioxide	secondary	2.07e+00	3.48e-01
US electric grid	Carbon dioxide	model/secondary	3.15e-02	5.31e-03
LCD landfilling	Carbon dioxide	primary	2.49e-02	4.20e-03
US electric grid	Methane	model/secondary	9.59e-04	1.62e-04
LPG Production	Carbon dioxide	secondary	5.95e-04	1.00e-04
LCD landfilling	Methane	primary	2.75e-04	4.64e-05
US electric grid	Nitrous oxide	model/secondary	7.46e-05	1.26e-05
LPG Production	Methane	secondary	6.94e-05	1.17e-05
LPG Production	Nitrous oxide	secondary	1.98e-05	3.34e-06
Natural Gas Prod.	Nitrous oxide	secondary	-1.19e-03	-2.00e-04
Fuel Oil #4 Prod.	Nitrous oxide	secondary	-1.27e-02	-2.13e-03
Fuel Oil #4 Prod.	Methane	secondary	-3.89e-02	-6.55e-03
LCD incineration	Methane	secondary	-2.07e-01	-3.49e-02
LCD incineration	Nitrous oxide	secondary	-2.09e-01	-3.53e-02
Fuel Oil #4 Prod.	Carbon dioxide	secondary	-2.99e-01	-5.05e-02
Natural Gas Prod.	Methane	secondary	-3.49e-01	-5.88e-02
Natural Gas Prod.	Carbon dioxide	secondary	-4.38e-01	-7.38e-02
Total End-of-life			**5.70e-01**	**9.60e-02**
Total All Life-cycle Stages			**5.93e+02**	**1.00e+02**

Table M-15. CRT LCIA Results for the Stratospheric Ozone Depletion Impact Category

Process Group	Materials	LCI Data Type	Ozone Depletion (kg CFC-11 Equivalents)	% of Total
Materials Processing Life-cycle Stage				
ABS Production	HALON-1301	secondary	4.10e-06	2.00e+01
Aluminum Prod.	HALON-1301	secondary	2.89e-06	1.41e+01
Invar	HALON-1301	secondary	1.22e-06	5.93e+00
Lead	HALON-1301	secondary	5.42e-07	2.65e+00
Steel Prod., cold-rolled, semi-finished	HALON-1301	secondary	4.03e-07	1.97e+00
Ferrite mfg.	HALON-1301	secondary	1.52e-07	7.43e-01
Invar	Dichlorodifluoromethane	secondary	8.02e-10	3.92e-03
Invar	CFC-13	secondary	5.04e-10	2.46e-03
ABS Production	HCFC-22	secondary	1.46e-10	7.14e-04
Ferrite mfg.	Dichlorodifluoromethane	secondary	5.94e-17	2.90e-10
Ferrite mfg.	CFC-13	secondary	3.74e-17	1.83e-10
Invar	HCFC-22	secondary	3.68e-18	1.80e-11
Ferrite mfg.	HCFC-22	secondary	3.59e-18	1.75e-11
Total Materials Processing			**9.30e-06**	**4.54e+01**
Manufacturing Life-cycle Stage				
LPG Production	Bromomethane	secondary	7.49e-07	3.66e+00
US electric grid	Bromomethane	model/secondary	1.60e-07	7.83e-01
Japanese Electric Grid	Bromomethane	model/secondary	1.28e-07	6.25e-01
LPG Production	1,1,1-Trichloroethane	secondary	1.61e-08	7.84e-02
LPG Production	HALON-1301	secondary	8.12e-09	3.96e-02
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	7.76e-09	3.79e-02
Fuel Oil #6 Prod.	Bromomethane	secondary	6.05e-09	2.95e-02
US electric grid	1,1,1-Trichloroethane	model/secondary	3.67e-09	1.79e-02
Fuel Oil #2 Prod.	Bromomethane	secondary	2.35e-09	1.15e-02
Natural Gas Prod.	Bromomethane	secondary	1.30e-09	6.34e-03
Fuel Oil #4 Prod.	Bromomethane	secondary	2.51e-10	1.22e-03
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	1.30e-10	6.32e-04
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	5.04e-11	2.46e-04
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	2.79e-11	1.36e-04
Fuel Oil #6 Prod.	HALON-1301	secondary	2.75e-11	1.34e-04
Fuel Oil #2 Prod.	HALON-1301	secondary	2.28e-11	1.11e-04
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	5.37e-12	2.62e-05
Fuel Oil #4 Prod.	HALON-1301	secondary	1.85e-12	9.04e-06
Natural Gas Prod.	HALON-1301	secondary	1.64e-13	8.01e-07
Total Manufacturing			**1.08e-06**	**5.29e+00**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Bromomethane	model/secondary	1.00e-05	4.90e+01
US electric grid	1,1,1-Trichloroethane	model/secondary	2.30e-07	1.12e+00
Total Use, Maintenance and Repair			**1.03e-05**	**5.01e+01**
End-of-life Life-cycle Stage				
CRT Incineration	Carbon tetrachloride	secondary	1.61e-09	7.88e-03
CRT landfilling	Carbon tetrachloride	primary	1.51e-09	7.35e-03
US electric grid	Bromomethane	model/secondary	1.00e-09	4.91e-03
US electric grid	1,1,1-Trichloroethane	model/secondary	2.30e-11	1.12e-04
LPG Production	Bromomethane	secondary	6.47e-12	3.16e-05
LPG Production	1,1,1-Trichloroethane	secondary	1.39e-13	6.77e-07
LPG Production	HALON-1301	secondary	7.01e-14	3.42e-07
Natural Gas Prod.	HALON-1301	secondary	-8.23e-14	-4.02e-07

Table M-15. CRT LCIA Results for the Stratospheric Ozone Depletion Impact Category

Process Group	Materials	LCI Data Type	Ozone Depletion (kg CFC-11 Equivalents)	% of Total
CRT Incineration	HALON-1301	secondary	-1.28e-12	-6.24e-06
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-1.40e-11	-6.82e-05
Fuel Oil #4 Prod.	HALON-1301	secondary	-1.99e-11	-9.72e-05
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-5.77e-11	-2.82e-04
Natural Gas Prod.	Bromomethane	secondary	-6.52e-10	-3.18e-03
Fuel Oil #4 Prod.	Bromomethane	secondary	-2.69e-09	-1.32e-02
CRT Incineration	1,1,1-Trichloroethane	secondary	-3.57e-09	-1.74e-02
CRT Incineration	Bromomethane	secondary	-1.67e-07	-8.13e-01
Total End-of-life			**-1.69e-07**	**-8.27e-01**
Total All Life-cycle Stages			**2.05e-05**	**1.00e+02**

Table M-16. LCD LCIA Results for the Stratospheric Ozone Depletion Impact Category

Process Group	Material	LCI Data Type	Ozone Depletion (kg CFC-11 Equivalents)	% of Total
Materials Processing Life-cycle Stage				
Aluminum Prod.	HALON-1301	secondary	1.07e-06	7.83e+00
Steel Prod., cold-rolled, semi-finished	HALON-1301	secondary	1.98e-07	1.44e+00
Natural Gas Prod.	Bromomethane	secondary	9.08e-08	6.62e-01
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	1.95e-09	1.42e-02
Natural Gas Prod.	HALON-1301	secondary	1.15e-11	8.36e-05
Total Materials Processing			**1.36e-06**	**9.95e+00**
Manufacturing Life-cycle Stage				
Panel components	HCFC-225cb	primary	4.62e-06	3.37e+01
Panel components	HCFC-225ca	primary	3.50e-06	2.55e+01
Japanese Electric Grid	Bromomethane	model/secondary	4.31e-07	3.14e+00
LPG Production	Bromomethane	secondary	3.60e-08	2.62e-01
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	2.61e-08	1.90e-01
US electric grid	Bromomethane	model/secondary	1.94e-08	1.42e-01
Natural Gas Prod.	Bromomethane	secondary	2.05e-09	1.49e-02
LPG Production	1,1,1-Trichloroethane	secondary	7.71e-10	5.62e-03
US electric grid	1,1,1-Trichloroethane	model/secondary	4.45e-10	3.25e-03
LPG Production	HALON-1301	secondary	3.90e-10	2.84e-03
Fuel Oil #4 Prod.	Bromomethane	secondary	3.86e-10	2.82e-03
Fuel Oil #6 Prod.	Bromomethane	secondary	2.06e-10	1.50e-03
Fuel Oil #2 Prod.	Bromomethane	secondary	1.10e-10	8.00e-04
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	4.39e-11	3.20e-04
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	8.28e-12	6.03e-05
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	4.41e-12	3.22e-05
Fuel Oil #4 Prod.	HALON-1301	secondary	2.85e-12	2.08e-05
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	2.35e-12	1.71e-05
Fuel Oil #2 Prod.	HALON-1301	secondary	1.06e-12	7.75e-06
Fuel Oil #6 Prod.	HALON-1301	secondary	9.35e-13	6.82e-06
Natural Gas Prod.	HALON-1301	secondary	2.59e-13	1.89e-06
Total Manufacturing			**8.63e-06**	**6.29e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Bromomethane	model/secondary	3.75e-06	2.73e+01
US electric grid	1,1,1-Trichloroethane	model/secondary	8.59e-08	6.26e-01
Total use, Maintenance and Repair			**3.83e-06**	**2.79e+01**
End-of-life Life-cycle Stage				
US electric grid	Bromomethane	model/secondary	7.11e-10	5.18e-03
LCD landfilling	Carbon tetrachloride	primary	3.63e-10	2.64e-03
LCD incineration	Carbon tetrachloride	secondary	2.81e-10	2.05e-03
US electric grid	1,1,1-Trichloroethane	model/secondary	1.63e-11	1.19e-04
LPG Production	Bromomethane	secondary	2.95e-12	2.15e-05
LPG Production	1,1,1-Trichloroethane	secondary	6.33e-14	4.61e-07
LPG Production	HALON-1301	secondary	3.20e-14	2.33e-07
Natural Gas Prod.	HALON-1301	secondary	-5.44e-14	-3.96e-07
LCD incineration	HALON-1301	secondary	-8.28e-13	-6.03e-06
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-9.22e-12	-6.72e-05
Fuel Oil #4 Prod.	HALON-1301	secondary	-1.32e-11	-9.58e-05
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-3.81e-11	-2.78e-04
Natural Gas Prod.	Bromomethane	secondary	-4.30e-10	-3.14e-03
Fuel Oil #4 Prod.	Bromomethane	secondary	-1.78e-09	-1.30e-02

Table M-16. LCD LCIA Results for the Stratospheric Ozone Depletion Impact Category

Process Group	Material	LCI Data Type	Ozone Depletion (kg CFC-11 Equivalents)	% of Total
LCD incineration	1,1,1-Trichloroethane	secondary	-2.31e-09	-1.69e-02
LCD incineration	Bromomethane	secondary	-1.08e-07	-7.86e-01
Total End-of-life			**-1.11e-07**	**-8.10e-01**
Total All Life-cycle Stages			**1.37e-05**	**1.00e+02**

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Nonmethane hydrocarbons, remaining unspeciated	secondary	3.32e-02	1.94e+01
Steel Prod., cold-rolled, semi-finished	Hydrocarbons, remaining unspeciated	secondary	3.44e-03	2.01e+00
ABS Production	Nonmethane hydrocarbons, remaining unspeciated	secondary	2.14e-03	1.25e+00
Polycarbonate Production	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.84e-03	1.07e+00
Aluminum Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.47e-03	8.60e-01
ABS Production	Hydrocarbons, remaining unspeciated	secondary	7.08e-04	4.14e-01
Styrene-butadiene Copolymer Prod.	Hydrocarbons, remaining unspeciated	secondary	6.59e-04	3.85e-01
Invar	Nonmethane hydrocarbons, remaining unspeciated	secondary	5.46e-04	3.19e-01
Lead	Nonmethane hydrocarbons, remaining unspeciated	secondary	3.66e-04	2.14e-01
Invar	VOCs, remaining unspeciated	secondary	2.31e-04	1.35e-01
Polystyrene Prod., high-impact	Hydrocarbons, remaining unspeciated	secondary	2.29e-04	1.34e-01
Ferrite mfg.	VOCs, remaining unspeciated	secondary	2.25e-04	1.32e-01
Steel Prod., cold-rolled, semi-finished	Ethylene	secondary	2.07e-04	1.21e-01
Ferrite mfg.	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.84e-04	1.08e-01
ABS Production	Aromatic hydrocarbons	secondary	1.45e-04	8.48e-02
Polycarbonate Production	Methane	secondary	1.42e-04	8.31e-02
Invar	Ethylene	secondary	1.01e-04	5.93e-02
Steel Prod., cold-rolled, semi-finished	Ethane	secondary	9.79e-05	5.72e-02
Ferrite mfg.	Ethylene	secondary	9.77e-05	5.71e-02
Steel Prod., cold-rolled, semi-finished	Methane	secondary	7.63e-05	4.46e-02
Polycarbonate Production	Aromatic hydrocarbons	secondary	6.25e-05	3.66e-02
Aluminum Prod.	Methane	secondary	5.63e-05	3.29e-02
Styrene-butadiene Copolymer Prod.	Aromatic hydrocarbons	secondary	5.16e-05	3.02e-02
Styrene-butadiene Copolymer Prod.	Methane	secondary	4.81e-05	2.81e-02
ABS Production	Ethane	secondary	4.72e-05	2.76e-02
Invar	Methane	secondary	4.03e-05	2.36e-02
Steel Prod., cold-rolled, semi-finished	n-Propane	secondary	3.83e-05	2.24e-02
ABS Production	Methane	secondary	3.56e-05	2.08e-02
Invar	Ethane	secondary	3.29e-05	1.92e-02
Ferrite mfg.	Ethane	secondary	3.21e-05	1.88e-02
Polycarbonate Production	Aldehydes	secondary	2.62e-05	1.53e-02
ABS Production	Ethylene	secondary	2.57e-05	1.50e-02
Steel Prod., cold-rolled, semi-finished	Propylene	secondary	2.49e-05	1.45e-02
Polystyrene Prod., high-impact	Aromatic hydrocarbons	secondary	2.30e-05	1.35e-02
Invar	Hydrocarbons, remaining unspeciated	secondary	2.21e-05	1.29e-02
Ferrite mfg.	Hydrocarbons, remaining unspeciated	secondary	2.16e-05	1.26e-02
Ferrite mfg.	Methane	secondary	2.00e-05	1.17e-02
Steel Prod., cold-rolled, semi-finished	Aldehydes	secondary	1.89e-05	1.10e-02
Lead	Methane	secondary	1.76e-05	1.03e-02
Lead	Ethylene	secondary	1.59e-05	9.31e-03
Aluminum Prod.	Xylene (mixed isomers)	secondary	1.41e-05	8.23e-03
Aluminum Prod.	Polycyclic aromatic hydrocarbons	secondary	1.38e-05	8.06e-03
Lead	Ethane	secondary	1.26e-05	7.35e-03
Invar	n-Propane	secondary	1.24e-05	7.26e-03
Ferrite mfg.	n-Propane	secondary	1.21e-05	7.09e-03
Polystyrene Prod., high-impact	Methane	secondary	1.16e-05	6.80e-03
Steel Prod., cold-rolled, semi-finished	Butane	secondary	9.05e-06	5.29e-03
Invar	Propylene	secondary	7.07e-06	4.14e-03

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Steel Prod., cold-rolled, semi-finished	Pentane	secondary	6.92e-06	4.04e-03
Ferrite mfg.	Propylene	secondary	6.90e-06	4.04e-03
ABS Production	Formaldehyde	secondary	5.89e-06	3.44e-03
Invar	Xylene (mixed isomers)	secondary	5.53e-06	3.24e-03
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	5.26e-06	3.07e-03
ABS Production	Heptane	secondary	4.74e-06	2.77e-03
Aluminum Prod.	Toluene	secondary	4.67e-06	2.73e-03
Aluminum Prod.	Aldehydes	secondary	4.59e-06	2.69e-03
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	4.37e-06	2.55e-03
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	4.16e-06	2.43e-03
Steel Prod., cold-rolled, semi-finished	Acetylene	secondary	3.91e-06	2.29e-03
Invar	Butane	secondary	3.80e-06	2.22e-03
Ferrite mfg.	Butane	secondary	3.71e-06	2.17e-03
Invar	Pentane	secondary	3.66e-06	2.14e-03
Ferrite mfg.	Pentane	secondary	3.57e-06	2.09e-03
Invar	Benzene	secondary	2.59e-06	1.52e-03
Lead	Xylene (mixed isomers)	secondary	2.59e-06	1.51e-03
Steel Prod., cold-rolled, semi-finished	Hexane	secondary	1.84e-06	1.08e-03
Ferrite mfg.	Benzene	secondary	1.76e-06	1.03e-03
Invar	Toluene	secondary	1.60e-06	9.33e-04
Ferrite mfg.	Toluene	secondary	1.56e-06	9.11e-04
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	1.53e-06	8.92e-04
Aluminum Prod.	Alcohols	secondary	1.50e-06	8.76e-04
Ferrite mfg.	Xylene (mixed isomers)	secondary	1.43e-06	8.39e-04
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	1.43e-06	8.35e-04
ABS Production	Ethanol	secondary	1.40e-06	8.17e-04
Aluminum Prod.	Benzene	secondary	1.22e-06	7.14e-04
Invar	Acetylene	secondary	1.11e-06	6.50e-04
Ferrite mfg.	Acetylene	secondary	1.08e-06	6.34e-04
Invar	Ethylbenzene	secondary	9.65e-07	5.64e-04
Invar	Benzo[a]pyrene	secondary	9.36e-07	5.48e-04
Steel Prod., cold-rolled, semi-finished	Heptane	secondary	8.81e-07	5.15e-04
Lead	Benzene	secondary	8.32e-07	4.87e-04
Invar	Aromatic hydrocarbons	secondary	7.76e-07	4.54e-04
Invar	Methanol	secondary	6.92e-07	4.05e-04
Invar	Ethanol	secondary	6.13e-07	3.58e-04
Invar	Formaldehyde	secondary	5.89e-07	3.44e-04
Ferrite mfg.	Formaldehyde	secondary	5.74e-07	3.36e-04
Invar	Hexane	secondary	5.36e-07	3.13e-04
Ferrite mfg.	Hexane	secondary	5.23e-07	3.06e-04
Invar	Acetaldehyde	secondary	5.10e-07	2.98e-04
Steel Prod., cold-rolled, semi-finished	Aromatic hydrocarbons	secondary	5.05e-07	2.95e-04
Steel Prod., cold-rolled, semi-finished	Methanol	secondary	4.42e-07	2.59e-04
Lead	Ethylbenzene	secondary	4.11e-07	2.40e-04
Invar	Phenol	secondary	4.05e-07	2.37e-04
Ferrite mfg.	Phenol	secondary	3.95e-07	2.31e-04
Steel Prod., cold-rolled, semi-finished	Ethanol	secondary	3.56e-07	2.08e-04
Polystyrene Prod., high-impact	Polycyclic aromatic hydrocarbons	secondary	3.45e-07	2.02e-04
Steel Prod., cold-rolled, semi-finished	Acetaldehyde	secondary	2.96e-07	1.73e-04

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Invar	Heptane	secondary	2.67e-07	1.56e-04
Ferrite mfg.	Heptane	secondary	2.61e-07	1.53e-04
Steel Prod., cold-rolled, semi-finished	Ethylbenzene	secondary	2.35e-07	1.37e-04
Invar	Acetone	secondary	2.04e-07	1.19e-04
Polycarbonate Production	Ethanethiol	secondary	1.84e-07	1.07e-04
Ferrite mfg.	Aromatic hydrocarbons	secondary	1.62e-07	9.45e-05
Ferrite mfg.	Methanol	secondary	1.24e-07	7.28e-05
Invar	Aldehydes	secondary	1.21e-07	7.05e-05
Steel Prod., cold-rolled, semi-finished	Acetone	secondary	1.18e-07	6.91e-05
Ferrite mfg.	Aldehydes	secondary	1.14e-07	6.64e-05
Ferrite mfg.	Ethylbenzene	secondary	1.03e-07	6.03e-05
Ferrite mfg.	Ethanol	secondary	1.00e-07	5.86e-05
ABS Production	Aldehydes	secondary	9.38e-08	5.48e-05
Styrene-butadiene Copolymer Prod.	Aldehydes	secondary	9.16e-08	5.36e-05
Ferrite mfg.	Acetaldehyde	secondary	8.48e-08	4.96e-05
ABS Production	Ethanethiol	secondary	8.43e-08	4.93e-05
Lead	Ethanol	secondary	7.77e-08	4.54e-05
Steel Prod., cold-rolled, semi-finished	Benzo[a]pyrene	secondary	6.79e-08	3.97e-05
Lead	Acetaldehyde	secondary	6.57e-08	3.84e-05
Lead	Methanol	secondary	6.02e-08	3.52e-05
Lead	Aromatic hydrocarbons	secondary	5.16e-08	3.02e-05
Steel Prod., cold-rolled, semi-finished	Polycyclic aromatic hydrocarbons	secondary	3.72e-08	2.18e-05
Invar	Polycyclic aromatic hydrocarbons	secondary	3.63e-08	2.12e-05
Ferrite mfg.	Polycyclic aromatic hydrocarbons	secondary	3.54e-08	2.07e-05
Ferrite mfg.	Acetone	secondary	3.34e-08	1.95e-05
Lead	Acetone	secondary	2.57e-08	1.50e-05
Invar	Alcohols	secondary	2.38e-08	1.39e-05
Ferrite mfg.	Alcohols	secondary	2.33e-08	1.36e-05
Ferrite mfg.	Benzo[a]pyrene	secondary	1.88e-08	1.10e-05
Steel Prod., cold-rolled, semi-finished	Naphthalene	secondary	1.13e-08	6.62e-06
Aluminum Prod.	1,2-Dichlorotetrafluoroethane	secondary	5.02e-09	2.93e-06
Aluminum Prod.	Phenol	secondary	3.04e-09	1.78e-06
Lead	Aldehydes	secondary	2.15e-09	1.26e-06
Invar	1,2-Dichlorotetrafluoroethane	secondary	2.08e-09	1.22e-06
Lead	Benzo[a]pyrene	secondary	1.49e-09	8.73e-07
Invar	Trichlorofluoromethane	secondary	1.27e-10	7.40e-08
ABS Production	HCFC-22	secondary	5.59e-11	3.27e-08
Ferrite mfg.	Trichlorofluoromethane	secondary	4.71e-11	2.75e-08
Invar	Ethanethiol	secondary	3.47e-11	2.03e-08
Ferrite mfg.	Ethanethiol	secondary	3.38e-11	1.98e-08
Invar	Dichlorodifluoromethane	secondary	1.69e-11	9.85e-09
Lead	Acrolein	secondary	1.05e-11	6.17e-09
Lead	Benzaldehyde	secondary	5.52e-12	3.22e-09
Invar	Propionaldehyde	secondary	9.34e-14	5.46e-11
Steel Prod., cold-rolled, semi-finished	Propionaldehyde	secondary	9.34e-14	5.46e-11
Ferrite mfg.	Propionaldehyde	secondary	9.12e-14	5.33e-11
Steel Prod., cold-rolled, semi-finished	Benzaldehyde	secondary	2.51e-14	1.47e-11
Invar	Benzaldehyde	secondary	2.50e-14	1.46e-11
Ferrite mfg.	Benzaldehyde	secondary	2.43e-14	1.42e-11

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Invar	Acrolein	secondary	4.38e-15	2.56e-12
Ferrite mfg.	1,2-Dichlorotetrafluoroethane	secondary	1.54e-16	8.98e-14
Invar	HCFC-22	secondary	1.41e-18	8.22e-16
Ferrite mfg.	HCFC-22	secondary	1.37e-18	8.02e-16
Ferrite mfg.	Dichlorodifluoromethane	secondary	1.25e-18	7.30e-16
Total Materials Processing			**4.69e-02**	**2.74e+01**
Manufacturing Life-cycle Stage				
LPG Production	Hydrocarbons, remaining unspeciated	secondary	6.22e-02	3.64e+01
LPG Production	Nonmethane hydrocarbons, remaining unspeciated	secondary	4.24e-02	2.48e+01
LPG Production	Methane	secondary	5.87e-03	3.43e+00
LPG Production	Benzene	secondary	2.71e-03	1.59e+00
CRT tube mfg.	Toluene	primary	2.16e-03	1.26e+00
Natural Gas Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	9.01e-04	5.27e-01
LPG Production	Aldehydes	secondary	6.61e-04	3.87e-01
Fuel Oil #6 Prod.	Hydrocarbons, remaining unspeciated	secondary	5.36e-04	3.13e-01
LPG Production	Formaldehyde	secondary	4.93e-04	2.88e-01
Fuel Oil #6 Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	3.55e-04	2.08e-01
Natural Gas Prod.	Methane	secondary	3.51e-04	2.05e-01
LPG Production	Ethane	secondary	3.09e-04	1.81e-01
CRT tube mfg.	Xylene (mixed isomers)	primary	2.92e-04	1.71e-01
LPG Production	Pentane	secondary	2.65e-04	1.55e-01
Natural Gas Prod.	Benzene	secondary	2.39e-04	1.40e-01
LPG Production	Butane	secondary	2.09e-04	1.22e-01
Fuel Oil #2 Prod.	Hydrocarbons, remaining unspeciated	secondary	1.97e-04	1.15e-01
LPG Production	Hexane	secondary	1.88e-04	1.10e-01
Fuel Oil #2 Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.34e-04	7.84e-02
US electric grid	Methane	model/secondary	7.20e-05	4.21e-02
CRT tube mfg.	Nonmethane hydrocarbons, remaining unspeciated	primary	6.33e-05	3.70e-02
Fuel Oil #6 Prod.	Methane	secondary	4.12e-05	2.41e-02
Natural Gas Prod.	Hydrocarbons, remaining unspeciated	secondary	2.48e-05	1.45e-02
Fuel Oil #4 Prod.	Hydrocarbons, remaining unspeciated	secondary	2.16e-05	1.26e-02
Fuel Oil #2 Prod.	Methane	secondary	1.80e-05	1.05e-02
PWB Mfg.	Formaldehyde	model/secondary	1.63e-05	9.55e-03
Fuel Oil #6 Prod.	Benzene	secondary	1.55e-05	9.06e-03
Fuel Oil #4 Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.45e-05	8.47e-03
Fuel Oil #2 Prod.	Benzene	secondary	8.06e-06	4.71e-03
Fuel Oil #6 Prod.	Formaldehyde	secondary	5.03e-06	2.94e-03
Natural Gas Prod.	Aldehydes	secondary	4.77e-06	2.79e-03
Japanese Electric Grid	Formaldehyde	model/secondary	4.30e-06	2.51e-03
Fuel Oil #6 Prod.	Aldehydes	secondary	3.77e-06	2.20e-03
LPG Production	Isophorone	secondary	2.95e-06	1.73e-03
Natural Gas Prod.	Ethane	secondary	2.78e-06	1.63e-03
Natural Gas Prod.	Pentane	secondary	2.39e-06	1.40e-03
LPG Production	Toluene	secondary	2.09e-06	1.22e-03
Fuel Oil #2 Prod.	Aldehydes	secondary	1.96e-06	1.15e-03
Natural Gas Prod.	Butane	secondary	1.88e-06	1.10e-03
Fuel Oil #4 Prod.	Methane	secondary	1.82e-06	1.07e-03
Fuel Oil #6 Prod.	Ethane	secondary	1.76e-06	1.03e-03
LPG Production	Acetaldehyde	secondary	1.69e-06	9.88e-04

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Natural Gas Prod.	Hexane	secondary	1.69e-06	9.87e-04
Fuel Oil #2 Prod.	Formaldehyde	secondary	1.62e-06	9.47e-04
LPG Production	Propionaldehyde	secondary	1.53e-06	8.96e-04
Fuel Oil #6 Prod.	Pentane	secondary	1.52e-06	8.87e-04
LPG Production	Methyl ethyl ketone	secondary	1.23e-06	7.22e-04
Fuel Oil #6 Prod.	Butane	secondary	1.20e-06	6.99e-04
Fuel Oil #6 Prod.	Hexane	secondary	1.07e-06	6.27e-04
Fuel Oil #2 Prod.	Ethane	secondary	9.17e-07	5.36e-04
LPG Production	Acrolein	secondary	8.60e-07	5.03e-04
Japanese Electric Grid	Toluene	model/secondary	8.05e-07	4.71e-04
Fuel Oil #2 Prod.	Pentane	secondary	7.89e-07	4.61e-04
LPG Production	o-xylene	secondary	7.85e-07	4.59e-04
Fuel Oil #4 Prod.	Benzene	secondary	7.62e-07	4.46e-04
LPG Production	n-Propane	secondary	7.01e-07	4.10e-04
US electric grid	Isophorone	model/secondary	6.32e-07	3.69e-04
Fuel Oil #2 Prod.	Butane	secondary	6.21e-07	3.63e-04
Japanese Electric Grid	Methane	model/secondary	5.69e-07	3.33e-04
US electric grid	Formaldehyde	model/secondary	5.69e-07	3.33e-04
Fuel Oil #2 Prod.	Hexane	secondary	5.57e-07	3.26e-04
Japanese Electric Grid	Isophorone	model/secondary	5.05e-07	2.95e-04
LPG Production	Ethylbenzene	secondary	4.83e-07	2.83e-04
LPG Production	Bromomethane	secondary	4.26e-07	2.49e-04
US electric grid	Acetaldehyde	model/secondary	3.61e-07	2.11e-04
US electric grid	Benzene	model/secondary	3.52e-07	2.06e-04
US electric grid	Propionaldehyde	model/secondary	3.28e-07	1.92e-04
Japanese Electric Grid	Acetaldehyde	model/secondary	2.89e-07	1.69e-04
Japanese Electric Grid	Benzene	model/secondary	2.88e-07	1.68e-04
LPG Production	Naphthalene	secondary	2.66e-07	1.55e-04
US electric grid	Methyl ethyl ketone	model/secondary	2.64e-07	1.54e-04
Japanese Electric Grid	Propionaldehyde	model/secondary	2.62e-07	1.53e-04
US electric grid	Toluene	model/secondary	2.28e-07	1.34e-04
Japanese Electric Grid	Methyl ethyl ketone	model/secondary	2.11e-07	1.23e-04
Fuel Oil #4 Prod.	Formaldehyde	secondary	1.89e-07	1.10e-04
Fuel Oil #4 Prod.	Aldehydes	secondary	1.86e-07	1.09e-04
US electric grid	Acrolein	model/secondary	1.84e-07	1.08e-04
Japanese Electric Grid	Naphthalene	model/secondary	1.68e-07	9.84e-05
Japanese Electric Grid	Acrolein	model/secondary	1.47e-07	8.59e-05
LPG Production	Styrene	secondary	1.27e-07	7.44e-05
US electric grid	Ethylbenzene	model/secondary	1.03e-07	6.01e-05
Natural Gas Prod.	Formaldehyde	secondary	1.02e-07	5.95e-05
LPG Production	Benzyl chloride	secondary	9.84e-08	5.75e-05
LPG Production	Methyl tert-butyl ether	secondary	9.32e-08	5.45e-05
US electric grid	Bromomethane	model/secondary	9.12e-08	5.33e-05
Japanese Electric Grid	Ethylbenzene	model/secondary	9.03e-08	5.28e-05
Fuel Oil #4 Prod.	Ethane	secondary	8.68e-08	5.07e-05
LPG Production	Phenol	secondary	8.15e-08	4.76e-05
LPG Production	Acetophenone	secondary	7.64e-08	4.47e-05
Fuel Oil #4 Prod.	Pentane	secondary	7.46e-08	4.36e-05
LPG Production	Methyl chloride	secondary	7.45e-08	4.35e-05

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Japanese Electric Grid	Bromomethane	model/secondary	7.28e-08	4.26e-05
Fuel Oil #4 Prod.	Butane	secondary	5.88e-08	3.44e-05
Fuel Oil #4 Prod.	Hexane	secondary	5.27e-08	3.08e-05
Natural Gas Prod.	o-xylene	secondary	5.27e-08	3.08e-05
LPG Production	Dichloromethane	secondary	4.07e-08	2.38e-05
US electric grid	Xylene (mixed isomers)	model/secondary	4.03e-08	2.36e-05
LPG Production	Aromatic hydrocarbons	secondary	4.00e-08	2.34e-05
US electric grid	Hexane	model/secondary	3.99e-08	2.33e-05
Japanese Electric Grid	Xylene (mixed isomers)	model/secondary	3.22e-08	1.88e-05
Japanese Electric Grid	Hexane	model/secondary	3.19e-08	1.86e-05
Natural Gas Prod.	Toluene	secondary	2.91e-08	1.70e-05
US electric grid	Styrene	model/secondary	2.72e-08	1.59e-05
LPG Production	Cumene	secondary	2.70e-08	1.58e-05
Fuel Oil #6 Prod.	Isophorone	secondary	2.38e-08	1.39e-05
US electric grid	Naphthalene	model/secondary	2.22e-08	1.30e-05
Japanese Electric Grid	Styrene	model/secondary	2.17e-08	1.27e-05
US electric grid	Benzyl chloride	model/secondary	2.10e-08	1.23e-05
US electric grid	Methyl tert-butyl ether	model/secondary	1.99e-08	1.17e-05
US electric grid	Phenol	model/secondary	1.74e-08	1.02e-05
LPG Production	Phenanthrene	secondary	1.72e-08	1.01e-05
Japanese Electric Grid	Benzyl chloride	model/secondary	1.68e-08	9.82e-06
US electric grid	Acetophenone	model/secondary	1.63e-08	9.55e-06
US electric grid	Methyl chloride	model/secondary	1.59e-08	9.32e-06
Japanese Electric Grid	Methyl tert-butyl ether	model/secondary	1.59e-08	9.28e-06
Japanese Electric Grid	o-xylene	model/secondary	1.47e-08	8.59e-06
Fuel Oil #6 Prod.	Toluene	secondary	1.41e-08	8.25e-06
Japanese Electric Grid	Phenol	model/secondary	1.39e-08	8.14e-06
Fuel Oil #6 Prod.	Acetaldehyde	secondary	1.36e-08	7.97e-06
Japanese Electric Grid	Acetophenone	model/secondary	1.30e-08	7.63e-06
Japanese Electric Grid	Methyl chloride	model/secondary	1.27e-08	7.44e-06
Fuel Oil #6 Prod.	Propionaldehyde	secondary	1.24e-08	7.23e-06
LPG Production	Vinyl acetate	secondary	1.13e-08	6.63e-06
Fuel Oil #6 Prod.	Methyl ethyl ketone	secondary	9.96e-09	5.82e-06
Fuel Oil #2 Prod.	Isophorone	secondary	9.26e-09	5.42e-06
US electric grid	Dichloromethane	model/secondary	8.72e-09	5.10e-06
LPG Production	Biphenyl	secondary	8.66e-09	5.06e-06
LPG Production	Chloroform	secondary	8.29e-09	4.85e-06
Japanese Electric Grid	Dichloromethane	model/secondary	6.96e-09	4.07e-06
Fuel Oil #6 Prod.	Acrolein	secondary	6.94e-09	4.06e-06
Fuel Oil #2 Prod.	Toluene	secondary	6.37e-09	3.72e-06
LPG Production	1,4-Dichlorobenzene	secondary	6.31e-09	3.69e-06
LPG Production	Tetrachloroethylene	secondary	6.04e-09	3.53e-06
LPG Production	Ethyl Chloride	secondary	5.90e-09	3.45e-06
US electric grid	Cumene	model/secondary	5.77e-09	3.38e-06
LPG Production	1,2-Dichloroethane	secondary	5.62e-09	3.29e-06
Fuel Oil #6 Prod.	n-Propane	secondary	5.62e-09	3.29e-06
Fuel Oil #2 Prod.	Acetaldehyde	secondary	5.30e-09	3.10e-06
LPG Production	Fluorene	secondary	5.28e-09	3.09e-06
Natural Gas Prod.	Isophorone	secondary	5.12e-09	3.00e-06

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #6 Prod.	o-xylene	secondary	4.91e-09	2.87e-06
Fuel Oil #2 Prod.	Propionaldehyde	secondary	4.81e-09	2.81e-06
Japanese Electric Grid	Cumene hydroperoxide	model/secondary	4.61e-09	2.69e-06
LPG Production	2-Methylnaphthalene	secondary	4.57e-09	2.67e-06
LPG Production	Fluoranthene	secondary	4.31e-09	2.52e-06
LPG Production	Acenaphthene	secondary	3.99e-09	2.33e-06
Japanese Electric Grid	Phenanthrene	model/secondary	3.96e-09	2.32e-06
Fuel Oil #6 Prod.	Ethylbenzene	secondary	3.89e-09	2.27e-06
Fuel Oil #2 Prod.	Methyl ethyl ketone	secondary	3.87e-09	2.26e-06
Fuel Oil #6 Prod.	Bromomethane	secondary	3.44e-09	2.01e-06
Japanese Electric Grid	Acenaphthene	model/secondary	3.29e-09	1.92e-06
LPG Production	Ethylene dibromide	secondary	3.20e-09	1.87e-06
LPG Production	Chlorobenzene	secondary	3.09e-09	1.81e-06
US electric grid	Phenanthrene	model/secondary	3.04e-09	1.78e-06
Natural Gas Prod.	Acetaldehyde	secondary	2.93e-09	1.71e-06
LPG Production	1,1,1-Trichloroethane	secondary	2.81e-09	1.64e-06
LPG Production	Pyrene	secondary	2.74e-09	1.60e-06
Fuel Oil #2 Prod.	Acrolein	secondary	2.70e-09	1.58e-06
Natural Gas Prod.	Propionaldehyde	secondary	2.66e-09	1.55e-06
US electric grid	Vinyl acetate	model/secondary	2.43e-09	1.42e-06
Fuel Oil #2 Prod.	o-xylene	secondary	2.36e-09	1.38e-06
Fuel Oil #2 Prod.	n-Propane	secondary	2.20e-09	1.28e-06
Natural Gas Prod.	Methyl ethyl ketone	secondary	2.14e-09	1.25e-06
Japanese Electric Grid	Vinyl acetate	model/secondary	1.93e-09	1.13e-06
US electric grid	Biphenyl	model/secondary	1.85e-09	1.08e-06
US electric grid	Chloroform	model/secondary	1.77e-09	1.04e-06
LPG Production	Acenaphthylene	secondary	1.63e-09	9.52e-07
Fuel Oil #6 Prod.	Naphthalene	secondary	1.61e-09	9.41e-07
LPG Production	Anthracene	secondary	1.59e-09	9.28e-07
Fuel Oil #2 Prod.	Ethylbenzene	secondary	1.52e-09	8.86e-07
Natural Gas Prod.	Acrolein	secondary	1.49e-09	8.72e-07
Japanese Electric Grid	Biphenyl	model/secondary	1.48e-09	8.64e-07
LPG Production	2,4-Dinitrotoluene	secondary	1.43e-09	8.34e-07
Japanese Electric Grid	Chloroform	model/secondary	1.42e-09	8.28e-07
Japanese Electric Grid	Fluorene	model/secondary	1.39e-09	8.14e-07
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	1.36e-09	7.94e-07
Natural Gas Prod.	Naphthalene	secondary	1.34e-09	7.84e-07
Natural Gas Prod.	n-Propane	secondary	1.34e-09	7.83e-07
Fuel Oil #2 Prod.	Bromomethane	secondary	1.34e-09	7.82e-07
Japanese Electric Grid	Fluoranthene	model/secondary	1.33e-09	7.77e-07
US electric grid	Tetrachloroethylene	model/secondary	1.29e-09	7.56e-07
US electric grid	Ethyl Chloride	model/secondary	1.26e-09	7.38e-07
US electric grid	1,2-Dichloroethane	model/secondary	1.20e-09	7.03e-07
Japanese Electric Grid	Tetrachloroethylene	model/secondary	1.03e-09	6.03e-07
Fuel Oil #6 Prod.	Styrene	secondary	1.03e-09	6.01e-07
US electric grid	Fluorene	model/secondary	1.02e-09	5.96e-07
Japanese Electric Grid	Ethyl Chloride	model/secondary	1.01e-09	5.89e-07
Fuel Oil #4 Prod.	Isophorone	secondary	9.88e-10	5.78e-07
LPG Production	2-Chloroacetophenone	secondary	9.84e-10	5.75e-07

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Japanese Electric Grid	1,2-Dichloroethane	model/secondary	9.60e-10	5.61e-07
Japanese Electric Grid	Pyrene	model/secondary	9.59e-10	5.61e-07
LPG Production	Benzo[a]anthracene	secondary	9.50e-10	5.55e-07
LPG Production	Chrysene	secondary	9.11e-10	5.33e-07
Natural Gas Prod.	Ethylbenzene	secondary	8.40e-10	4.91e-07
US electric grid	Fluoranthene	model/secondary	8.15e-10	4.77e-07
Fuel Oil #2 Prod.	Naphthalene	secondary	7.96e-10	4.65e-07
Fuel Oil #6 Prod.	Benzyl chloride	secondary	7.94e-10	4.64e-07
Fuel Oil #6 Prod.	Methyl tert-butyl ether	secondary	7.52e-10	4.40e-07
Natural Gas Prod.	Bromomethane	secondary	7.39e-10	4.32e-07
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	7.07e-10	4.13e-07
US electric grid	o-xylene	model/secondary	6.93e-10	4.05e-07
US electric grid	Acenaphthene	model/secondary	6.90e-10	4.03e-07
US electric grid	Ethylene dibromide	model/secondary	6.84e-10	4.00e-07
US electric grid	Chlorobenzene	model/secondary	6.61e-10	3.87e-07
Fuel Oil #6 Prod.	Phenol	secondary	6.57e-10	3.84e-07
US electric grid	1,1,1-Trichloroethane	model/secondary	6.43e-10	3.76e-07
Fuel Oil #4 Prod.	Toluene	secondary	6.37e-10	3.72e-07
Fuel Oil #6 Prod.	Acetophenone	secondary	6.16e-10	3.60e-07
Japanese Electric Grid	Benzo[a]anthracene	model/secondary	6.09e-10	3.56e-07
Fuel Oil #6 Prod.	Methyl chloride	secondary	6.01e-10	3.51e-07
Fuel Oil #4 Prod.	Acetaldehyde	secondary	5.65e-10	3.30e-07
LPG Production	Benzo[b,j,k]fluoranthene	secondary	5.60e-10	3.27e-07
Japanese Electric Grid	Ethylene dibromide	model/secondary	5.46e-10	3.19e-07
Japanese Electric Grid	Chlorobenzene	model/secondary	5.28e-10	3.09e-07
LPG Production	Benzo[a]pyrene	secondary	5.20e-10	3.04e-07
Fuel Oil #4 Prod.	Propionaldehyde	secondary	5.13e-10	3.00e-07
LPG Production	Benzo[g,h,i]perylene	secondary	4.22e-10	2.47e-07
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	4.13e-10	2.41e-07
Japanese Electric Grid	Chrysene	model/secondary	4.07e-10	2.38e-07
US electric grid	Pyrene	model/secondary	4.05e-10	2.37e-07
Fuel Oil #2 Prod.	Styrene	secondary	3.99e-10	2.33e-07
Japanese Electric Grid	Anthracene	model/secondary	3.47e-10	2.03e-07
Japanese Electric Grid	Indeno(1,2,3-cd)pyrene	model/secondary	3.41e-10	1.99e-07
Fuel Oil #6 Prod.	Dichloromethane	secondary	3.29e-10	1.92e-07
Japanese Electric Grid	Benzo[g,h,i]perylene	model/secondary	3.27e-10	1.91e-07
Fuel Oil #2 Prod.	Benzyl chloride	secondary	3.09e-10	1.80e-07
US electric grid	2,4-Dinitrotoluene	model/secondary	3.05e-10	1.78e-07
Japanese Electric Grid	Benzo[b,j,k]fluoranthene	model/secondary	2.96e-10	1.73e-07
Fuel Oil #2 Prod.	Methyl tert-butyl ether	secondary	2.92e-10	1.71e-07
Fuel Oil #4 Prod.	Acrolein	secondary	2.88e-10	1.68e-07
US electric grid	Acenaphthylene	model/secondary	2.74e-10	1.60e-07
Fuel Oil #2 Prod.	Phenol	secondary	2.56e-10	1.49e-07
Japanese Electric Grid	Acenaphthylene	model/secondary	2.51e-10	1.47e-07
Japanese Electric Grid	2,4-Dinitrotoluene	model/secondary	2.43e-10	1.42e-07
Fuel Oil #2 Prod.	Acetophenone	secondary	2.40e-10	1.40e-07
US electric grid	Anthracene	model/secondary	2.37e-10	1.38e-07
Fuel Oil #4 Prod.	n-Propane	secondary	2.34e-10	1.37e-07
Fuel Oil #2 Prod.	Methyl chloride	secondary	2.34e-10	1.37e-07

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #4 Prod.	o-xylene	secondary	2.30e-10	1.35e-07
Natural Gas Prod.	Styrene	secondary	2.21e-10	1.29e-07
Fuel Oil #6 Prod.	Cumene	secondary	2.18e-10	1.27e-07
US electric grid	2-Chloroacetophenone	model/secondary	2.10e-10	1.23e-07
Japanese Electric Grid	2-Methylnaphthalene	model/secondary	1.81e-10	1.06e-07
Natural Gas Prod.	Benzyl chloride	secondary	1.71e-10	9.97e-08
Japanese Electric Grid	2-Chloroacetophenone	model/secondary	1.68e-10	9.83e-08
Natural Gas Prod.	Methyl tert-butyl ether	secondary	1.62e-10	9.45e-08
Fuel Oil #4 Prod.	Ethylbenzene	secondary	1.61e-10	9.43e-08
Fuel Oil #4 Prod.	Bromomethane	secondary	1.43e-10	8.33e-08
Natural Gas Prod.	Phenol	secondary	1.41e-10	8.26e-08
Fuel Oil #6 Prod.	Aromatic hydrocarbons	secondary	1.35e-10	7.90e-08
Natural Gas Prod.	Acetophenone	secondary	1.32e-10	7.75e-08
Fuel Oil #6 Prod.	Phenanthrene	secondary	1.30e-10	7.62e-08
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	1.29e-10	7.56e-08
Natural Gas Prod.	Methyl chloride	secondary	1.29e-10	7.55e-08
Fuel Oil #2 Prod.	Dichloromethane	secondary	1.28e-10	7.47e-08
US electric grid	Chrysene	model/secondary	1.24e-10	7.25e-08
US electric grid	Benzo[a]anthracene	model/secondary	1.13e-10	6.59e-08
Fuel Oil #2 Prod.	Aromatic hydrocarbons	secondary	1.12e-10	6.56e-08
LPG Production	5-Methyl chrysene	secondary	1.12e-10	6.55e-08
Fuel Oil #6 Prod.	Vinyl acetate	secondary	9.15e-11	5.35e-08
Fuel Oil #2 Prod.	Cumene	secondary	8.47e-11	4.95e-08
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	8.01e-11	4.68e-08
Fuel Oil #4 Prod.	Naphthalene	secondary	7.67e-11	4.49e-08
Natural Gas Prod.	Dichloromethane	secondary	7.07e-11	4.13e-08
Fuel Oil #6 Prod.	Biphenyl	secondary	6.98e-11	4.08e-08
Fuel Oil #6 Prod.	Chloroform	secondary	6.69e-11	3.91e-08
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	5.68e-11	3.32e-08
Natural Gas Prod.	Phenanthrene	secondary	5.36e-11	3.14e-08
Fuel Oil #2 Prod.	Phenanthrene	secondary	5.35e-11	3.13e-08
Fuel Oil #6 Prod.	Tetrachloroethylene	secondary	4.87e-11	2.85e-08
Fuel Oil #6 Prod.	Ethyl Chloride	secondary	4.76e-11	2.78e-08
Natural Gas Prod.	Cumene	secondary	4.68e-11	2.74e-08
Fuel Oil #6 Prod.	1,2-Dichloroethane	secondary	4.53e-11	2.65e-08
LPG Production	Polycyclic aromatic hydrocarbons	secondary	4.44e-11	2.60e-08
US electric grid	Benzo[g,h,i]perylene	model/secondary	4.38e-11	2.56e-08
Fuel Oil #4 Prod.	Styrene	secondary	4.26e-11	2.49e-08
US electric grid	Benzo[a]pyrene	model/secondary	4.14e-11	2.42e-08
Natural Gas Prod.	2-Methylnaphthalene	secondary	4.12e-11	2.41e-08
Fuel Oil #6 Prod.	Fluorene	secondary	4.08e-11	2.39e-08
Fuel Oil #6 Prod.	1,4-Dichlorobenzene	secondary	3.60e-11	2.11e-08
Fuel Oil #2 Prod.	Vinyl acetate	secondary	3.56e-11	2.08e-08
Japanese Electric Grid	Benzo[a]pyrene	model/secondary	3.31e-11	1.93e-08
Fuel Oil #4 Prod.	Benzyl chloride	secondary	3.29e-11	1.92e-08
Fuel Oil #6 Prod.	Fluoranthene	secondary	3.28e-11	1.92e-08
US electric grid	2-Methylnaphthalene	model/secondary	3.24e-11	1.89e-08
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	3.12e-11	1.82e-08
Fuel Oil #4 Prod.	Phenol	secondary	2.73e-11	1.59e-08

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #2 Prod.	Biphenyl	secondary	2.72e-11	1.59e-08
Fuel Oil #6 Prod.	Acenaphthene	secondary	2.65e-11	1.55e-08
Fuel Oil #6 Prod.	2-Methylnaphthalene	secondary	2.61e-11	1.53e-08
Fuel Oil #2 Prod.	Chloroform	secondary	2.60e-11	1.52e-08
Fuel Oil #6 Prod.	Ethylene dibromide	secondary	2.58e-11	1.51e-08
Fuel Oil #4 Prod.	Acetophenone	secondary	2.56e-11	1.49e-08
Fuel Oil #6 Prod.	Chlorobenzene	secondary	2.49e-11	1.46e-08
Fuel Oil #4 Prod.	Methyl chloride	secondary	2.49e-11	1.46e-08
US electric grid	5-Methyl chrysene	model/secondary	2.40e-11	1.40e-08
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	2.27e-11	1.33e-08
Natural Gas Prod.	Vinyl acetate	secondary	1.97e-11	1.15e-08
Fuel Oil #6 Prod.	Pyrene	secondary	1.94e-11	1.13e-08
Japanese Electric Grid	5-Methyl chrysene	model/secondary	1.91e-11	1.12e-08
Fuel Oil #2 Prod.	Tetrachloroethylene	secondary	1.90e-11	1.11e-08
Fuel Oil #2 Prod.	1,4-Dichlorobenzene	secondary	1.87e-11	1.10e-08
Fuel Oil #2 Prod.	Ethyl Chloride	secondary	1.85e-11	1.08e-08
Fuel Oil #2 Prod.	1,2-Dichloroethane	secondary	1.76e-11	1.03e-08
Fuel Oil #2 Prod.	Fluorene	secondary	1.64e-11	9.61e-09
Natural Gas Prod.	Biphenyl	secondary	1.50e-11	8.78e-09
Natural Gas Prod.	Chloroform	secondary	1.44e-11	8.41e-09
Fuel Oil #4 Prod.	Dichloromethane	secondary	1.36e-11	7.97e-09
Fuel Oil #2 Prod.	2-Methylnaphthalene	secondary	1.36e-11	7.94e-09
Fuel Oil #2 Prod.	Fluoranthene	secondary	1.34e-11	7.82e-09
Natural Gas Prod.	Fluorene	secondary	1.31e-11	7.66e-09
Fuel Oil #6 Prod.	Acenaphthylene	secondary	1.23e-11	7.18e-09
Fuel Oil #2 Prod.	Acenaphthene	secondary	1.21e-11	7.09e-09
Natural Gas Prod.	Pyrene	secondary	1.17e-11	6.86e-09
Natural Gas Prod.	Fluoranthene	secondary	1.17e-11	6.84e-09
Fuel Oil #6 Prod.	2,4-Dinitrotoluene	secondary	1.15e-11	6.73e-09
Fuel Oil #6 Prod.	Anthracene	secondary	1.14e-11	6.69e-09
Natural Gas Prod.	Tetrachloroethylene	secondary	1.05e-11	6.13e-09
Natural Gas Prod.	Ethyl Chloride	secondary	1.02e-11	5.98e-09
Natural Gas Prod.	Acenaphthene	secondary	1.01e-11	5.89e-09
Fuel Oil #2 Prod.	Ethylene dibromide	secondary	1.00e-11	5.86e-09
Natural Gas Prod.	1,2-Dichloroethane	secondary	9.75e-12	5.70e-09
Fuel Oil #2 Prod.	Chlorobenzene	secondary	9.70e-12	5.67e-09
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	9.11e-12	5.33e-09
Fuel Oil #4 Prod.	Cumene	secondary	9.03e-12	5.28e-09
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	8.82e-12	5.15e-09
Fuel Oil #2 Prod.	Pyrene	secondary	8.40e-12	4.91e-09
Fuel Oil #6 Prod.	2-Chloroacetophenone	secondary	7.94e-12	4.64e-09
Fuel Oil #6 Prod.	Chrysene	secondary	6.27e-12	3.67e-09
Natural Gas Prod.	Anthracene	secondary	6.11e-12	3.57e-09
Fuel Oil #6 Prod.	Benzo[a]anthracene	secondary	5.93e-12	3.47e-09
Fuel Oil #4 Prod.	Phenanthrene	secondary	5.57e-12	3.26e-09
Natural Gas Prod.	Ethylene dibromide	secondary	5.54e-12	3.24e-09
Natural Gas Prod.	Chlorobenzene	secondary	5.36e-12	3.13e-09
Natural Gas Prod.	Acenaphthylene	secondary	5.32e-12	3.11e-09
Fuel Oil #2 Prod.	Acenaphthylene	secondary	5.05e-12	2.95e-09

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #2 Prod.	Anthracene	secondary	4.88e-12	2.86e-09
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	4.87e-12	2.85e-09
Fuel Oil #6 Prod.	Indeno(1,2,3-cd)pyrene	secondary	4.65e-12	2.72e-09
Fuel Oil #6 Prod.	Benzo[b,j,k]fluoranthene	secondary	4.52e-12	2.64e-09
Fuel Oil #2 Prod.	2,4-Dinitrotoluene	secondary	4.47e-12	2.62e-09
Natural Gas Prod.	Benzo[a]anthracene	secondary	4.27e-12	2.49e-09
Natural Gas Prod.	Chrysene	secondary	4.11e-12	2.40e-09
Fuel Oil #6 Prod.	Benzo[a]pyrene	secondary	3.88e-12	2.27e-09
Fuel Oil #4 Prod.	Vinyl acetate	secondary	3.79e-12	2.22e-09
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	3.75e-12	2.19e-09
Fuel Oil #2 Prod.	2-Chloroacetophenone	secondary	3.09e-12	1.80e-09
Fuel Oil #4 Prod.	Biphenyl	secondary	2.90e-12	1.69e-09
Fuel Oil #2 Prod.	Benzo[a]anthracene	secondary	2.86e-12	1.67e-09
Fuel Oil #2 Prod.	Chrysene	secondary	2.78e-12	1.63e-09
Fuel Oil #4 Prod.	Chloroform	secondary	2.77e-12	1.62e-09
Fuel Oil #6 Prod.	Benzo[g,h,i]perylene	secondary	2.61e-12	1.53e-09
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	2.47e-12	1.45e-09
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	2.43e-12	1.42e-09
Natural Gas Prod.	Benzo[a]pyrene	secondary	2.40e-12	1.40e-09
Fuel Oil #2 Prod.	Indeno(1,2,3-cd)pyrene	secondary	2.14e-12	1.25e-09
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	2.02e-12	1.18e-09
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	1.97e-12	1.15e-09
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	1.88e-12	1.10e-09
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	1.77e-12	1.04e-09
Fuel Oil #2 Prod.	Benzo[b,j,k]fluoranthene	secondary	1.76e-12	1.03e-09
Fuel Oil #4 Prod.	Fluorene	secondary	1.73e-12	1.01e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	1.71e-12	9.97e-10
Fuel Oil #2 Prod.	Benzo[a]pyrene	secondary	1.61e-12	9.41e-10
Fuel Oil #4 Prod.	Fluoranthene	secondary	1.40e-12	8.17e-10
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	1.28e-12	7.51e-10
Fuel Oil #2 Prod.	Benzo[g,h,i]perylene	secondary	1.27e-12	7.42e-10
Fuel Oil #4 Prod.	Acenaphthene	secondary	1.21e-12	7.05e-10
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	1.07e-12	6.25e-10
Fuel Oil #4 Prod.	Chlorobenzene	secondary	1.03e-12	6.05e-10
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	9.72e-13	5.68e-10
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	9.40e-13	5.50e-10
Fuel Oil #6 Prod.	5-Methyl chrysene	secondary	9.04e-13	5.28e-10
Fuel Oil #4 Prod.	Pyrene	secondary	8.54e-13	4.99e-10
Natural Gas Prod.	Aromatic hydrocarbons	secondary	8.08e-13	4.72e-10
Fuel Oil #4 Prod.	Acenaphthylene	secondary	5.25e-13	3.07e-10
Fuel Oil #4 Prod.	Anthracene	secondary	5.00e-13	2.92e-10
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	4.77e-13	2.79e-10
Fuel Oil #2 Prod.	5-Methyl chrysene	secondary	3.51e-13	2.05e-10
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	3.29e-13	1.92e-10
Fuel Oil #4 Prod.	Chrysene	secondary	2.80e-13	1.64e-10
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	2.78e-13	1.63e-10
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	2.12e-13	1.24e-10
Natural Gas Prod.	5-Methyl chrysene	secondary	1.94e-13	1.14e-10
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	1.87e-13	1.10e-10

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	1.67e-13	9.75e-11
Fuel Oil #6 Prod.	Polycyclic aromatic hydrocarbons	secondary	1.50e-13	8.78e-11
Fuel Oil #2 Prod.	Polycyclic aromatic hydrocarbons	secondary	1.25e-13	7.29e-11
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	1.23e-13	7.20e-11
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	3.75e-14	2.19e-11
Fuel Oil #4 Prod.	Polycyclic aromatic hydrocarbons	secondary	1.01e-14	5.92e-12
Natural Gas Prod.	Polycyclic aromatic hydrocarbons	secondary	8.98e-16	5.25e-13
Total Manufacturing			**1.21e-01**	**7.07e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Methane	model/secondary	4.51e-03	2.64e+00
US electric grid	Isophorone	model/secondary	3.96e-05	2.31e-02
US electric grid	Formaldehyde	model/secondary	3.56e-05	2.08e-02
US electric grid	Acetaldehyde	model/secondary	2.26e-05	1.32e-02
US electric grid	Benzene	model/secondary	2.21e-05	1.29e-02
US electric grid	Propionaldehyde	model/secondary	2.05e-05	1.20e-02
US electric grid	Methyl ethyl ketone	model/secondary	1.65e-05	9.67e-03
US electric grid	Toluene	model/secondary	1.43e-05	8.37e-03
US electric grid	Acrolein	model/secondary	1.15e-05	6.74e-03
US electric grid	Ethylbenzene	model/secondary	6.44e-06	3.77e-03
US electric grid	Bromomethane	model/secondary	5.71e-06	3.34e-03
US electric grid	Xylene (mixed isomers)	model/secondary	2.53e-06	1.48e-03
US electric grid	Hexane	model/secondary	2.50e-06	1.46e-03
US electric grid	Styrene	model/secondary	1.71e-06	9.98e-04
US electric grid	Naphthalene	model/secondary	1.39e-06	8.14e-04
US electric grid	Benzyl chloride	model/secondary	1.32e-06	7.71e-04
US electric grid	Methyl tert-butyl ether	model/secondary	1.25e-06	7.30e-04
US electric grid	Phenol	model/secondary	1.09e-06	6.38e-04
US electric grid	Acetophenone	model/secondary	1.02e-06	5.99e-04
US electric grid	Methyl chloride	model/secondary	9.98e-07	5.84e-04
US electric grid	Dichloromethane	model/secondary	5.46e-07	3.19e-04
US electric grid	Cumene	model/secondary	3.62e-07	2.11e-04
US electric grid	Phenanthrene	model/secondary	1.91e-07	1.11e-04
US electric grid	Vinyl acetate	model/secondary	1.52e-07	8.89e-05
US electric grid	Biphenyl	model/secondary	1.16e-07	6.78e-05
US electric grid	Chloroform	model/secondary	1.11e-07	6.50e-05
US electric grid	Tetrachloroethylene	model/secondary	8.10e-08	4.73e-05
US electric grid	Ethyl Chloride	model/secondary	7.91e-08	4.62e-05
US electric grid	1,2-Dichloroethane	model/secondary	7.53e-08	4.40e-05
US electric grid	Fluorene	model/secondary	6.39e-08	3.74e-05
US electric grid	Fluoranthene	model/secondary	5.11e-08	2.99e-05
US electric grid	o-xylene	model/secondary	4.34e-08	2.54e-05
US electric grid	Acenaphthene	model/secondary	4.32e-08	2.53e-05
US electric grid	Ethylene dibromide	model/secondary	4.28e-08	2.50e-05
US electric grid	Chlorobenzene	model/secondary	4.14e-08	2.42e-05
US electric grid	1,1,1-Trichloroethane	model/secondary	4.03e-08	2.35e-05
US electric grid	Pyrene	model/secondary	2.53e-08	1.48e-05
US electric grid	2,4-Dinitrotoluene	model/secondary	1.91e-08	1.12e-05
US electric grid	Acenaphthylene	model/secondary	1.72e-08	1.00e-05
US electric grid	Anthracene	model/secondary	1.48e-08	8.66e-06

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
US electric grid	2-Chloroacetophenone	model/secondary	1.32e-08	7.71e-06
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	8.10e-09	4.73e-06
US electric grid	Chrysene	model/secondary	7.77e-09	4.54e-06
US electric grid	Benzo[a]anthracene	model/secondary	7.06e-09	4.13e-06
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	5.02e-09	2.93e-06
US electric grid	Benzo[g,h,i]perylene	model/secondary	2.74e-09	1.60e-06
US electric grid	Benzo[a]pyrene	model/secondary	2.59e-09	1.52e-06
US electric grid	2-Methylnaphthalene	model/secondary	2.03e-09	1.19e-06
US electric grid	5-Methyl chrysene	model/secondary	1.50e-09	8.78e-07
Total Use, Maintenance and Repair			**4.72e-03**	**2.76e+00**
End-of-life Life-cycle Stage				
CRT landfilling	Hydrocarbons, remaining unspeciated	primary	1.07e-04	6.28e-02
LPG Production	Hydrocarbons, remaining unspeciated	secondary	5.37e-07	3.14e-04
US electric grid	Methane	model/secondary	4.52e-07	2.64e-04
CRT landfilling	Methane	primary	3.81e-07	2.23e-04
LPG Production	Nonmethane hydrocarbons, remaining unspeciated	secondary	3.66e-07	2.14e-04
CRT landfilling	Benzene	primary	1.28e-07	7.48e-05
LPG Production	Methane	secondary	5.07e-08	2.96e-05
CRT landfilling	Toluene	primary	2.69e-08	1.57e-05
LPG Production	Benzene	secondary	2.34e-08	1.37e-05
CRT landfilling	Xylene (mixed isomers)	primary	1.88e-08	1.10e-05
LPG Production	Aldehydes	secondary	5.71e-09	3.34e-06
LPG Production	Formaldehyde	secondary	4.25e-09	2.49e-06
US electric grid	Isophorone	model/secondary	3.96e-09	2.32e-06
CRT landfilling	Ethylbenzene	primary	3.75e-09	2.19e-06
US electric grid	Formaldehyde	model/secondary	3.56e-09	2.08e-06
LPG Production	Ethane	secondary	2.66e-09	1.56e-06
LPG Production	Pentane	secondary	2.29e-09	1.34e-06
US electric grid	Acetaldehyde	model/secondary	2.27e-09	1.32e-06
US electric grid	Benzene	model/secondary	2.21e-09	1.29e-06
US electric grid	Propionaldehyde	model/secondary	2.06e-09	1.20e-06
LPG Production	Butane	secondary	1.81e-09	1.06e-06
US electric grid	Methyl ethyl ketone	model/secondary	1.66e-09	9.68e-07
LPG Production	Hexane	secondary	1.62e-09	9.47e-07
US electric grid	Toluene	model/secondary	1.43e-09	8.37e-07
US electric grid	Acrolein	model/secondary	1.15e-09	6.74e-07
US electric grid	Ethylbenzene	model/secondary	6.44e-10	3.77e-07
US electric grid	Bromomethane	model/secondary	5.71e-10	3.34e-07
US electric grid	Xylene (mixed isomers)	model/secondary	2.53e-10	1.48e-07
US electric grid	Hexane	model/secondary	2.50e-10	1.46e-07
US electric grid	Styrene	model/secondary	1.71e-10	9.98e-08
US electric grid	Naphthalene	model/secondary	1.39e-10	8.14e-08
US electric grid	Benzyl chloride	model/secondary	1.32e-10	7.71e-08
US electric grid	Methyl tert-butyl ether	model/secondary	1.25e-10	7.31e-08
US electric grid	Phenol	model/secondary	1.09e-10	6.39e-08
US electric grid	Acetophenone	model/secondary	1.02e-10	5.99e-08
US electric grid	Methyl chloride	model/secondary	9.99e-11	5.84e-08
CRT Incineration	Trichloroethylene	secondary	9.69e-11	5.67e-08
CRT landfilling	Trichloroethylene	primary	9.04e-11	5.28e-08

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
CRT Incineration	Vinyl chloride	secondary	6.16e-11	3.60e-08
CRT landfilling	Vinyl chloride	primary	5.74e-11	3.36e-08
US electric grid	Dichloromethane	model/secondary	5.46e-11	3.19e-08
CRT landfilling	Dichloromethane	primary	4.60e-11	2.69e-08
US electric grid	Cumene	model/secondary	3.62e-11	2.12e-08
CRT Incineration	Carbon tetrachloride	secondary	3.08e-11	1.80e-08
CRT landfilling	1,2-Dichloroethane	primary	2.87e-11	1.68e-08
CRT landfilling	Carbon tetrachloride	primary	2.87e-11	1.68e-08
CRT landfilling	Chloroform	primary	2.87e-11	1.68e-08
CRT landfilling	Tetrachloroethylene	primary	2.87e-11	1.68e-08
LPG Production	Isophorone	secondary	2.55e-11	1.49e-08
US electric grid	Phenanthrene	model/secondary	1.91e-11	1.12e-08
LPG Production	Toluene	secondary	1.81e-11	1.06e-08
US electric grid	Vinyl acetate	model/secondary	1.52e-11	8.89e-09
LPG Production	Acetaldehyde	secondary	1.46e-11	8.53e-09
LPG Production	Propionaldehyde	secondary	1.32e-11	7.74e-09
US electric grid	Biphenyl	model/secondary	1.16e-11	6.79e-09
US electric grid	Chloroform	model/secondary	1.11e-11	6.50e-09
LPG Production	Methyl ethyl ketone	secondary	1.07e-11	6.23e-09
US electric grid	Tetrachloroethylene	model/secondary	8.10e-12	4.74e-09
US electric grid	Ethyl Chloride	model/secondary	7.91e-12	4.63e-09
US electric grid	1,2-Dichloroethane	model/secondary	7.54e-12	4.41e-09
LPG Production	Acrolein	secondary	7.42e-12	4.34e-09
LPG Production	o-xylene	secondary	6.78e-12	3.96e-09
US electric grid	Fluorene	model/secondary	6.39e-12	3.74e-09
LPG Production	n-Propane	secondary	6.05e-12	3.54e-09
US electric grid	Fluoranthene	model/secondary	5.11e-12	2.99e-09
US electric grid	o-xylene	model/secondary	4.35e-12	2.54e-09
US electric grid	Acenaphthene	model/secondary	4.32e-12	2.53e-09
US electric grid	Ethylene dibromide	model/secondary	4.29e-12	2.51e-09
LPG Production	Ethylbenzene	secondary	4.17e-12	2.44e-09
US electric grid	Chlorobenzene	model/secondary	4.15e-12	2.42e-09
US electric grid	1,1,1-Trichloroethane	model/secondary	4.03e-12	2.36e-09
LPG Production	Bromomethane	secondary	3.68e-12	2.15e-09
US electric grid	Pyrene	model/secondary	2.54e-12	1.48e-09
LPG Production	Naphthalene	secondary	2.29e-12	1.34e-09
US electric grid	2,4-Dinitrotoluene	model/secondary	1.91e-12	1.12e-09
US electric grid	Acenaphthylene	model/secondary	1.72e-12	1.00e-09
US electric grid	Anthracene	model/secondary	1.48e-12	8.67e-10
US electric grid	2-Chloroacetophenone	model/secondary	1.32e-12	7.71e-10
LPG Production	Styrene	secondary	1.10e-12	6.42e-10
LPG Production	Benzyl chloride	secondary	8.49e-13	4.96e-10
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	8.10e-13	4.74e-10
LPG Production	Methyl tert-butyl ether	secondary	8.05e-13	4.70e-10
US electric grid	Chrysene	model/secondary	7.78e-13	4.55e-10
US electric grid	Benzo[a]anthracene	model/secondary	7.06e-13	4.13e-10
LPG Production	Phenol	secondary	7.03e-13	4.11e-10
LPG Production	Acetophenone	secondary	6.59e-13	3.85e-10
LPG Production	Methyl chloride	secondary	6.43e-13	3.76e-10

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	5.02e-13	2.93e-10
LPG Production	Dichloromethane	secondary	3.52e-13	2.06e-10
LPG Production	Aromatic hydrocarbons	secondary	3.45e-13	2.02e-10
US electric grid	Benzo[g,h,i]perylene	model/secondary	2.74e-13	1.60e-10
US electric grid	Benzo[a]pyrene	model/secondary	2.59e-13	1.52e-10
LPG Production	Cumene	secondary	2.33e-13	1.36e-10
US electric grid	2-Methylnaphthalene	model/secondary	2.03e-13	1.19e-10
US electric grid	5-Methyl chrysene	model/secondary	1.50e-13	8.78e-11
LPG Production	Phenanthrene	secondary	1.49e-13	8.70e-11
LPG Production	Vinyl acetate	secondary	9.79e-14	5.72e-11
LPG Production	Biphenyl	secondary	7.47e-14	4.37e-11
LPG Production	Chloroform	secondary	7.16e-14	4.18e-11
LPG Production	1,4-Dichlorobenzene	secondary	5.44e-14	3.18e-11
LPG Production	Tetrachloroethylene	secondary	5.22e-14	3.05e-11
LPG Production	Ethyl Chloride	secondary	5.09e-14	2.98e-11
LPG Production	1,2-Dichloroethane	secondary	4.85e-14	2.84e-11
LPG Production	Fluorene	secondary	4.56e-14	2.66e-11
LPG Production	2-Methylnaphthalene	secondary	3.94e-14	2.31e-11
LPG Production	Fluoranthene	secondary	3.72e-14	2.17e-11
LPG Production	Acenaphthene	secondary	3.44e-14	2.01e-11
LPG Production	Ethylene dibromide	secondary	2.76e-14	1.61e-11
LPG Production	Chlorobenzene	secondary	2.67e-14	1.56e-11
LPG Production	1,1,1-Trichloroethane	secondary	2.43e-14	1.42e-11
LPG Production	Pyrene	secondary	2.36e-14	1.38e-11
LPG Production	Acenaphthylene	secondary	1.41e-14	8.22e-12
LPG Production	Anthracene	secondary	1.37e-14	8.01e-12
LPG Production	2,4-Dinitrotoluene	secondary	1.23e-14	7.20e-12
LPG Production	2-Chloroacetophenone	secondary	8.49e-15	4.96e-12
LPG Production	Benzo[a]anthracene	secondary	8.20e-15	4.79e-12
LPG Production	Chrysene	secondary	7.87e-15	4.60e-12
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	6.10e-15	3.57e-12
LPG Production	Benzo[b,j,k]fluoranthene	secondary	4.83e-15	2.83e-12
LPG Production	Benzo[a]pyrene	secondary	4.49e-15	2.62e-12
LPG Production	Benzo[g,h,i]perylene	secondary	3.65e-15	2.13e-12
LPG Production	5-Methyl chrysene	secondary	9.67e-16	5.65e-13
LPG Production	Polycyclic aromatic hydrocarbons	secondary	3.83e-16	2.24e-13
Natural Gas Prod.	Polycyclic aromatic hydrocarbons	secondary	-4.51e-16	-2.63e-13
CRT Incineration	Polycyclic aromatic hydrocarbons	secondary	-6.98e-15	-4.08e-12
Natural Gas Prod.	5-Methyl chrysene	secondary	-9.74e-14	-5.70e-11
Fuel Oil #4 Prod.	Polycyclic aromatic hydrocarbons	secondary	-1.09e-13	-6.36e-11
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	-4.03e-13	-2.36e-10
Natural Gas Prod.	Aromatic hydrocarbons	secondary	-4.05e-13	-2.37e-10
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	-4.87e-13	-2.85e-10
Natural Gas Prod.	2-Chloroacetophenone	secondary	-8.56e-13	-5.00e-10
Natural Gas Prod.	Benzo[a]pyrene	secondary	-1.20e-12	-7.02e-10
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	-1.22e-12	-7.12e-10
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	-1.24e-12	-7.25e-10
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	-1.32e-12	-7.74e-10
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	-1.79e-12	-1.05e-09

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	-1.88e-12	-1.10e-09
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	-2.01e-12	-1.18e-09
Natural Gas Prod.	Chrysene	secondary	-2.06e-12	-1.21e-09
Natural Gas Prod.	Benzo[a]anthracene	secondary	-2.14e-12	-1.25e-09
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	-2.28e-12	-1.34e-09
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-2.44e-12	-1.43e-09
Natural Gas Prod.	Acenaphthylene	secondary	-2.67e-12	-1.56e-09
Natural Gas Prod.	Chlorobenzene	secondary	-2.69e-12	-1.57e-09
Natural Gas Prod.	Ethylene dibromide	secondary	-2.78e-12	-1.63e-09
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	-2.99e-12	-1.75e-09
Fuel Oil #4 Prod.	Chrysene	secondary	-3.01e-12	-1.76e-09
Natural Gas Prod.	Anthracene	secondary	-3.07e-12	-1.79e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	-3.54e-12	-2.07e-09
Natural Gas Prod.	1,2-Dichloroethane	secondary	-4.89e-12	-2.86e-09
Natural Gas Prod.	Acenaphthene	secondary	-5.05e-12	-2.95e-09
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	-5.13e-12	-3.00e-09
Natural Gas Prod.	Ethyl Chloride	secondary	-5.13e-12	-3.00e-09
Natural Gas Prod.	Tetrachloroethylene	secondary	-5.26e-12	-3.07e-09
Fuel Oil #4 Prod.	Anthracene	secondary	-5.38e-12	-3.14e-09
Fuel Oil #4 Prod.	Acenaphthylene	secondary	-5.64e-12	-3.30e-09
Natural Gas Prod.	Fluoranthene	secondary	-5.87e-12	-3.43e-09
Natural Gas Prod.	Pyrene	secondary	-5.89e-12	-3.44e-09
CRT Incineration	Aromatic hydrocarbons	secondary	-6.29e-12	-3.68e-09
Natural Gas Prod.	Fluorene	secondary	-6.57e-12	-3.84e-09
CRT Incineration	2-Methylnaphthalene	secondary	-6.63e-12	-3.88e-09
Natural Gas Prod.	Chloroform	secondary	-7.21e-12	-4.22e-09
Natural Gas Prod.	Biphenyl	secondary	-7.53e-12	-4.40e-09
CRT Incineration	Dichlorobenzene (mixed isomers)	secondary	-9.15e-12	-5.35e-09
Fuel Oil #4 Prod.	Pyrene	secondary	-9.18e-12	-5.37e-09
Natural Gas Prod.	Vinyl acetate	secondary	-9.86e-12	-5.77e-09
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-1.01e-11	-5.91e-09
Fuel Oil #4 Prod.	Chlorobenzene	secondary	-1.11e-11	-6.50e-09
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	-1.15e-11	-6.72e-09
Fuel Oil #4 Prod.	Acenaphthene	secondary	-1.30e-11	-7.58e-09
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	-1.38e-11	-8.07e-09
Fuel Oil #4 Prod.	Fluoranthene	secondary	-1.50e-11	-8.78e-09
Fuel Oil #4 Prod.	Fluorene	secondary	-1.85e-11	-1.08e-08
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	-1.91e-11	-1.11e-08
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	-2.02e-11	-1.18e-08
Natural Gas Prod.	2-Methylnaphthalene	secondary	-2.06e-11	-1.21e-08
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	-2.12e-11	-1.24e-08
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	-2.17e-11	-1.27e-08
Natural Gas Prod.	Cumene	secondary	-2.35e-11	-1.37e-08
CRT Incineration	5-Methyl chrysene	secondary	-2.49e-11	-1.46e-08
Natural Gas Prod.	Phenanthrene	secondary	-2.69e-11	-1.57e-08
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	-2.85e-11	-1.67e-08
Fuel Oil #4 Prod.	Chloroform	secondary	-2.98e-11	-1.74e-08
CRT Incineration	Benzo[g,h,i]perylene	secondary	-3.09e-11	-1.81e-08
Fuel Oil #4 Prod.	Biphenyl	secondary	-3.11e-11	-1.82e-08

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Natural Gas Prod.	Dichloromethane	secondary	-3.54e-11	-2.07e-08
Fuel Oil #4 Prod.	Vinyl acetate	secondary	-4.08e-11	-2.38e-08
CRT Incineration	Benzo[a]pyrene	secondary	-4.34e-11	-2.53e-08
Fuel Oil #4 Prod.	Phenanthrene	secondary	-5.99e-11	-3.50e-08
Natural Gas Prod.	Methyl chloride	secondary	-6.48e-11	-3.79e-08
Natural Gas Prod.	Acetophenone	secondary	-6.64e-11	-3.88e-08
CRT Incineration	Indeno(1,2,3-cd)pyrene	secondary	-6.95e-11	-4.07e-08
Natural Gas Prod.	Phenol	secondary	-7.09e-11	-4.14e-08
Natural Gas Prod.	Methyl tert-butyl ether	secondary	-8.11e-11	-4.74e-08
Natural Gas Prod.	Benzyl chloride	secondary	-8.56e-11	-5.00e-08
CRT Incineration	Benzo[a]anthracene	secondary	-9.11e-11	-5.32e-08
Fuel Oil #4 Prod.	Cumene	secondary	-9.70e-11	-5.67e-08
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	-9.80e-11	-5.73e-08
Natural Gas Prod.	Styrene	secondary	-1.11e-10	-6.47e-08
CRT Incineration	Chrysene	secondary	-1.14e-10	-6.65e-08
CRT Incineration	Benzo[b,j,k]fluoranthene	secondary	-1.24e-10	-7.28e-08
Fuel Oil #4 Prod.	Dichloromethane	secondary	-1.47e-10	-8.57e-08
CRT Incineration	Anthracene	secondary	-2.38e-10	-1.39e-07
Fuel Oil #4 Prod.	Methyl chloride	secondary	-2.68e-10	-1.57e-07
Fuel Oil #4 Prod.	Acetophenone	secondary	-2.75e-10	-1.61e-07
CRT Incineration	Acenaphthylene	secondary	-2.83e-10	-1.66e-07
Fuel Oil #4 Prod.	Phenol	secondary	-2.93e-10	-1.71e-07
CRT Incineration	2,4-Dinitrotoluene	secondary	-3.17e-10	-1.85e-07
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	-3.35e-10	-1.96e-07
Fuel Oil #4 Prod.	Benzyl chloride	secondary	-3.54e-10	-2.07e-07
Natural Gas Prod.	Bromomethane	secondary	-3.71e-10	-2.17e-07
CRT Incineration	Pyrene	secondary	-3.75e-10	-2.19e-07
Natural Gas Prod.	Ethylbenzene	secondary	-4.21e-10	-2.46e-07
Fuel Oil #4 Prod.	Styrene	secondary	-4.58e-10	-2.68e-07
CRT Incineration	Acenaphthene	secondary	-5.78e-10	-3.38e-07
CRT Incineration	1,1,1-Trichloroethane	secondary	-6.24e-10	-3.65e-07
Natural Gas Prod.	n-Propane	secondary	-6.72e-10	-3.93e-07
Natural Gas Prod.	Naphthalene	secondary	-6.72e-10	-3.93e-07
CRT Incineration	Chlorobenzene	secondary	-6.87e-10	-4.02e-07
CRT Incineration	Ethylene dibromide	secondary	-7.10e-10	-4.15e-07
Natural Gas Prod.	Acrolein	secondary	-7.48e-10	-4.37e-07
CRT Incineration	Fluoranthene	secondary	-8.04e-10	-4.70e-07
Fuel Oil #4 Prod.	Naphthalene	secondary	-8.25e-10	-4.82e-07
CRT Incineration	Fluorene	secondary	-1.03e-09	-6.02e-07
Natural Gas Prod.	Methyl ethyl ketone	secondary	-1.07e-09	-6.28e-07
CRT Incineration	1,2-Dichloroethane	secondary	-1.22e-09	-7.12e-07
CRT Incineration	Ethyl Chloride	secondary	-1.31e-09	-7.67e-07
CRT Incineration	Tetrachloroethylene	secondary	-1.31e-09	-7.67e-07
Natural Gas Prod.	Propionaldehyde	secondary	-1.33e-09	-7.80e-07
Natural Gas Prod.	Acetaldehyde	secondary	-1.47e-09	-8.59e-07
Fuel Oil #4 Prod.	Bromomethane	secondary	-1.53e-09	-8.96e-07
Fuel Oil #4 Prod.	Ethylbenzene	secondary	-1.73e-09	-1.01e-06
CRT Incineration	Chloroform	secondary	-1.81e-09	-1.06e-06
CRT Incineration	Biphenyl	secondary	-1.92e-09	-1.12e-06

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #4 Prod.	o-xylene	secondary	-2.47e-09	-1.45e-06
Fuel Oil #4 Prod.	n-Propane	secondary	-2.51e-09	-1.47e-06
CRT Incineration	Vinyl acetate	secondary	-2.52e-09	-1.47e-06
Natural Gas Prod.	Isophorone	secondary	-2.57e-09	-1.50e-06
CRT Incineration	Phenanthrene	secondary	-3.06e-09	-1.79e-06
Fuel Oil #4 Prod.	Acrolein	secondary	-3.09e-09	-1.81e-06
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	-4.44e-09	-2.60e-06
Fuel Oil #4 Prod.	Propionaldehyde	secondary	-5.51e-09	-3.22e-06
CRT Incineration	Cumene	secondary	-6.00e-09	-3.51e-06
Fuel Oil #4 Prod.	Acetaldehyde	secondary	-6.08e-09	-3.55e-06
Fuel Oil #4 Prod.	Toluene	secondary	-6.85e-09	-4.00e-06
CRT Incineration	Dichloromethane	secondary	-9.01e-09	-5.27e-06
Fuel Oil #4 Prod.	Isophorone	secondary	-1.06e-08	-6.21e-06
Natural Gas Prod.	Toluene	secondary	-1.46e-08	-8.52e-06
CRT Incineration	Methyl chloride	secondary	-1.65e-08	-9.67e-06
CRT Incineration	Acetophenone	secondary	-1.70e-08	-9.92e-06
CRT Incineration	Phenol	secondary	-1.81e-08	-1.06e-05
CRT Incineration	Methyl tert-butyl ether	secondary	-2.07e-08	-1.21e-05
CRT Incineration	Naphthalene	secondary	-2.09e-08	-1.22e-05
CRT Incineration	Benzyl chloride	secondary	-2.19e-08	-1.28e-05
CRT Incineration	Xylene (mixed isomers)	secondary	-2.44e-08	-1.43e-05
Natural Gas Prod.	o-xylene	secondary	-2.64e-08	-1.54e-05
CRT Incineration	Styrene	secondary	-2.83e-08	-1.65e-05
Natural Gas Prod.	Formaldehyde	secondary	-5.11e-08	-2.99e-05
CRT Incineration	Bromomethane	secondary	-9.47e-08	-5.54e-05
CRT Incineration	Ethylbenzene	secondary	-1.03e-07	-6.00e-05
CRT Incineration	n-Propane	secondary	-1.52e-07	-8.90e-05
CRT Incineration	Acrolein	secondary	-1.91e-07	-1.12e-04
CRT Incineration	Toluene	secondary	-2.25e-07	-1.31e-04
CRT Incineration	Methyl ethyl ketone	secondary	-2.74e-07	-1.60e-04
CRT Incineration	Butane	secondary	-3.03e-07	-1.77e-04
CRT Incineration	Hexane	secondary	-3.13e-07	-1.83e-04
CRT Incineration	Propionaldehyde	secondary	-3.41e-07	-1.99e-04
CRT Incineration	Acetaldehyde	secondary	-3.75e-07	-2.20e-04
CRT Incineration	Pentane	secondary	-3.85e-07	-2.25e-04
CRT Incineration	Ethane	secondary	-4.48e-07	-2.62e-04
Fuel Oil #4 Prod.	Hexane	secondary	-5.67e-07	-3.31e-04
Fuel Oil #4 Prod.	Butane	secondary	-6.32e-07	-3.69e-04
CRT Incineration	Isophorone	secondary	-6.56e-07	-3.84e-04
Fuel Oil #4 Prod.	Pentane	secondary	-8.02e-07	-4.69e-04
Natural Gas Prod.	Hexane	secondary	-8.46e-07	-4.95e-04
Fuel Oil #4 Prod.	Ethane	secondary	-9.33e-07	-5.45e-04
Natural Gas Prod.	Butane	secondary	-9.45e-07	-5.52e-04
Natural Gas Prod.	Pentane	secondary	-1.20e-06	-7.01e-04
Natural Gas Prod.	Ethane	secondary	-1.39e-06	-8.15e-04
CRT Incineration	Formaldehyde	secondary	-1.64e-06	-9.60e-04
Fuel Oil #4 Prod.	Aldehydes	secondary	-2.00e-06	-1.17e-03
Fuel Oil #4 Prod.	Formaldehyde	secondary	-2.03e-06	-1.19e-03
Natural Gas Prod.	Aldehydes	secondary	-2.39e-06	-1.40e-03

Table M-17. CRT LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #4 Prod.	Benzene	secondary	-8.19e-06	-4.79e-03
CRT Incineration	Benzene	secondary	-1.00e-05	-5.87e-03
Natural Gas Prod.	Hydrocarbons, remaining unspeciated	secondary	-1.24e-05	-7.26e-03
Fuel Oil #4 Prod.	Methane	secondary	-1.96e-05	-1.15e-02
CRT Incineration	Aldehydes	secondary	-6.76e-05	-3.95e-02
CRT Incineration	Methane	secondary	-1.06e-04	-6.20e-02
CRT Incineration	Hydrocarbons, remaining unspeciated	secondary	-1.07e-04	-6.27e-02
Natural Gas Prod.	Benzene	secondary	-1.20e-04	-7.02e-02
CRT Incineration	Nonmethane hydrocarbons, remaining unspeciated	secondary	-1.54e-04	-9.02e-02
Fuel Oil #4 Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	-1.56e-04	-9.11e-02
Natural Gas Prod.	Methane	secondary	-1.76e-04	-1.03e-01
Fuel Oil #4 Prod.	Hydrocarbons, remaining unspeciated	secondary	-2.32e-04	-1.36e-01
Natural Gas Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	-4.52e-04	-2.64e-01
Total End-of-life			**-1.53e-03**	**-8.95e-01**
Total All Life-cycle Stages			**1.71e-01**	**1.00e+02**

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Materials Processing Life-cycle Stage				
Natural Gas Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	6.30e-02	4.45e+01
Natural Gas Prod.	Methane	secondary	2.45e-02	1.73e+01
Natural Gas Prod.	Benzene	secondary	1.67e-02	1.18e+01
Steel Prod., cold-rolled, semi-finished	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.62e-02	1.15e+01
Natural Gas Prod.	Hydrocarbons, remaining unspeciated	secondary	1.73e-03	1.22e+00
Steel Prod., cold-rolled, semi-finished	Hydrocarbons, remaining unspeciated	secondary	1.68e-03	1.19e+00
PMMA Sheet Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.24e-03	8.74e-01
Polycarbonate Production	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.03e-03	7.26e-01
Aluminum Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	5.48e-04	3.87e-01
PET Resin Production	Nonmethane hydrocarbons, remaining unspeciated	secondary	5.06e-04	3.58e-01
Natural Gas Prod.	Aldehydes	secondary	3.33e-04	2.36e-01
Styrene-butadiene Copolymer Prod.	Hydrocarbons, remaining unspeciated	secondary	2.88e-04	2.04e-01
Natural Gas Prod.	Ethane	secondary	1.94e-04	1.37e-01
Natural Gas Prod.	Pentane	secondary	1.67e-04	1.18e-01
Natural Gas Prod.	Butane	secondary	1.32e-04	9.30e-02
Natural Gas Prod.	Hexane	secondary	1.18e-04	8.34e-02
Steel Prod., cold-rolled, semi-finished	Ethylene	secondary	1.02e-04	7.18e-02
PMMA Sheet Prod.	Methane	secondary	8.05e-05	5.69e-02
Polycarbonate Production	Methane	secondary	7.94e-05	5.62e-02
Steel Prod., cold-rolled, semi-finished	Ethane	secondary	4.80e-05	3.39e-02
Steel Prod., cold-rolled, semi-finished	Methane	secondary	3.74e-05	2.64e-02
Polycarbonate Production	Aromatic hydrocarbons	secondary	3.49e-05	2.47e-02
Styrene-butadiene Copolymer Prod.	Aromatic hydrocarbons	secondary	2.26e-05	1.60e-02
Styrene-butadiene Copolymer Prod.	Methane	secondary	2.10e-05	1.49e-02
Aluminum Prod.	Methane	secondary	2.10e-05	1.48e-02
Steel Prod., cold-rolled, semi-finished	n-Propane	secondary	1.88e-05	1.33e-02
PMMA Sheet Prod.	Aldehydes	secondary	1.87e-05	1.32e-02
Polycarbonate Production	Aldehydes	secondary	1.46e-05	1.03e-02
Steel Prod., cold-rolled, semi-finished	Propylene	secondary	1.22e-05	8.62e-03
Steel Prod., cold-rolled, semi-finished	Aldehydes	secondary	9.25e-06	6.54e-03
Natural Gas Prod.	Formaldehyde	secondary	7.11e-06	5.03e-03
PET Resin Production	Methane	secondary	6.99e-06	4.94e-03
Aluminum Prod.	Xylene (mixed isomers)	secondary	5.24e-06	3.71e-03
Aluminum Prod.	Polycyclic aromatic hydrocarbons	secondary	5.13e-06	3.63e-03
Steel Prod., cold-rolled, semi-finished	Butane	secondary	4.43e-06	3.13e-03
Natural Gas Prod.	o-xylene	secondary	3.68e-06	2.60e-03
Steel Prod., cold-rolled, semi-finished	Pentane	secondary	3.39e-06	2.40e-03
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	2.58e-06	1.82e-03
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	2.14e-06	1.51e-03
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	2.04e-06	1.44e-03
Natural Gas Prod.	Toluene	secondary	2.03e-06	1.44e-03
Steel Prod., cold-rolled, semi-finished	Acetylene	secondary	1.92e-06	1.36e-03
Aluminum Prod.	Toluene	secondary	1.74e-06	1.23e-03
Aluminum Prod.	Aldehydes	secondary	1.71e-06	1.21e-03
Steel Prod., cold-rolled, semi-finished	Hexane	secondary	9.03e-07	6.39e-04
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	7.47e-07	5.28e-04
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	7.00e-07	4.95e-04
PMMA Sheet Prod.	Aromatic hydrocarbons	secondary	5.84e-07	4.13e-04
Aluminum Prod.	Alcohols	secondary	5.58e-07	3.94e-04

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Aluminum Prod.	Benzene	secondary	4.55e-07	3.21e-04
Steel Prod., cold-rolled, semi-finished	Heptane	secondary	4.32e-07	3.05e-04
Natural Gas Prod.	Isophorone	secondary	3.58e-07	2.53e-04
Steel Prod., cold-rolled, semi-finished	Aromatic hydrocarbons	secondary	2.47e-07	1.75e-04
Steel Prod., cold-rolled, semi-finished	Methanol	secondary	2.17e-07	1.53e-04
Natural Gas Prod.	Acetaldehyde	secondary	2.05e-07	1.45e-04
Natural Gas Prod.	Propionaldehyde	secondary	1.86e-07	1.31e-04
Steel Prod., cold-rolled, semi-finished	Ethanol	secondary	1.74e-07	1.23e-04
Natural Gas Prod.	Methyl ethyl ketone	secondary	1.50e-07	1.06e-04
Steel Prod., cold-rolled, semi-finished	Acetaldehyde	secondary	1.45e-07	1.03e-04
Steel Prod., cold-rolled, semi-finished	Ethylbenzene	secondary	1.15e-07	8.14e-05
Natural Gas Prod.	Acrolein	secondary	1.04e-07	7.36e-05
Polycarbonate Production	Ethanethiol	secondary	1.03e-07	7.26e-05
Natural Gas Prod.	Naphthalene	secondary	9.37e-08	6.62e-05
Natural Gas Prod.	n-Propane	secondary	9.36e-08	6.61e-05
PMMA Sheet Prod.	Ethanethiol	secondary	7.63e-08	5.40e-05
Natural Gas Prod.	Ethylbenzene	secondary	5.87e-08	4.15e-05
Steel Prod., cold-rolled, semi-finished	Acetone	secondary	5.80e-08	4.10e-05
Natural Gas Prod.	Bromomethane	secondary	5.16e-08	3.65e-05
PET Resin Production	Aldehydes	secondary	4.02e-08	2.84e-05
Styrene-butadiene Copolymer Prod.	Aldehydes	secondary	4.01e-08	2.83e-05
Steel Prod., cold-rolled, semi-finished	Benzo[a]pyrene	secondary	3.33e-08	2.35e-05
Steel Prod., cold-rolled, semi-finished	Polycyclic aromatic hydrocarbons	secondary	1.82e-08	1.29e-05
Natural Gas Prod.	Styrene	secondary	1.54e-08	1.09e-05
Natural Gas Prod.	Benzyl chloride	secondary	1.19e-08	8.43e-06
Natural Gas Prod.	Methyl tert-butyl ether	secondary	1.13e-08	7.98e-06
Natural Gas Prod.	Phenol	secondary	9.87e-09	6.98e-06
Natural Gas Prod.	Acetophenone	secondary	9.25e-09	6.54e-06
Natural Gas Prod.	Methyl chloride	secondary	9.02e-09	6.38e-06
Steel Prod., cold-rolled, semi-finished	Naphthalene	secondary	5.55e-09	3.92e-06
Natural Gas Prod.	Dichloromethane	secondary	4.94e-09	3.49e-06
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	3.97e-09	2.80e-06
Natural Gas Prod.	Phenanthrene	secondary	3.75e-09	2.65e-06
Natural Gas Prod.	Cumene	secondary	3.27e-09	2.31e-06
Natural Gas Prod.	2-Methylnaphthalene	secondary	2.88e-09	2.03e-06
Aluminum Prod.	1,2-Dichlorotetrafluoroethane	secondary	1.87e-09	1.32e-06
Natural Gas Prod.	Vinyl acetate	secondary	1.37e-09	9.71e-07
Aluminum Prod.	Phenol	secondary	1.13e-09	8.00e-07
Natural Gas Prod.	Biphenyl	secondary	1.05e-09	7.41e-07
Natural Gas Prod.	Chloroform	secondary	1.00e-09	7.10e-07
Natural Gas Prod.	Fluorene	secondary	9.15e-10	6.47e-07
Natural Gas Prod.	Pyrene	secondary	8.20e-10	5.80e-07
Natural Gas Prod.	Fluoranthene	secondary	8.17e-10	5.78e-07
Natural Gas Prod.	Tetrachloroethylene	secondary	7.32e-10	5.18e-07
Natural Gas Prod.	Ethyl Chloride	secondary	7.15e-10	5.06e-07
Natural Gas Prod.	Acenaphthene	secondary	7.04e-10	4.98e-07
Natural Gas Prod.	1,2-Dichloroethane	secondary	6.81e-10	4.81e-07
Natural Gas Prod.	Anthracene	secondary	4.27e-10	3.02e-07

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Natural Gas Prod.	Ethylene dibromide	secondary	3.87e-10	2.74e-07
Natural Gas Prod.	Chlorobenzene	secondary	3.75e-10	2.65e-07
Natural Gas Prod.	Acenaphthylene	secondary	3.72e-10	2.63e-07
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	3.40e-10	2.41e-07
Natural Gas Prod.	Benzo[a]anthracene	secondary	2.98e-10	2.11e-07
Natural Gas Prod.	Chrysene	secondary	2.87e-10	2.03e-07
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	2.62e-10	1.85e-07
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	1.73e-10	1.22e-07
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	1.70e-10	1.20e-07
Natural Gas Prod.	Benzo[a]pyrene	secondary	1.67e-10	1.18e-07
Natural Gas Prod.	2-Chloroacetophenone	secondary	1.19e-10	8.43e-08
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	6.79e-11	4.80e-08
Natural Gas Prod.	Aromatic hydrocarbons	secondary	5.64e-11	3.99e-08
Natural Gas Prod.	5-Methyl chrysene	secondary	1.36e-11	9.60e-09
Natural Gas Prod.	Polycyclic aromatic hydrocarbons	secondary	6.28e-14	4.44e-11
Steel Prod., cold-rolled, semi-finished	Propionaldehyde	secondary	4.58e-14	3.23e-11
Steel Prod., cold-rolled, semi-finished	Benzaldehyde	secondary	1.23e-14	8.71e-12
Total Materials Processing			**1.29e-01**	**9.12e+01**
Manufacturing Life-cycle Stage				
Monitor/module	Isopropyl alcohol	primary	3.48e-03	2.46e+00
LPG Production	Hydrocarbons, remaining unspeciated	secondary	2.99e-03	2.11e+00
LPG Production	Nonmethane hydrocarbons, remaining unspeciated	secondary	2.04e-03	1.44e+00
Natural Gas Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.42e-03	1.00e+00
Natural Gas Prod.	Methane	secondary	5.54e-04	3.91e-01
Natural Gas Prod.	Benzene	secondary	3.77e-04	2.67e-01
LPG Production	Methane	secondary	2.82e-04	1.99e-01
LPG Production	Benzene	secondary	1.30e-04	9.20e-02
Natural Gas Prod.	Hydrocarbons, remaining unspeciated	secondary	3.91e-05	2.76e-02
Backlight	Diethyl ether	primary	3.69e-05	2.61e-02
Fuel Oil #4 Prod.	Hydrocarbons, remaining unspeciated	secondary	3.32e-05	2.35e-02
Monitor/module	Acetone	primary	3.31e-05	2.34e-02
LPG Production	Aldehydes	secondary	3.17e-05	2.24e-02
Panel components	Heptane	primary	3.09e-05	2.19e-02
Panel components	Nonmethane hydrocarbons, remaining unspeciated	primary	3.09e-05	2.19e-02
Panel components	Toluene	primary	3.06e-05	2.17e-02
LPG Production	Formaldehyde	secondary	2.36e-05	1.67e-02
Fuel Oil #4 Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	2.23e-05	1.58e-02
Monitor/module	Cyclohexane	primary	1.93e-05	1.36e-02
Fuel Oil #6 Prod.	Hydrocarbons, remaining unspeciated	secondary	1.83e-05	1.29e-02
LPG Production	Ethane	secondary	1.48e-05	1.05e-02
Japanese Electric Grid	Formaldehyde	model/secondary	1.44e-05	1.02e-02
LPG Production	Pentane	secondary	1.27e-05	9.00e-03
Backlight	Ethanol	primary	1.24e-05	8.76e-03
Fuel Oil #6 Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.21e-05	8.55e-03
LPG Production	Butane	secondary	1.00e-05	7.09e-03
Fuel Oil #2 Prod.	Hydrocarbons, remaining unspeciated	secondary	9.21e-06	6.51e-03
LPG Production	Hexane	secondary	9.00e-06	6.36e-03
US electric grid	Methane	model/secondary	8.74e-06	6.18e-03
Natural Gas Prod.	Aldehydes	secondary	7.53e-06	5.32e-03

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
PWB Mfg.	Formaldehyde	model/secondary	7.21e-06	5.09e-03
Fuel Oil #2 Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	6.26e-06	4.42e-03
Natural Gas Prod.	Ethane	secondary	4.38e-06	3.10e-03
Natural Gas Prod.	Pentane	secondary	3.77e-06	2.66e-03
Natural Gas Prod.	Butane	secondary	2.97e-06	2.10e-03
Panel components	HCFC-225ca	primary	2.94e-06	2.08e-03
Panel components	HCFC-225cb	primary	2.94e-06	2.08e-03
Fuel Oil #4 Prod.	Methane	secondary	2.81e-06	1.99e-03
Japanese Electric Grid	Toluene	model/secondary	2.71e-06	1.91e-03
Natural Gas Prod.	Hexane	secondary	2.66e-06	1.88e-03
Japanese Electric Grid	Methane	model/secondary	1.91e-06	1.35e-03
Japanese Electric Grid	Isophorone	model/secondary	1.70e-06	1.20e-03
Fuel Oil #6 Prod.	Methane	secondary	1.40e-06	9.92e-04
Fuel Oil #4 Prod.	Benzene	secondary	1.17e-06	8.30e-04
Japanese Electric Grid	Acetaldehyde	model/secondary	9.71e-07	6.86e-04
Japanese Electric Grid	Benzene	model/secondary	9.69e-07	6.85e-04
Japanese Electric Grid	Propionaldehyde	model/secondary	8.81e-07	6.23e-04
Fuel Oil #2 Prod.	Methane	secondary	8.39e-07	5.93e-04
Japanese Electric Grid	Methyl ethyl ketone	model/secondary	7.09e-07	5.01e-04
Japanese Electric Grid	Naphthalene	model/secondary	5.66e-07	4.00e-04
Fuel Oil #6 Prod.	Benzene	secondary	5.27e-07	3.73e-04
Japanese Electric Grid	Acrolein	model/secondary	4.94e-07	3.49e-04
Fuel Oil #2 Prod.	Benzene	secondary	3.76e-07	2.66e-04
Panel components	Methyl ethyl ketone	primary	3.46e-07	2.45e-04
Japanese Electric Grid	Ethylbenzene	model/secondary	3.04e-07	2.15e-04
Fuel Oil #4 Prod.	Formaldehyde	secondary	2.91e-07	2.06e-04
Fuel Oil #4 Prod.	Aldehydes	secondary	2.86e-07	2.02e-04
Japanese Electric Grid	Bromomethane	model/secondary	2.45e-07	1.73e-04
Fuel Oil #6 Prod.	Formaldehyde	secondary	1.71e-07	1.21e-04
Natural Gas Prod.	Formaldehyde	secondary	1.61e-07	1.13e-04
LPG Production	Isophorone	secondary	1.42e-07	1.00e-04
Fuel Oil #4 Prod.	Ethane	secondary	1.34e-07	9.45e-05
Fuel Oil #6 Prod.	Aldehydes	secondary	1.28e-07	9.07e-05
Fuel Oil #4 Prod.	Pentane	secondary	1.15e-07	8.13e-05
Japanese Electric Grid	Xylene (mixed isomers)	model/secondary	1.08e-07	7.65e-05
Japanese Electric Grid	Hexane	model/secondary	1.07e-07	7.57e-05
LPG Production	Toluene	secondary	1.00e-07	7.10e-05
Fuel Oil #2 Prod.	Aldehydes	secondary	9.17e-08	6.48e-05
Fuel Oil #4 Prod.	Butane	secondary	9.06e-08	6.40e-05
Natural Gas Prod.	o-xylene	secondary	8.30e-08	5.87e-05
Fuel Oil #4 Prod.	Hexane	secondary	8.12e-08	5.74e-05
LPG Production	Acetaldehyde	secondary	8.11e-08	5.73e-05
US electric grid	Isophorone	model/secondary	7.66e-08	5.42e-05
Fuel Oil #2 Prod.	Formaldehyde	secondary	7.56e-08	5.35e-05
LPG Production	Propionaldehyde	secondary	7.36e-08	5.20e-05
Japanese Electric Grid	Styrene	model/secondary	7.31e-08	5.17e-05
US electric grid	Formaldehyde	model/secondary	6.90e-08	4.88e-05
Fuel Oil #6 Prod.	Ethane	secondary	6.01e-08	4.25e-05
LPG Production	Methyl ethyl ketone	secondary	5.92e-08	4.19e-05

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Japanese Electric Grid	Benzyl chloride	model/secondary	5.65e-08	4.00e-05
Japanese Electric Grid	Methyl tert-butyl ether	model/secondary	5.34e-08	3.77e-05
Fuel Oil #6 Prod.	Pentane	secondary	5.17e-08	3.65e-05
Japanese Electric Grid	o-xylene	model/secondary	4.94e-08	3.49e-05
Japanese Electric Grid	Phenol	model/secondary	4.68e-08	3.31e-05
Natural Gas Prod.	Toluene	secondary	4.58e-08	3.24e-05
Japanese Electric Grid	Acetophenone	model/secondary	4.39e-08	3.10e-05
US electric grid	Acetaldehyde	model/secondary	4.38e-08	3.10e-05
Fuel Oil #2 Prod.	Ethane	secondary	4.28e-08	3.03e-05
Japanese Electric Grid	Methyl chloride	model/secondary	4.28e-08	3.03e-05
US electric grid	Benzene	model/secondary	4.27e-08	3.02e-05
LPG Production	Acrolein	secondary	4.12e-08	2.92e-05
Fuel Oil #6 Prod.	Butane	secondary	4.07e-08	2.88e-05
US electric grid	Propionaldehyde	model/secondary	3.98e-08	2.81e-05
LPG Production	o-xylene	secondary	3.77e-08	2.66e-05
Fuel Oil #2 Prod.	Pentane	secondary	3.68e-08	2.60e-05
Fuel Oil #6 Prod.	Hexane	secondary	3.65e-08	2.58e-05
LPG Production	n-Propane	secondary	3.36e-08	2.38e-05
US electric grid	Methyl ethyl ketone	model/secondary	3.20e-08	2.26e-05
Fuel Oil #2 Prod.	Butane	secondary	2.90e-08	2.05e-05
US electric grid	Toluene	model/secondary	2.77e-08	1.96e-05
Fuel Oil #2 Prod.	Hexane	secondary	2.60e-08	1.84e-05
Japanese Electric Grid	Dichloromethane	model/secondary	2.34e-08	1.66e-05
LPG Production	Ethylbenzene	secondary	2.32e-08	1.64e-05
US electric grid	Acrolein	model/secondary	2.23e-08	1.58e-05
LPG Production	Bromomethane	secondary	2.04e-08	1.45e-05
Japanese Electric Grid	Cumene hydroperoxide	model/secondary	1.55e-08	1.10e-05
Japanese Electric Grid	Phenanthrene	model/secondary	1.33e-08	9.42e-06
LPG Production	Naphthalene	secondary	1.27e-08	9.01e-06
US electric grid	Ethylbenzene	model/secondary	1.25e-08	8.82e-06
US electric grid	Bromomethane	model/secondary	1.11e-08	7.82e-06
Japanese Electric Grid	Acenaphthene	model/secondary	1.11e-08	7.81e-06
Natural Gas Prod.	Isophorone	secondary	8.08e-09	5.71e-06
Japanese Electric Grid	Vinyl acetate	model/secondary	6.50e-09	4.60e-06
LPG Production	Styrene	secondary	6.11e-09	4.32e-06
Japanese Electric Grid	Biphenyl	model/secondary	4.97e-09	3.52e-06
US electric grid	Xylene (mixed isomers)	model/secondary	4.89e-09	3.46e-06
US electric grid	Hexane	model/secondary	4.84e-09	3.42e-06
Japanese Electric Grid	Chloroform	model/secondary	4.76e-09	3.37e-06
LPG Production	Benzyl chloride	secondary	4.72e-09	3.34e-06
Japanese Electric Grid	Fluorene	model/secondary	4.68e-09	3.31e-06
Natural Gas Prod.	Acetaldehyde	secondary	4.62e-09	3.27e-06
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	4.57e-09	3.23e-06
LPG Production	Methyl tert-butyl ether	secondary	4.47e-09	3.16e-06
Japanese Electric Grid	Fluoranthene	model/secondary	4.47e-09	3.16e-06
Natural Gas Prod.	Propionaldehyde	secondary	4.19e-09	2.96e-06
LPG Production	Phenol	secondary	3.91e-09	2.76e-06
LPG Production	Acetophenone	secondary	3.66e-09	2.59e-06
LPG Production	Methyl chloride	secondary	3.57e-09	2.53e-06
Japanese Electric Grid	Tetrachloroethylene	model/secondary	3.47e-09	2.45e-06

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Japanese Electric Grid	Ethyl Chloride	model/secondary	3.39e-09	2.40e-06
Natural Gas Prod.	Methyl ethyl ketone	secondary	3.38e-09	2.39e-06
US electric grid	Styrene	model/secondary	3.30e-09	2.34e-06
Japanese Electric Grid	1,2-Dichloroethane	model/secondary	3.23e-09	2.28e-06
Japanese Electric Grid	Pyrene	model/secondary	3.23e-09	2.28e-06
US electric grid	Naphthalene	model/secondary	2.69e-09	1.90e-06
US electric grid	Benzyl chloride	model/secondary	2.55e-09	1.80e-06
US electric grid	Methyl tert-butyl ether	model/secondary	2.42e-09	1.71e-06
Natural Gas Prod.	Acrolein	secondary	2.35e-09	1.66e-06
US electric grid	Phenol	model/secondary	2.11e-09	1.49e-06
Natural Gas Prod.	Naphthalene	secondary	2.11e-09	1.49e-06
Natural Gas Prod.	n-Propane	secondary	2.11e-09	1.49e-06
Japanese Electric Grid	Benzo[a]anthracene	model/secondary	2.05e-09	1.45e-06
US electric grid	Acetophenone	model/secondary	1.98e-09	1.40e-06
LPG Production	Dichloromethane	secondary	1.96e-09	1.38e-06
US electric grid	Methyl chloride	model/secondary	1.93e-09	1.37e-06
LPG Production	Aromatic hydrocarbons	secondary	1.92e-09	1.36e-06
Japanese Electric Grid	Ethylene dibromide	model/secondary	1.84e-09	1.30e-06
Japanese Electric Grid	Chlorobenzene	model/secondary	1.78e-09	1.26e-06
Fuel Oil #4 Prod.	Isophorone	secondary	1.52e-09	1.08e-06
Japanese Electric Grid	Chrysene	model/secondary	1.37e-09	9.68e-07
Natural Gas Prod.	Ethylbenzene	secondary	1.32e-09	9.37e-07
LPG Production	Cumene	secondary	1.29e-09	9.15e-07
Japanese Electric Grid	Anthracene	model/secondary	1.17e-09	8.24e-07
Natural Gas Prod.	Bromomethane	secondary	1.17e-09	8.24e-07
Japanese Electric Grid	Indeno(1,2,3-cd)pyrene	model/secondary	1.15e-09	8.10e-07
Japanese Electric Grid	Benzo[g,h,i]perylene	model/secondary	1.10e-09	7.78e-07
US electric grid	Dichloromethane	model/secondary	1.06e-09	7.48e-07
Japanese Electric Grid	Benzo[b,j,k]fluoranthene	model/secondary	9.94e-10	7.03e-07
Fuel Oil #4 Prod.	Toluene	secondary	9.81e-10	6.94e-07
Fuel Oil #4 Prod.	Acetaldehyde	secondary	8.71e-10	6.16e-07
Japanese Electric Grid	Acenaphthylene	model/secondary	8.43e-10	5.96e-07
LPG Production	Phenanthrene	secondary	8.28e-10	5.85e-07
Japanese Electric Grid	2,4-Dinitrotoluene	model/secondary	8.17e-10	5.77e-07
Fuel Oil #6 Prod.	Isophorone	secondary	8.11e-10	5.74e-07
Fuel Oil #4 Prod.	Propionaldehyde	secondary	7.90e-10	5.59e-07
US electric grid	Cumene	model/secondary	7.00e-10	4.95e-07
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	6.36e-10	4.50e-07
Japanese Electric Grid	2-Methylnaphthalene	model/secondary	6.09e-10	4.30e-07
Japanese Electric Grid	2-Chloroacetophenone	model/secondary	5.65e-10	4.00e-07
LPG Production	Vinyl acetate	secondary	5.44e-10	3.85e-07
Fuel Oil #6 Prod.	Toluene	secondary	4.80e-10	3.39e-07
Fuel Oil #6 Prod.	Acetaldehyde	secondary	4.64e-10	3.28e-07
Fuel Oil #4 Prod.	Acrolein	secondary	4.43e-10	3.13e-07
Fuel Oil #2 Prod.	Isophorone	secondary	4.32e-10	3.06e-07
Fuel Oil #6 Prod.	Propionaldehyde	secondary	4.21e-10	2.98e-07
LPG Production	Biphenyl	secondary	4.15e-10	2.94e-07
LPG Production	Chloroform	secondary	3.98e-10	2.81e-07

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
US electric grid	Phenanthrene	model/secondary	3.69e-10	2.61e-07
Fuel Oil #4 Prod.	n-Propane	secondary	3.60e-10	2.55e-07
Fuel Oil #4 Prod.	o-xylene	secondary	3.55e-10	2.51e-07
Natural Gas Prod.	Styrene	secondary	3.48e-10	2.46e-07
Fuel Oil #6 Prod.	Methyl ethyl ketone	secondary	3.39e-10	2.40e-07
LPG Production	1,4-Dichlorobenzene	secondary	3.03e-10	2.14e-07
Fuel Oil #2 Prod.	Toluene	secondary	2.97e-10	2.10e-07
US electric grid	Vinyl acetate	model/secondary	2.94e-10	2.08e-07
LPG Production	Tetrachloroethylene	secondary	2.90e-10	2.05e-07
LPG Production	Ethyl Chloride	secondary	2.83e-10	2.00e-07
LPG Production	1,2-Dichloroethane	secondary	2.70e-10	1.91e-07
Natural Gas Prod.	Benzyl chloride	secondary	2.69e-10	1.90e-07
Natural Gas Prod.	Methyl tert-butyl ether	secondary	2.55e-10	1.80e-07
LPG Production	Fluorene	secondary	2.53e-10	1.79e-07
Fuel Oil #4 Prod.	Ethylbenzene	secondary	2.49e-10	1.76e-07
Fuel Oil #2 Prod.	Acetaldehyde	secondary	2.47e-10	1.75e-07
Fuel Oil #6 Prod.	Acrolein	secondary	2.36e-10	1.67e-07
US electric grid	Biphenyl	model/secondary	2.25e-10	1.59e-07
Fuel Oil #2 Prod.	Propionaldehyde	secondary	2.24e-10	1.59e-07
Natural Gas Prod.	Phenol	secondary	2.23e-10	1.58e-07
Fuel Oil #4 Prod.	Bromomethane	secondary	2.20e-10	1.55e-07
LPG Production	2-Methylnaphthalene	secondary	2.19e-10	1.55e-07
US electric grid	Chloroform	model/secondary	2.15e-10	1.52e-07
Natural Gas Prod.	Acetophenone	secondary	2.09e-10	1.48e-07
LPG Production	Fluoranthene	secondary	2.07e-10	1.46e-07
Natural Gas Prod.	Methyl chloride	secondary	2.04e-10	1.44e-07
LPG Production	Acenaphthene	secondary	1.92e-10	1.35e-07
Fuel Oil #6 Prod.	n-Propane	secondary	1.91e-10	1.35e-07
Fuel Oil #2 Prod.	Methyl ethyl ketone	secondary	1.81e-10	1.28e-07
Fuel Oil #6 Prod.	o-xylene	secondary	1.67e-10	1.18e-07
US electric grid	Tetrachloroethylene	model/secondary	1.57e-10	1.11e-07
LPG Production	Ethylene dibromide	secondary	1.53e-10	1.08e-07
US electric grid	Ethyl Chloride	model/secondary	1.53e-10	1.08e-07
LPG Production	Chlorobenzene	secondary	1.48e-10	1.05e-07
US electric grid	1,2-Dichloroethane	model/secondary	1.46e-10	1.03e-07
LPG Production	1,1,1-Trichloroethane	secondary	1.35e-10	9.53e-08
Fuel Oil #6 Prod.	Ethylbenzene	secondary	1.32e-10	9.35e-08
LPG Production	Pyrene	secondary	1.31e-10	9.29e-08
Fuel Oil #2 Prod.	Acrolein	secondary	1.26e-10	8.90e-08
US electric grid	Fluorene	model/secondary	1.24e-10	8.75e-08
Fuel Oil #4 Prod.	Naphthalene	secondary	1.18e-10	8.36e-08
Fuel Oil #6 Prod.	Bromomethane	secondary	1.17e-10	8.28e-08
Natural Gas Prod.	Dichloromethane	secondary	1.11e-10	7.88e-08
Japanese Electric Grid	Benzo[a]pyrene	model/secondary	1.11e-10	7.87e-08
Fuel Oil #2 Prod.	o-xylene	secondary	1.10e-10	7.80e-08
Fuel Oil #2 Prod.	n-Propane	secondary	1.03e-10	7.25e-08
US electric grid	Fluoranthene	model/secondary	9.89e-11	6.99e-08
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	8.95e-11	6.33e-08
Natural Gas Prod.	Phenanthrene	secondary	8.45e-11	5.98e-08
US electric grid	o-xylene	model/secondary	8.41e-11	5.94e-08

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
US electric grid	Acenaphthene	model/secondary	8.37e-11	5.92e-08
US electric grid	Ethylene dibromide	model/secondary	8.29e-11	5.86e-08
US electric grid	Chlorobenzene	model/secondary	8.02e-11	5.67e-08
LPG Production	Acenaphthylene	secondary	7.81e-11	5.52e-08
US electric grid	1,1,1-Trichloroethane	model/secondary	7.80e-11	5.51e-08
LPG Production	Anthracene	secondary	7.62e-11	5.38e-08
Natural Gas Prod.	Cumene	secondary	7.38e-11	5.22e-08
Fuel Oil #2 Prod.	Ethylbenzene	secondary	7.07e-11	5.00e-08
LPG Production	2,4-Dinitrotoluene	secondary	6.84e-11	4.84e-08
Fuel Oil #4 Prod.	Styrene	secondary	6.56e-11	4.64e-08
Natural Gas Prod.	2-Methylnaphthalene	secondary	6.49e-11	4.59e-08
Japanese Electric Grid	5-Methyl chrysene	model/secondary	6.43e-11	4.55e-08
Fuel Oil #2 Prod.	Bromomethane	secondary	6.24e-11	4.41e-08
Fuel Oil #6 Prod.	Naphthalene	secondary	5.48e-11	3.87e-08
Fuel Oil #4 Prod.	Benzyl chloride	secondary	5.07e-11	3.58e-08
US electric grid	Pyrene	model/secondary	4.91e-11	3.47e-08
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	4.80e-11	3.40e-08
LPG Production	2-Chloroacetophenone	secondary	4.72e-11	3.34e-08
LPG Production	Benzo[a]anthracene	secondary	4.56e-11	3.22e-08
LPG Production	Chrysene	secondary	4.37e-11	3.09e-08
Fuel Oil #4 Prod.	Phenol	secondary	4.20e-11	2.97e-08
Fuel Oil #4 Prod.	Acetophenone	secondary	3.94e-11	2.78e-08
Fuel Oil #4 Prod.	Methyl chloride	secondary	3.84e-11	2.71e-08
Fuel Oil #2 Prod.	Naphthalene	secondary	3.71e-11	2.62e-08
US electric grid	2,4-Dinitrotoluene	model/secondary	3.70e-11	2.62e-08
Fuel Oil #6 Prod.	Styrene	secondary	3.50e-11	2.47e-08
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	3.39e-11	2.40e-08
US electric grid	Acenaphthylene	model/secondary	3.32e-11	2.35e-08
Natural Gas Prod.	Vinyl acetate	secondary	3.10e-11	2.19e-08
US electric grid	Anthracene	model/secondary	2.87e-11	2.03e-08
Fuel Oil #6 Prod.	Benzyl chloride	secondary	2.70e-11	1.91e-08
LPG Production	Benzo[b,j,k]fluoranthene	secondary	2.69e-11	1.90e-08
Fuel Oil #6 Prod.	Methyl tert-butyl ether	secondary	2.56e-11	1.81e-08
US electric grid	2-Chloroacetophenone	model/secondary	2.55e-11	1.80e-08
LPG Production	Benzo[a]pyrene	secondary	2.50e-11	1.76e-08
Natural Gas Prod.	Biphenyl	secondary	2.37e-11	1.67e-08
Natural Gas Prod.	Chloroform	secondary	2.27e-11	1.60e-08
Fuel Oil #6 Prod.	Phenol	secondary	2.24e-11	1.58e-08
Fuel Oil #4 Prod.	Dichloromethane	secondary	2.10e-11	1.48e-08
Fuel Oil #6 Prod.	Acetophenone	secondary	2.10e-11	1.48e-08
Natural Gas Prod.	Fluorene	secondary	2.07e-11	1.46e-08
Fuel Oil #6 Prod.	Methyl chloride	secondary	2.05e-11	1.45e-08
LPG Production	Benzo[g,h,i]perylene	secondary	2.03e-11	1.43e-08
Fuel Oil #2 Prod.	Styrene	secondary	1.86e-11	1.32e-08
Natural Gas Prod.	Pyrene	secondary	1.85e-11	1.31e-08
Natural Gas Prod.	Fluoranthene	secondary	1.84e-11	1.30e-08
Natural Gas Prod.	Tetrachloroethylene	secondary	1.65e-11	1.17e-08
Natural Gas Prod.	Ethyl Chloride	secondary	1.61e-11	1.14e-08

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Natural Gas Prod.	Acenaphthene	secondary	1.59e-11	1.12e-08
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	1.57e-11	1.11e-08
Natural Gas Prod.	1,2-Dichloroethane	secondary	1.54e-11	1.09e-08
US electric grid	Chrysene	model/secondary	1.51e-11	1.06e-08
Fuel Oil #2 Prod.	Benzyl chloride	secondary	1.44e-11	1.02e-08
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	1.40e-11	9.93e-09
Fuel Oil #4 Prod.	Cumene	secondary	1.39e-11	9.83e-09
US electric grid	Benzo[a]anthracene	model/secondary	1.37e-11	9.66e-09
Fuel Oil #2 Prod.	Methyl tert-butyl ether	secondary	1.36e-11	9.65e-09
Fuel Oil #2 Prod.	Phenol	secondary	1.19e-11	8.43e-09
Fuel Oil #6 Prod.	Dichloromethane	secondary	1.12e-11	7.91e-09
Fuel Oil #2 Prod.	Acetophenone	secondary	1.12e-11	7.91e-09
Fuel Oil #2 Prod.	Methyl chloride	secondary	1.09e-11	7.71e-09
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	9.71e-12	6.87e-09
Natural Gas Prod.	Anthracene	secondary	9.64e-12	6.81e-09
Natural Gas Prod.	Ethylene dibromide	secondary	8.74e-12	6.18e-09
Fuel Oil #4 Prod.	Phenanthrene	secondary	8.58e-12	6.07e-09
Natural Gas Prod.	Chlorobenzene	secondary	8.45e-12	5.98e-09
Natural Gas Prod.	Acenaphthylene	secondary	8.39e-12	5.93e-09
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	7.68e-12	5.43e-09
Fuel Oil #6 Prod.	Cumene	secondary	7.41e-12	5.24e-09
Natural Gas Prod.	Benzo[a]anthracene	secondary	6.72e-12	4.75e-09
Natural Gas Prod.	Chrysene	secondary	6.48e-12	4.58e-09
Fuel Oil #2 Prod.	Dichloromethane	secondary	5.97e-12	4.22e-09
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	5.91e-12	4.18e-09
Fuel Oil #4 Prod.	Vinyl acetate	secondary	5.85e-12	4.13e-09
LPG Production	5-Methyl chrysene	secondary	5.38e-12	3.80e-09
US electric grid	Benzo[g,h,i]perylene	model/secondary	5.31e-12	3.75e-09
Fuel Oil #2 Prod.	Aromatic hydrocarbons	secondary	5.23e-12	3.70e-09
US electric grid	Benzo[a]pyrene	model/secondary	5.02e-12	3.55e-09
Fuel Oil #6 Prod.	Aromatic hydrocarbons	secondary	4.60e-12	3.25e-09
Fuel Oil #4 Prod.	Biphenyl	secondary	4.46e-12	3.15e-09
Fuel Oil #6 Prod.	Phenanthrene	secondary	4.44e-12	3.14e-09
Fuel Oil #4 Prod.	Chloroform	secondary	4.27e-12	3.02e-09
Fuel Oil #2 Prod.	Cumene	secondary	3.95e-12	2.79e-09
US electric grid	2-Methylnaphthalene	model/secondary	3.93e-12	2.78e-09
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	3.90e-12	2.76e-09
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	3.83e-12	2.71e-09
Natural Gas Prod.	Benzo[a]pyrene	secondary	3.78e-12	2.67e-09
Fuel Oil #6 Prod.	Vinyl acetate	secondary	3.12e-12	2.20e-09
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	3.11e-12	2.20e-09
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	3.04e-12	2.15e-09
US electric grid	5-Methyl chrysene	model/secondary	2.91e-12	2.06e-09
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	2.90e-12	2.05e-09
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	2.73e-12	1.93e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	2.69e-12	1.90e-09
Fuel Oil #4 Prod.	Fluorene	secondary	2.66e-12	1.88e-09
Fuel Oil #2 Prod.	Phenanthrene	secondary	2.50e-12	1.76e-09
Fuel Oil #6 Prod.	Biphenyl	secondary	2.38e-12	1.68e-09
Fuel Oil #6 Prod.	Chloroform	secondary	2.28e-12	1.61e-09

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #4 Prod.	Fluoranthene	secondary	2.15e-12	1.52e-09
LPG Production	Polycyclic aromatic hydrocarbons	secondary	2.13e-12	1.51e-09
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	1.98e-12	1.40e-09
Fuel Oil #4 Prod.	Acenaphthene	secondary	1.86e-12	1.31e-09
Fuel Oil #2 Prod.	Vinyl acetate	secondary	1.66e-12	1.17e-09
Fuel Oil #6 Prod.	Tetrachloroethylene	secondary	1.66e-12	1.17e-09
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	1.65e-12	1.16e-09
Fuel Oil #6 Prod.	Ethyl Chloride	secondary	1.62e-12	1.15e-09
Fuel Oil #4 Prod.	Chlorobenzene	secondary	1.59e-12	1.13e-09
Fuel Oil #6 Prod.	1,2-Dichloroethane	secondary	1.54e-12	1.09e-09
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	1.53e-12	1.08e-09
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	1.45e-12	1.02e-09
Fuel Oil #6 Prod.	Fluorene	secondary	1.39e-12	9.83e-10
Fuel Oil #4 Prod.	Pyrene	secondary	1.32e-12	9.30e-10
Natural Gas Prod.	Aromatic hydrocarbons	secondary	1.27e-12	9.00e-10
Fuel Oil #2 Prod.	Biphenyl	secondary	1.27e-12	8.96e-10
Fuel Oil #6 Prod.	1,4-Dichlorobenzene	secondary	1.23e-12	8.68e-10
Fuel Oil #2 Prod.	Chloroform	secondary	1.21e-12	8.58e-10
Fuel Oil #6 Prod.	Fluoranthene	secondary	1.12e-12	7.91e-10
Fuel Oil #6 Prod.	Acenaphthene	secondary	9.03e-13	6.39e-10
Fuel Oil #6 Prod.	2-Methylnaphthalene	secondary	8.89e-13	6.29e-10
Fuel Oil #2 Prod.	Tetrachloroethylene	secondary	8.85e-13	6.25e-10
Fuel Oil #6 Prod.	Ethylene dibromide	secondary	8.78e-13	6.21e-10
Fuel Oil #2 Prod.	1,4-Dichlorobenzene	secondary	8.74e-13	6.18e-10
Fuel Oil #2 Prod.	Ethyl Chloride	secondary	8.64e-13	6.11e-10
Fuel Oil #6 Prod.	Chlorobenzene	secondary	8.49e-13	6.00e-10
Fuel Oil #2 Prod.	1,2-Dichloroethane	secondary	8.23e-13	5.82e-10
Fuel Oil #4 Prod.	Acenaphthylene	secondary	8.09e-13	5.72e-10
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	7.72e-13	5.46e-10
Fuel Oil #4 Prod.	Anthracene	secondary	7.71e-13	5.45e-10
Fuel Oil #2 Prod.	Fluorene	secondary	7.67e-13	5.42e-10
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	7.35e-13	5.20e-10
Fuel Oil #6 Prod.	Pyrene	secondary	6.59e-13	4.66e-10
Fuel Oil #2 Prod.	2-Methylnaphthalene	secondary	6.34e-13	4.48e-10
Fuel Oil #2 Prod.	Fluoranthene	secondary	6.24e-13	4.41e-10
Fuel Oil #2 Prod.	Acenaphthene	secondary	5.66e-13	4.00e-10
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	5.07e-13	3.58e-10
Fuel Oil #2 Prod.	Ethylene dibromide	secondary	4.68e-13	3.31e-10
Fuel Oil #2 Prod.	Chlorobenzene	secondary	4.53e-13	3.20e-10
Fuel Oil #4 Prod.	Chrysene	secondary	4.32e-13	3.05e-10
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	4.29e-13	3.03e-10
Fuel Oil #6 Prod.	Acenaphthylene	secondary	4.18e-13	2.95e-10
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	4.11e-13	2.91e-10
Fuel Oil #2 Prod.	Pyrene	secondary	3.92e-13	2.77e-10
Fuel Oil #6 Prod.	2,4-Dinitrotoluene	secondary	3.92e-13	2.77e-10
Fuel Oil #6 Prod.	Anthracene	secondary	3.90e-13	2.76e-10
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	3.27e-13	2.31e-10
Natural Gas Prod.	5-Methyl chrysene	secondary	3.06e-13	2.17e-10

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	2.89e-13	2.04e-10
Fuel Oil #6 Prod.	2-Chloroacetophenone	secondary	2.70e-13	1.91e-10
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	2.57e-13	1.82e-10
Fuel Oil #2 Prod.	Acenaphthylene	secondary	2.36e-13	1.67e-10
Fuel Oil #2 Prod.	Anthracene	secondary	2.28e-13	1.61e-10
Fuel Oil #6 Prod.	Chrysene	secondary	2.14e-13	1.51e-10
Fuel Oil #2 Prod.	2,4-Dinitrotoluene	secondary	2.09e-13	1.48e-10
Fuel Oil #6 Prod.	Benzo[a]anthracene	secondary	2.02e-13	1.43e-10
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	1.90e-13	1.34e-10
Fuel Oil #6 Prod.	Indeno(1,2,3-cd)pyrene	secondary	1.58e-13	1.12e-10
Fuel Oil #6 Prod.	Benzo[b,j,k]fluoranthene	secondary	1.54e-13	1.09e-10
Fuel Oil #2 Prod.	2-Chloroacetophenone	secondary	1.44e-13	1.02e-10
Fuel Oil #2 Prod.	Benzo[a]anthracene	secondary	1.33e-13	9.43e-11
Fuel Oil #6 Prod.	Benzo[a]pyrene	secondary	1.32e-13	9.35e-11
Fuel Oil #2 Prod.	Chrysene	secondary	1.30e-13	9.18e-11
Fuel Oil #2 Prod.	Indeno(1,2,3-cd)pyrene	secondary	1.00e-13	7.07e-11
Fuel Oil #6 Prod.	Benzo[g,h,i]perylene	secondary	8.88e-14	6.28e-11
Fuel Oil #2 Prod.	Benzo[b,j,k]fluoranthene	secondary	8.20e-14	5.80e-11
Fuel Oil #2 Prod.	Benzo[a]pyrene	secondary	7.51e-14	5.31e-11
Fuel Oil #2 Prod.	Benzo[g,h,i]perylene	secondary	5.92e-14	4.19e-11
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	5.77e-14	4.08e-11
Fuel Oil #6 Prod.	5-Methyl chrysene	secondary	3.08e-14	2.18e-11
Fuel Oil #2 Prod.	5-Methyl chrysene	secondary	1.64e-14	1.16e-11
Fuel Oil #4 Prod.	Polycyclic aromatic hydrocarbons	secondary	1.56e-14	1.10e-11
Fuel Oil #2 Prod.	Polycyclic aromatic hydrocarbons	secondary	5.82e-15	4.11e-12
Fuel Oil #6 Prod.	Polycyclic aromatic hydrocarbons	secondary	5.11e-15	3.62e-12
Natural Gas Prod.	Polycyclic aromatic hydrocarbons	secondary	1.42e-15	1.00e-12
Total Manufacturing			**1.18e-02**	**8.33e+00**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Methane	model/secondary	1.68e-03	1.19e+00
US electric grid	Isophorone	model/secondary	1.48e-05	1.04e-02
US electric grid	Formaldehyde	model/secondary	1.33e-05	9.40e-03
US electric grid	Acetaldehyde	model/secondary	8.45e-06	5.98e-03
US electric grid	Benzene	model/secondary	8.23e-06	5.82e-03
US electric grid	Propionaldehyde	model/secondary	7.67e-06	5.42e-03
US electric grid	Methyl ethyl ketone	model/secondary	6.17e-06	4.37e-03
US electric grid	Toluene	model/secondary	5.34e-06	3.78e-03
US electric grid	Acrolein	model/secondary	4.30e-06	3.04e-03
US electric grid	Ethylbenzene	model/secondary	2.40e-06	1.70e-03
US electric grid	Bromomethane	model/secondary	2.13e-06	1.51e-03
US electric grid	Xylene (mixed isomers)	model/secondary	9.42e-07	6.66e-04
US electric grid	Hexane	model/secondary	9.33e-07	6.60e-04
US electric grid	Styrene	model/secondary	6.37e-07	4.50e-04
US electric grid	Naphthalene	model/secondary	5.19e-07	3.67e-04
US electric grid	Benzyl chloride	model/secondary	4.92e-07	3.48e-04
US electric grid	Methyl tert-butyl ether	model/secondary	4.66e-07	3.30e-04
US electric grid	Phenol	model/secondary	4.08e-07	2.88e-04
US electric grid	Acetophenone	model/secondary	3.82e-07	2.70e-04
US electric grid	Methyl chloride	model/secondary	3.73e-07	2.63e-04

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
US electric grid	Dichloromethane	model/secondary	2.04e-07	1.44e-04
US electric grid	Cumene	model/secondary	1.35e-07	9.54e-05
US electric grid	Phenanthrene	model/secondary	7.12e-08	5.03e-05
US electric grid	Vinyl acetate	model/secondary	5.67e-08	4.01e-05
US electric grid	Biphenyl	model/secondary	4.33e-08	3.06e-05
US electric grid	Chloroform	model/secondary	4.15e-08	2.93e-05
US electric grid	Tetrachloroethylene	model/secondary	3.02e-08	2.14e-05
US electric grid	Ethyl Chloride	model/secondary	2.95e-08	2.09e-05
US electric grid	1,2-Dichloroethane	model/secondary	2.81e-08	1.99e-05
US electric grid	Fluorene	model/secondary	2.38e-08	1.69e-05
US electric grid	Fluoranthene	model/secondary	1.91e-08	1.35e-05
US electric grid	o-xylene	model/secondary	1.62e-08	1.15e-05
US electric grid	Acenaphthene	model/secondary	1.61e-08	1.14e-05
US electric grid	Ethylene dibromide	model/secondary	1.60e-08	1.13e-05
US electric grid	Chlorobenzene	model/secondary	1.55e-08	1.09e-05
US electric grid	1,1,1-Trichloroethane	model/secondary	1.50e-08	1.06e-05
US electric grid	Pyrene	model/secondary	9.46e-09	6.69e-06
US electric grid	2,4-Dinitrotoluene	model/secondary	7.13e-09	5.04e-06
US electric grid	Acenaphthylene	model/secondary	6.41e-09	4.53e-06
US electric grid	Anthracene	model/secondary	5.53e-09	3.91e-06
US electric grid	2-Chloroacetophenone	model/secondary	4.92e-09	3.48e-06
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	3.02e-09	2.14e-06
US electric grid	Chrysene	model/secondary	2.90e-09	2.05e-06
US electric grid	Benzo[a]anthracene	model/secondary	2.63e-09	1.86e-06
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	1.87e-09	1.32e-06
US electric grid	Benzo[g,h,i]perylene	model/secondary	1.02e-09	7.24e-07
US electric grid	Benzo[a]pyrene	model/secondary	9.68e-10	6.84e-07
US electric grid	2-Methylnaphthalene	model/secondary	7.57e-10	5.36e-07
US electric grid	5-Methyl chrysene	model/secondary	5.60e-10	3.96e-07
Total Use, Maintenance and Repair			**1.76e-03**	**1.25e+00**
End-of-life Life-cycle Stage				
LCD landfilling	Hydrocarbons, remaining unspeciated	primary	2.58e-05	1.83e-02
US electric grid	Methane	model/secondary	3.20e-07	2.26e-04
LPG Production	Hydrocarbons, remaining unspeciated	secondary	2.45e-07	1.73e-04
LPG Production	Nonmethane hydrocarbons, remaining unspeciated	secondary	1.67e-07	1.18e-04
LCD landfilling	Methane	primary	9.18e-08	6.49e-05
LCD landfilling	Benzene	primary	3.08e-08	2.18e-05
LPG Production	Methane	secondary	2.31e-08	1.64e-05
LPG Production	Benzene	secondary	1.07e-08	7.55e-06
LCD landfilling	Toluene	primary	6.48e-09	4.58e-06
LCD landfilling	Xylene (mixed isomers)	primary	4.54e-09	3.21e-06
US electric grid	Isophorone	model/secondary	2.80e-09	1.98e-06
LPG Production	Aldehydes	secondary	2.61e-09	1.84e-06
US electric grid	Formaldehyde	model/secondary	2.52e-09	1.78e-06
LPG Production	Formaldehyde	secondary	1.94e-09	1.37e-06
US electric grid	Acetaldehyde	model/secondary	1.60e-09	1.13e-06
US electric grid	Benzene	model/secondary	1.56e-09	1.10e-06
US electric grid	Propionaldehyde	model/secondary	1.46e-09	1.03e-06
LPG Production	Ethane	secondary	1.22e-09	8.60e-07

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
US electric grid	Methyl ethyl ketone	model/secondary	1.17e-09	8.28e-07
LPG Production	Pentane	secondary	1.05e-09	7.39e-07
US electric grid	Toluene	model/secondary	1.01e-09	7.17e-07
LCD landfilling	Ethylbenzene	primary	9.02e-10	6.38e-07
LPG Production	Butane	secondary	8.24e-10	5.82e-07
US electric grid	Acrolein	model/secondary	8.16e-10	5.77e-07
LPG Production	Hexane	secondary	7.39e-10	5.22e-07
US electric grid	Ethylbenzene	model/secondary	4.56e-10	3.22e-07
US electric grid	Bromomethane	model/secondary	4.04e-10	2.86e-07
US electric grid	Xylene (mixed isomers)	model/secondary	1.79e-10	1.26e-07
US electric grid	Hexane	model/secondary	1.77e-10	1.25e-07
US electric grid	Styrene	model/secondary	1.21e-10	8.54e-08
US electric grid	Naphthalene	model/secondary	9.85e-11	6.97e-08
US electric grid	Benzyl chloride	model/secondary	9.34e-11	6.60e-08
US electric grid	Methyl tert-butyl ether	model/secondary	8.85e-11	6.25e-08
US electric grid	Phenol	model/secondary	7.73e-11	5.47e-08
US electric grid	Acetophenone	model/secondary	7.25e-11	5.13e-08
US electric grid	Methyl chloride	model/secondary	7.07e-11	5.00e-08
US electric grid	Dichloromethane	model/secondary	3.87e-11	2.73e-08
US electric grid	Cumene	model/secondary	2.56e-11	1.81e-08
LCD landfilling	Trichloroethylene	primary	2.18e-11	1.54e-08
LCD incineration	Trichloroethylene	secondary	1.69e-11	1.19e-08
LCD landfilling	Vinyl chloride	primary	1.38e-11	9.78e-09
US electric grid	Phenanthrene	model/secondary	1.35e-11	9.55e-09
LPG Production	Isophorone	secondary	1.16e-11	8.22e-09
LCD landfilling	Dichloromethane	primary	1.11e-11	7.82e-09
US electric grid	Vinyl acetate	model/secondary	1.08e-11	7.61e-09
LCD incineration	Vinyl chloride	secondary	1.07e-11	7.59e-09
LPG Production	Toluene	secondary	8.24e-12	5.83e-09
US electric grid	Biphenyl	model/secondary	8.22e-12	5.81e-09
US electric grid	Chloroform	model/secondary	7.87e-12	5.56e-09
LCD landfilling	1,2-Dichloroethane	primary	6.92e-12	4.90e-09
LCD landfilling	Carbon tetrachloride	primary	6.92e-12	4.90e-09
LCD landfilling	Chloroform	primary	6.92e-12	4.90e-09
LCD landfilling	Tetrachloroethylene	primary	6.92e-12	4.90e-09
LPG Production	Acetaldehyde	secondary	6.66e-12	4.71e-09
LPG Production	Propionaldehyde	secondary	6.04e-12	4.27e-09
US electric grid	Tetrachloroethylene	model/secondary	5.73e-12	4.05e-09
US electric grid	Ethyl Chloride	model/secondary	5.60e-12	3.96e-09
LCD incineration	Carbon tetrachloride	secondary	5.37e-12	3.80e-09
US electric grid	1,2-Dichloroethane	model/secondary	5.33e-12	3.77e-09
LPG Production	Methyl ethyl ketone	secondary	4.86e-12	3.44e-09
US electric grid	Fluorene	model/secondary	4.52e-12	3.20e-09
US electric grid	Fluoranthene	model/secondary	3.62e-12	2.56e-09
LPG Production	Acrolein	secondary	3.39e-12	2.39e-09
LPG Production	o-xylene	secondary	3.09e-12	2.19e-09
US electric grid	o-xylene	model/secondary	3.08e-12	2.17e-09
US electric grid	Acenaphthene	model/secondary	3.06e-12	2.16e-09
US electric grid	Ethylene dibromide	model/secondary	3.03e-12	2.14e-09
US electric grid	Chlorobenzene	model/secondary	2.93e-12	2.07e-09

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
US electric grid	1,1,1-Trichloroethane	model/secondary	2.85e-12	2.02e-09
LPG Production	n-Propane	secondary	2.76e-12	1.95e-09
LPG Production	Ethylbenzene	secondary	1.90e-12	1.35e-09
US electric grid	Pyrene	model/secondary	1.79e-12	1.27e-09
LPG Production	Bromomethane	secondary	1.68e-12	1.19e-09
US electric grid	2,4-Dinitrotoluene	model/secondary	1.35e-12	9.57e-10
US electric grid	Acenaphthylene	model/secondary	1.22e-12	8.59e-10
US electric grid	Anthracene	model/secondary	1.05e-12	7.42e-10
LPG Production	Naphthalene	secondary	1.05e-12	7.40e-10
US electric grid	2-Chloroacetophenone	model/secondary	9.34e-13	6.60e-10
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	5.73e-13	4.05e-10
US electric grid	Chrysene	model/secondary	5.50e-13	3.89e-10
LPG Production	Styrene	secondary	5.01e-13	3.54e-10
US electric grid	Benzo[a]anthracene	model/secondary	5.00e-13	3.53e-10
LPG Production	Benzyl chloride	secondary	3.87e-13	2.74e-10
LPG Production	Methyl tert-butyl ether	secondary	3.67e-13	2.60e-10
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	3.55e-13	2.51e-10
LPG Production	Phenol	secondary	3.21e-13	2.27e-10
LPG Production	Acetophenone	secondary	3.01e-13	2.13e-10
LPG Production	Methyl chloride	secondary	2.93e-13	2.07e-10
US electric grid	Benzo[g,h,i]perylene	model/secondary	1.94e-13	1.37e-10
US electric grid	Benzo[a]pyrene	model/secondary	1.84e-13	1.30e-10
LPG Production	Dichloromethane	secondary	1.61e-13	1.13e-10
LPG Production	Aromatic hydrocarbons	secondary	1.57e-13	1.11e-10
US electric grid	2-Methylnaphthalene	model/secondary	1.44e-13	1.02e-10
US electric grid	5-Methyl chrysene	model/secondary	1.06e-13	7.52e-11
LPG Production	Cumene	secondary	1.06e-13	7.52e-11
LPG Production	Phenanthrene	secondary	6.79e-14	4.80e-11
LPG Production	Vinyl acetate	secondary	4.47e-14	3.16e-11
LPG Production	Biphenyl	secondary	3.41e-14	2.41e-11
LPG Production	Chloroform	secondary	3.27e-14	2.31e-11
LPG Production	1,4-Dichlorobenzene	secondary	2.48e-14	1.76e-11
LPG Production	Tetrachloroethylene	secondary	2.38e-14	1.68e-11
LPG Production	Ethyl Chloride	secondary	2.32e-14	1.64e-11
LPG Production	1,2-Dichloroethane	secondary	2.21e-14	1.57e-11
LPG Production	Fluorene	secondary	2.08e-14	1.47e-11
LPG Production	2-Methylnaphthalene	secondary	1.80e-14	1.27e-11
LPG Production	Fluoranthene	secondary	1.70e-14	1.20e-11
LPG Production	Acenaphthene	secondary	1.57e-14	1.11e-11
LPG Production	Ethylene dibromide	secondary	1.26e-14	8.90e-12
LPG Production	Chlorobenzene	secondary	1.22e-14	8.61e-12
LPG Production	1,1,1-Trichloroethane	secondary	1.11e-14	7.83e-12
LPG Production	Pyrene	secondary	1.08e-14	7.63e-12
LPG Production	Acenaphthylene	secondary	6.41e-15	4.53e-12
LPG Production	Anthracene	secondary	6.25e-15	4.42e-12
LPG Production	2,4-Dinitrotoluene	secondary	5.62e-15	3.97e-12
LPG Production	2-Chloroacetophenone	secondary	3.87e-15	2.74e-12
LPG Production	Benzo[a]anthracene	secondary	3.74e-15	2.65e-12

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
LPG Production	Chrysene	secondary	3.59e-15	2.54e-12
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	2.78e-15	1.97e-12
LPG Production	Benzo[b,j,k]fluoranthene	secondary	2.21e-15	1.56e-12
LPG Production	Benzo[a]pyrene	secondary	2.05e-15	1.45e-12
LPG Production	Benzo[g,h,i]perylene	secondary	1.66e-15	1.18e-12
LPG Production	5-Methyl chrysene	secondary	4.41e-16	3.12e-13
LPG Production	Polycyclic aromatic hydrocarbons	secondary	1.75e-16	1.24e-13
Natural Gas Prod.	Polycyclic aromatic hydrocarbons	secondary	-2.97e-16	-2.10e-13
LCD incineration	Polycyclic aromatic hydrocarbons	secondary	-4.52e-15	-3.20e-12
Natural Gas Prod.	5-Methyl chrysene	secondary	-6.43e-14	-4.55e-11
Fuel Oil #4 Prod.	Polycyclic aromatic hydrocarbons	secondary	-7.19e-14	-5.08e-11
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	-2.66e-13	-1.88e-10
Natural Gas Prod.	Aromatic hydrocarbons	secondary	-2.67e-13	-1.89e-10
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	-3.22e-13	-2.27e-10
Natural Gas Prod.	2-Chloroacetophenone	secondary	-5.65e-13	-3.99e-10
Natural Gas Prod.	Benzo[a]pyrene	secondary	-7.93e-13	-5.61e-10
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	-8.04e-13	-5.69e-10
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	-8.19e-13	-5.79e-10
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	-8.74e-13	-6.18e-10
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	-1.18e-12	-8.37e-10
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	-1.24e-12	-8.78e-10
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	-1.33e-12	-9.40e-10
Natural Gas Prod.	Chrysene	secondary	-1.36e-12	-9.62e-10
Natural Gas Prod.	Benzo[a]anthracene	secondary	-1.41e-12	-9.98e-10
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	-1.51e-12	-1.07e-09
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-1.61e-12	-1.14e-09
Natural Gas Prod.	Acenaphthylene	secondary	-1.76e-12	-1.25e-09
Natural Gas Prod.	Chlorobenzene	secondary	-1.78e-12	-1.25e-09
Natural Gas Prod.	Ethylene dibromide	secondary	-1.83e-12	-1.30e-09
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	-1.98e-12	-1.40e-09
Fuel Oil #4 Prod.	Chrysene	secondary	-1.99e-12	-1.41e-09
Natural Gas Prod.	Anthracene	secondary	-2.02e-12	-1.43e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	-2.34e-12	-1.65e-09
Natural Gas Prod.	1,2-Dichloroethane	secondary	-3.23e-12	-2.28e-09
Natural Gas Prod.	Acenaphthene	secondary	-3.34e-12	-2.36e-09
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	-3.39e-12	-2.39e-09
Natural Gas Prod.	Ethyl Chloride	secondary	-3.39e-12	-2.40e-09
Natural Gas Prod.	Tetrachloroethylene	secondary	-3.47e-12	-2.45e-09
Fuel Oil #4 Prod.	Anthracene	secondary	-3.55e-12	-2.51e-09
Fuel Oil #4 Prod.	Acenaphthylene	secondary	-3.73e-12	-2.64e-09
Natural Gas Prod.	Fluoranthene	secondary	-3.87e-12	-2.74e-09
Natural Gas Prod.	Pyrene	secondary	-3.89e-12	-2.75e-09
LCD incineration	Aromatic hydrocarbons	secondary	-4.07e-12	-2.88e-09
LCD incineration	2-Methylnaphthalene	secondary	-4.30e-12	-3.04e-09
Natural Gas Prod.	Fluorene	secondary	-4.34e-12	-3.07e-09
Natural Gas Prod.	Chloroform	secondary	-4.76e-12	-3.37e-09
Natural Gas Prod.	Biphenyl	secondary	-4.97e-12	-3.51e-09
LCD incineration	Dichlorobenzene (mixed isomers)	secondary	-5.93e-12	-4.19e-09
Fuel Oil #4 Prod.	Pyrene	secondary	-6.06e-12	-4.29e-09
Natural Gas Prod.	Vinyl acetate	secondary	-6.51e-12	-4.60e-09

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-6.67e-12	-4.72e-09
Fuel Oil #4 Prod.	Chlorobenzene	secondary	-7.34e-12	-5.19e-09
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	-7.59e-12	-5.37e-09
Fuel Oil #4 Prod.	Acenaphthene	secondary	-8.56e-12	-6.05e-09
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	-9.12e-12	-6.45e-09
Fuel Oil #4 Prod.	Fluoranthene	secondary	-9.92e-12	-7.01e-09
Fuel Oil #4 Prod.	Fluorene	secondary	-1.23e-11	-8.66e-09
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	-1.26e-11	-8.90e-09
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	-1.33e-11	-9.44e-09
Natural Gas Prod.	2-Methylnaphthalene	secondary	-1.36e-11	-9.63e-09
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	-1.40e-11	-9.91e-09
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	-1.43e-11	-1.01e-08
Natural Gas Prod.	Cumene	secondary	-1.55e-11	-1.10e-08
LCD incineration	5-Methyl chrysene	secondary	-1.61e-11	-1.14e-08
Natural Gas Prod.	Phenanthrene	secondary	-1.78e-11	-1.25e-08
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	-1.88e-11	-1.33e-08
Fuel Oil #4 Prod.	Chloroform	secondary	-1.97e-11	-1.39e-08
LCD incineration	Benzo[g,h,i]perylene	secondary	-2.00e-11	-1.42e-08
Fuel Oil #4 Prod.	Biphenyl	secondary	-2.06e-11	-1.45e-08
Natural Gas Prod.	Dichloromethane	secondary	-2.34e-11	-1.65e-08
Fuel Oil #4 Prod.	Vinyl acetate	secondary	-2.69e-11	-1.90e-08
LCD incineration	Benzo[a]pyrene	secondary	-2.81e-11	-1.99e-08
Fuel Oil #4 Prod.	Phenanthrene	secondary	-3.95e-11	-2.80e-08
Natural Gas Prod.	Methyl chloride	secondary	-4.28e-11	-3.02e-08
Natural Gas Prod.	Acetophenone	secondary	-4.39e-11	-3.10e-08
LCD incineration	Indeno(1,2,3-cd)pyrene	secondary	-4.51e-11	-3.19e-08
Natural Gas Prod.	Phenol	secondary	-4.68e-11	-3.31e-08
Natural Gas Prod.	Methyl tert-butyl ether	secondary	-5.35e-11	-3.78e-08
Natural Gas Prod.	Benzyl chloride	secondary	-5.65e-11	-3.99e-08
LCD incineration	Benzo[a]anthracene	secondary	-5.90e-11	-4.17e-08
Fuel Oil #4 Prod.	Cumene	secondary	-6.41e-11	-4.53e-08
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	-6.47e-11	-4.57e-08
Natural Gas Prod.	Styrene	secondary	-7.31e-11	-5.17e-08
LCD incineration	Chrysene	secondary	-7.36e-11	-5.21e-08
LCD incineration	Benzo[b,j,k]fluoranthene	secondary	-8.06e-11	-5.70e-08
Fuel Oil #4 Prod.	Dichloromethane	secondary	-9.68e-11	-6.84e-08
LCD incineration	Anthracene	secondary	-1.54e-10	-1.09e-07
Fuel Oil #4 Prod.	Methyl chloride	secondary	-1.77e-10	-1.25e-07
Fuel Oil #4 Prod.	Acetophenone	secondary	-1.81e-10	-1.28e-07
LCD incineration	Acenaphthylene	secondary	-1.84e-10	-1.30e-07
Fuel Oil #4 Prod.	Phenol	secondary	-1.93e-10	-1.37e-07
LCD incineration	2,4-Dinitrotoluene	secondary	-2.05e-10	-1.45e-07
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	-2.21e-10	-1.56e-07
Fuel Oil #4 Prod.	Benzyl chloride	secondary	-2.34e-10	-1.65e-07
LCD incineration	Pyrene	secondary	-2.43e-10	-1.72e-07
Natural Gas Prod.	Bromomethane	secondary	-2.45e-10	-1.73e-07
Natural Gas Prod.	Ethylbenzene	secondary	-2.78e-10	-1.97e-07
Fuel Oil #4 Prod.	Styrene	secondary	-3.02e-10	-2.14e-07

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
LCD incineration	Acenaphthene	secondary	-3.74e-10	-2.65e-07
LCD incineration	1,1,1-Trichloroethane	secondary	-4.05e-10	-2.86e-07
Natural Gas Prod.	n-Propane	secondary	-4.43e-10	-3.14e-07
Natural Gas Prod.	Naphthalene	secondary	-4.44e-10	-3.14e-07
LCD incineration	Chlorobenzene	secondary	-4.45e-10	-3.15e-07
LCD incineration	Ethylene dibromide	secondary	-4.60e-10	-3.25e-07
Natural Gas Prod.	Acrolein	secondary	-4.94e-10	-3.49e-07
LCD incineration	Fluoranthene	secondary	-5.21e-10	-3.68e-07
Fuel Oil #4 Prod.	Naphthalene	secondary	-5.45e-10	-3.85e-07
LCD incineration	Fluorene	secondary	-6.68e-10	-4.72e-07
Natural Gas Prod.	Methyl ethyl ketone	secondary	-7.09e-10	-5.01e-07
LCD incineration	1,2-Dichloroethane	secondary	-8.04e-10	-5.68e-07
LCD incineration	Ethyl Chloride	secondary	-8.50e-10	-6.01e-07
LCD incineration	Tetrachloroethylene	secondary	-8.65e-10	-6.11e-07
Natural Gas Prod.	Propionaldehyde	secondary	-8.80e-10	-6.22e-07
Natural Gas Prod.	Acetaldehyde	secondary	-9.70e-10	-6.86e-07
Fuel Oil #4 Prod.	Bromomethane	secondary	-1.01e-09	-7.15e-07
Fuel Oil #4 Prod.	Ethylbenzene	secondary	-1.15e-09	-8.10e-07
LCD incineration	Chloroform	secondary	-1.19e-09	-8.40e-07
LCD incineration	Biphenyl	secondary	-1.25e-09	-8.81e-07
LCD incineration	Vinyl acetate	secondary	-1.63e-09	-1.15e-06
Fuel Oil #4 Prod.	o-xylene	secondary	-1.63e-09	-1.16e-06
Fuel Oil #4 Prod.	n-Propane	secondary	-1.66e-09	-1.17e-06
Natural Gas Prod.	Isophorone	secondary	-1.70e-09	-1.20e-06
LCD incineration	Phenanthrene	secondary	-1.98e-09	-1.40e-06
Fuel Oil #4 Prod.	Acrolein	secondary	-2.04e-09	-1.44e-06
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	-2.93e-09	-2.07e-06
Fuel Oil #4 Prod.	Propionaldehyde	secondary	-3.64e-09	-2.57e-06
LCD incineration	Cumene	secondary	-3.89e-09	-2.75e-06
Fuel Oil #4 Prod.	Acetaldehyde	secondary	-4.01e-09	-2.84e-06
Fuel Oil #4 Prod.	Toluene	secondary	-4.52e-09	-3.20e-06
LCD incineration	Dichloromethane	secondary	-5.86e-09	-4.14e-06
Fuel Oil #4 Prod.	Isophorone	secondary	-7.01e-09	-4.96e-06
Natural Gas Prod.	Toluene	secondary	-9.63e-09	-6.80e-06
LCD incineration	Methyl chloride	secondary	-1.07e-08	-7.58e-06
LCD incineration	Acetophenone	secondary	-1.10e-08	-7.77e-06
LCD incineration	Phenol	secondary	-1.17e-08	-8.29e-06
LCD incineration	Methyl tert-butyl ether	secondary	-1.34e-08	-9.49e-06
LCD incineration	Naphthalene	secondary	-1.35e-08	-9.57e-06
LCD incineration	Benzyl chloride	secondary	-1.42e-08	-1.00e-05
Natural Gas Prod.	o-xylene	secondary	-1.74e-08	-1.23e-05
LCD incineration	Styrene	secondary	-1.83e-08	-1.30e-05
LCD incineration	Xylene (mixed isomers)	secondary	-2.54e-08	-1.79e-05
Natural Gas Prod.	Formaldehyde	secondary	-3.37e-08	-2.38e-05
LCD incineration	Bromomethane	secondary	-6.14e-08	-4.34e-05
LCD incineration	Ethylbenzene	secondary	-6.84e-08	-4.84e-05
LCD incineration	n-Propane	secondary	-9.86e-08	-6.97e-05
LCD incineration	Acrolein	secondary	-1.24e-07	-8.75e-05
LCD incineration	Toluene	secondary	-1.59e-07	-1.13e-04
LCD incineration	Methyl ethyl ketone	secondary	-1.78e-07	-1.26e-04

Table M-18. LCD LCIA Results for the Photochemical Smog Impact Category

Process Group	Material	LCI Data Type	Photo. Smog (kg ethene-equivalents)	% of Total
LCD incineration	Butane	secondary	-1.97e-07	-1.39e-04
LCD incineration	Hexane	secondary	-2.03e-07	-1.44e-04
LCD incineration	Propionaldehyde	secondary	-2.21e-07	-1.56e-04
LCD incineration	Acetaldehyde	secondary	-2.43e-07	-1.72e-04
LCD incineration	Pentane	secondary	-2.50e-07	-1.76e-04
LCD incineration	Ethane	secondary	-2.90e-07	-2.05e-04
Fuel Oil #4 Prod.	Hexane	secondary	-3.74e-07	-2.65e-04
Fuel Oil #4 Prod.	Butane	secondary	-4.17e-07	-2.95e-04
LCD incineration	Isophorone	secondary	-4.25e-07	-3.01e-04
Fuel Oil #4 Prod.	Pentane	secondary	-5.30e-07	-3.74e-04
Natural Gas Prod.	Hexane	secondary	-5.59e-07	-3.95e-04
Fuel Oil #4 Prod.	Ethane	secondary	-6.16e-07	-4.36e-04
Natural Gas Prod.	Butane	secondary	-6.24e-07	-4.41e-04
Natural Gas Prod.	Pentane	secondary	-7.91e-07	-5.60e-04
Natural Gas Prod.	Ethane	secondary	-9.20e-07	-6.51e-04
LCD incineration	Formaldehyde	secondary	-1.06e-06	-7.52e-04
Fuel Oil #4 Prod.	Aldehydes	secondary	-1.32e-06	-9.32e-04
Fuel Oil #4 Prod.	Formaldehyde	secondary	-1.34e-06	-9.48e-04
Natural Gas Prod.	Aldehydes	secondary	-1.58e-06	-1.12e-03
Fuel Oil #4 Prod.	Benzene	secondary	-5.41e-06	-3.82e-03
LCD incineration	Benzene	secondary	-6.58e-06	-4.65e-03
Natural Gas Prod.	Hydrocarbons, remaining unspeciated	secondary	-8.20e-06	-5.80e-03
Fuel Oil #4 Prod.	Methane	secondary	-1.30e-05	-9.16e-03
LCD incineration	Aldehydes	secondary	-4.38e-05	-3.10e-02
LCD incineration	Methane	secondary	-6.89e-05	-4.87e-02
Natural Gas Prod.	Benzene	secondary	-7.92e-05	-5.60e-02
LCD incineration	Nonmethane hydrocarbons, remaining unspeciated	secondary	-9.99e-05	-7.07e-02
Fuel Oil #4 Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	-1.03e-04	-7.27e-02
Natural Gas Prod.	Methane	secondary	-1.16e-04	-8.22e-02
LCD incineration	Hydrocarbons, remaining unspeciated	secondary	-1.24e-04	-8.77e-02
Fuel Oil #4 Prod.	Hydrocarbons, remaining unspeciated	secondary	-1.53e-04	-1.08e-01
Natural Gas Prod.	Nonmethane hydrocarbons, remaining unspeciated	secondary	-2.98e-04	-2.11e-01
Total End-of-life			**-1.11e-03**	**-7.82e-01**
Total All Life-cycle Stages			**1.41e-01**	**1.00e+02**

Table M-19. CRT LCIA Results for the Acidification Impact Category

Process Group	Material	LCI Data Type	Acidification (kg SO2 Equivalents)	% of Total
Materials Processing Life-cycle Stage				
Invar	Sulfur dioxide	secondary	2.50e-01	4.75e+00
Steel Prod., cold-rolled, semi-finished	Sulfur dioxide	secondary	3.84e-02	7.31e-01
Aluminum Prod.	Sulfur dioxide	secondary	2.09e-02	3.98e-01
Polycarbonate Production	Nitrogen dioxide	secondary	1.36e-02	2.59e-01
Polycarbonate Production	Sulfur dioxide	secondary	1.20e-02	2.29e-01
Steel Prod., cold-rolled, semi-finished	Nitrogen dioxide	secondary	9.36e-03	1.78e-01
Lead	Sulfur dioxide	secondary	6.92e-03	1.32e-01
Styrene-butadiene Copolymer Prod.	Sulfur oxides	secondary	5.71e-03	1.09e-01
Aluminum Prod.	Nitrogen dioxide	secondary	4.99e-03	9.51e-02
Styrene-butadiene Copolymer Prod.	Nitrogen oxides	secondary	4.89e-03	9.32e-02
ABS Production	Sulfur dioxide	secondary	4.24e-03	8.07e-02
Ferrite mfg.	Sulfur dioxide	secondary	3.56e-03	6.78e-02
Invar	Nitrogen dioxide	secondary	3.55e-03	6.75e-02
ABS Production	Nitrogen dioxide	secondary	3.26e-03	6.21e-02
Lead	Nitrogen dioxide	secondary	2.93e-03	5.58e-02
Polystyrene Prod., high-impact	Sulfur dioxide	secondary	1.81e-03	3.45e-02
Ferrite mfg.	Nitrogen dioxide	secondary	1.42e-03	2.70e-02
Polystyrene Prod., high-impact	Nitrogen dioxide	secondary	1.27e-03	2.42e-02
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	7.79e-04	1.48e-02
ABS Production	Hydrochloric acid	secondary	5.63e-04	1.07e-02
Steel Prod., cold-rolled, semi-finished	Nitrous oxide	secondary	5.44e-04	1.04e-02
Steel Prod., cold-rolled, semi-finished	Hydrochloric acid	secondary	3.93e-04	7.48e-03
ABS Production	Hydrofluoric acid	secondary	3.90e-04	7.42e-03
Aluminum Prod.	Hydrofluoric acid	secondary	3.85e-04	7.33e-03
Invar	Hydrochloric acid	secondary	3.56e-04	6.77e-03
Aluminum Prod.	Hydrochloric acid	secondary	3.43e-04	6.53e-03
Lead	Hydrochloric acid	secondary	2.06e-04	3.92e-03
Ferrite mfg.	Hydrochloric acid	secondary	1.33e-04	2.54e-03
Aluminum Prod.	Nitrous oxide	secondary	9.67e-05	1.84e-03
Polycarbonate Production	Hydrochloric acid	secondary	8.94e-05	1.70e-03
Invar	Hydrofluoric acid	secondary	4.30e-05	8.19e-04
Steel Prod., cold-rolled, semi-finished	Hydrofluoric acid	secondary	3.03e-05	5.77e-04
Steel Prod., cold-rolled, semi-finished	Hydrogen sulfide	secondary	2.55e-05	4.87e-04
Lead	Hydrofluoric acid	secondary	2.18e-05	4.16e-04
ABS Production	Hydrogen sulfide	secondary	1.90e-05	3.62e-04
Aluminum Prod.	Ammonia	secondary	1.69e-05	3.22e-04
Lead	Nitrous oxide	secondary	1.42e-05	2.71e-04
Invar	Hydrogen sulfide	secondary	1.37e-05	2.60e-04
Styrene-butadiene Copolymer Prod.	Hydrochloric acid	secondary	1.31e-05	2.50e-04
Lead	Ammonia	secondary	1.30e-05	2.47e-04
Ferrite mfg.	Hydrofluoric acid	secondary	1.02e-05	1.94e-04
Ferrite mfg.	Hydrogen sulfide	secondary	9.72e-06	1.85e-04
Ferrite mfg.	Nitrous oxide	secondary	7.44e-06	1.42e-04
Aluminum Prod.	Hydrogen sulfide	secondary	7.08e-06	1.35e-04
Invar	Ammonia	secondary	6.66e-06	1.27e-04
Polycarbonate Production	Hydrofluoric acid	secondary	5.91e-06	1.13e-04
Lead	Hydrogen sulfide	secondary	5.57e-06	1.06e-04
Polystyrene Prod., high-impact	Hydrochloric acid	secondary	4.66e-06	8.87e-05
Polycarbonate Production	Hydrogen sulfide	secondary	3.47e-06	6.61e-05
Ferrite mfg.	Ammonia	secondary	2.20e-06	4.19e-05

Table M-19. CRT LCIA Results for the Acidification Impact Category

Process Group	Material	LCI Data Type	Acidification (kg SO2 Equivalents)	% of Total
ABS Production	Ammonia	secondary	1.59e-06	3.03e-05
Styrene-butadiene Copolymer Prod.	Hydrofluoric acid	secondary	6.62e-07	1.26e-05
Styrene-butadiene Copolymer Prod.	Ammonia	secondary	3.89e-07	7.41e-06
Styrene-butadiene Copolymer Prod.	Hydrogen sulfide	secondary	3.89e-07	7.41e-06
Polycarbonate Production	Nitrous oxide	secondary	3.23e-07	6.15e-06
Polycarbonate Production	Sulfuric acid	secondary	3.00e-07	5.72e-06
ABS Production	Nitrous oxide	secondary	1.48e-07	2.82e-06
Styrene-butadiene Copolymer Prod.	Nitrous oxide	secondary	1.45e-07	2.76e-06
ABS Production	Sulfuric acid	secondary	1.38e-07	2.62e-06
Styrene-butadiene Copolymer Prod.	Sulfuric acid	secondary	1.34e-07	2.56e-06
Invar	Nitrous oxide	secondary	3.39e-08	6.46e-07
Invar	Sulfuric acid	secondary	5.66e-11	1.08e-09
Ferrite mfg.	Sulfuric acid	secondary	5.53e-11	1.05e-09
Total Materials Processing			**3.93e-01**	**7.48e+00**
Manufacturing Life-cycle Stage				
LPG Production	Sulfur oxides	secondary	8.01e-01	1.53e+01
LPG Production	Nitrogen oxides	secondary	4.01e-01	7.64e+00
Japanese Electric Grid	Sulfur dioxide	model/secondary	8.62e-02	1.64e+00
US electric grid	Sulfur dioxide	model/secondary	3.98e-02	7.58e-01
Glass/frit	Nitrogen oxides	primary	3.09e-02	5.88e-01
Japanese Electric Grid	Nitrogen oxides	model/secondary	2.85e-02	5.42e-01
US electric grid	Nitrogen oxides	model/secondary	1.32e-02	2.50e-01
LPG Production	Nitrous oxide	secondary	1.14e-02	2.16e-01
CRT tube mfg.	Sulfur oxides	primary	9.96e-03	1.90e-01
LPG Production	Hydrochloric acid	secondary	7.07e-03	1.35e-01
Natural Gas Prod.	Nitrogen oxides	secondary	6.53e-03	1.24e-01
LPG Production	Hydrogen sulfide	secondary	5.76e-03	1.10e-01
Fuel Oil #6 Prod.	Sulfur oxides	secondary	5.47e-03	1.04e-01
LPG Production	Ammonia	secondary	4.09e-03	7.79e-02
Fuel Oil #6 Prod.	Nitrogen oxides	secondary	2.87e-03	5.46e-02
Fuel Oil #2 Prod.	Sulfur oxides	secondary	2.44e-03	4.64e-02
LPG Production	Hydrofluoric acid	secondary	1.61e-03	3.06e-02
CRT tube mfg.	Nitrogen oxides	primary	1.52e-03	2.89e-02
US electric grid	Hydrochloric acid	model/secondary	1.51e-03	2.88e-02
Fuel Oil #2 Prod.	Nitrogen oxides	secondary	1.23e-03	2.34e-02
Japanese Electric Grid	Hydrochloric acid	model/secondary	1.21e-03	2.30e-02
Glass/frit	Nitrogen oxides	primary	3.73e-04	7.11e-03
US electric grid	Hydrofluoric acid	model/secondary	3.44e-04	6.54e-03
Natural Gas Prod.	Ammonia	secondary	2.94e-04	5.61e-03
Natural Gas Prod.	Sulfur oxides	secondary	2.76e-04	5.25e-03
Japanese Electric Grid	Hydrofluoric acid	model/secondary	2.74e-04	5.22e-03
Fuel Oil #4 Prod.	Sulfur oxides	secondary	2.45e-04	4.66e-03
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	1.26e-04	2.39e-03
Fuel Oil #6 Prod.	Nitrous oxide	secondary	1.02e-04	1.93e-03
Japanese Electric Grid	Nitrous oxide	model/secondary	7.82e-05	1.49e-03
Fuel Oil #6 Prod.	Hydrogen sulfide	secondary	5.97e-05	1.14e-03
Fuel Oil #6 Prod.	Hydrochloric acid	secondary	5.70e-05	1.09e-03
Glass/frit	Sulfur oxides	primary	5.08e-05	9.68e-04
US electric grid	Nitrous oxide	model/secondary	3.80e-05	7.23e-04

Table M-19. CRT LCIA Results for the Acidification Impact Category

Process Group	Material	LCI Data Type	Acidification (kg SO2 Equivalents)	% of Total
Fuel Oil #2 Prod.	Nitrous oxide	secondary	3.63e-05	6.91e-04
Fuel Oil #2 Prod.	Hydrochloric acid	secondary	2.22e-05	4.22e-04
Fuel Oil #6 Prod.	Ammonia	secondary	2.20e-05	4.20e-04
Fuel Oil #2 Prod.	Hydrogen sulfide	secondary	1.90e-05	3.62e-04
Fuel Oil #6 Prod.	Hydrofluoric acid	secondary	1.30e-05	2.47e-04
Natural Gas Prod.	Hydrochloric acid	secondary	1.23e-05	2.34e-04
Fuel Oil #2 Prod.	Ammonia	secondary	1.21e-05	2.30e-04
Natural Gas Prod.	Nitrous oxide	secondary	8.08e-06	1.54e-04
Fuel Oil #2 Prod.	Hydrofluoric acid	secondary	5.04e-06	9.60e-05
Fuel Oil #4 Prod.	Nitrous oxide	secondary	4.02e-06	7.66e-05
Natural Gas Prod.	Hydrofluoric acid	secondary	2.79e-06	5.31e-05
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	2.36e-06	4.50e-05
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	2.23e-06	4.24e-05
Fuel Oil #4 Prod.	Ammonia	secondary	1.12e-06	2.13e-05
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	5.37e-07	1.02e-05
Natural Gas Prod.	Hydrogen sulfide	secondary	1.27e-07	2.41e-06
Total Manufacturing			**1.47e+00**	**2.79e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Sulfur dioxide	model/secondary	2.49e+00	4.75e+01
US electric grid	Nitrogen oxides	model/secondary	8.24e-01	1.57e+01
US electric grid	Hydrochloric acid	model/secondary	9.47e-02	1.80e+00
US electric grid	Hydrofluoric acid	model/secondary	2.15e-02	4.10e-01
US electric grid	Nitrous oxide	model/secondary	2.38e-03	4.53e-02
Total Use, Maintenance and Repair			**3.44e+00**	**6.54e+01**
End-of-life Life-cycle Stage				
CRT landfilling	Nitrogen dioxide	primary	1.30e-03	2.47e-02
CRT Incineration	Sulfur dioxide	secondary	3.00e-04	5.72e-03
CRT landfilling	Sulfur dioxide	primary	2.80e-04	5.33e-03
US electric grid	Sulfur dioxide	model/secondary	2.49e-04	4.75e-03
US electric grid	Nitrogen oxides	model/secondary	8.24e-05	1.57e-03
US electric grid	Hydrochloric acid	model/secondary	9.48e-06	1.80e-04
LPG Production	Sulfur oxides	secondary	6.92e-06	1.32e-04
LPG Production	Nitrogen oxides	secondary	3.46e-06	6.59e-05
US electric grid	Hydrofluoric acid	model/secondary	2.15e-06	4.10e-05
CRT landfilling	Hydrochloric acid	primary	9.00e-07	1.71e-05
CRT landfilling	Hydrogen sulfide	primary	4.33e-07	8.25e-06
US electric grid	Nitrous oxide	model/secondary	2.38e-07	4.53e-06
LPG Production	Nitrous oxide	secondary	9.80e-08	1.87e-06
LPG Production	Hydrochloric acid	secondary	6.10e-08	1.16e-06
LPG Production	Hydrogen sulfide	secondary	4.97e-08	9.47e-07
LPG Production	Ammonia	secondary	3.53e-08	6.73e-07
LPG Production	Hydrofluoric acid	secondary	1.39e-08	2.64e-07
Natural Gas Prod.	Hydrogen sulfide	secondary	-6.34e-08	-1.21e-06
CRT Incineration	Hydrogen sulfide	secondary	-1.15e-06	-2.19e-05
Natural Gas Prod.	Hydrofluoric acid	secondary	-1.40e-06	-2.66e-05
Natural Gas Prod.	Nitrous oxide	secondary	-4.05e-06	-7.72e-05
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	-5.78e-06	-1.10e-04
Natural Gas Prod.	Hydrochloric acid	secondary	-6.16e-06	-1.17e-04
Fuel Oil #4 Prod.	Ammonia	secondary	-1.20e-05	-2.29e-04
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	-2.40e-05	-4.56e-04

Table M-19. CRT LCIA Results for the Acidification Impact Category

Process Group	Material	LCI Data Type	Acidification (kg SO2 Equivalents)	% of Total
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	-2.54e-05	-4.84e-04
CRT Incineration	Ammonia	secondary	-3.91e-05	-7.44e-04
Fuel Oil #4 Prod.	Nitrous oxide	secondary	-4.33e-05	-8.24e-04
Natural Gas Prod.	Sulfur oxides	secondary	-1.38e-04	-2.63e-03
Natural Gas Prod.	Ammonia	secondary	-1.48e-04	-2.81e-03
CRT Incineration	Hydrofluoric acid	secondary	-3.57e-04	-6.80e-03
CRT Incineration	Nitrous oxide	secondary	-7.29e-04	-1.39e-02
CRT Incineration	Hydrochloric acid	secondary	-8.95e-04	-1.70e-02
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	-1.35e-03	-2.57e-02
Fuel Oil #4 Prod.	Sulfur oxides	secondary	-2.63e-03	-5.01e-02
Natural Gas Prod.	Nitrogen oxides	secondary	-3.27e-03	-6.23e-02
CRT Incineration	Nitrogen oxides	secondary	-8.78e-03	-1.67e-01
CRT Incineration	Sulfur oxides	secondary	-2.70e-02	-5.14e-01
Total End-of-life			**-4.32e-02**	**-8.23e-01**
Total All Life-cycle Stages			**5.25e+00**	**1.00e+02**

Table M-20. LCD LCIA Results for the Acidification Impact Category

Process Group	Material	LCI Data Type	Acidification (kg SO2 Equivalents)	% of Total
Materials Processing Life-cycle Stage				
Natural Gas Prod.	Nitrogen oxides	secondary	4.56e-01	1.54e+01
Natural Gas Prod.	Ammonia	secondary	2.06e-02	6.95e-01
Natural Gas Prod.	Sulfur oxides	secondary	1.93e-02	6.51e-01
Steel Prod., cold-rolled, semi-finished	Sulfur dioxide	secondary	1.88e-02	6.36e-01
PMMA Sheet Prod.	Sulfur dioxide	secondary	1.30e-02	4.41e-01
Aluminum Prod.	Sulfur dioxide	secondary	7.77e-03	2.63e-01
Polycarbonate Production	Nitrogen dioxide	secondary	7.58e-03	2.56e-01
PMMA Sheet Prod.	Nitrogen dioxide	secondary	7.52e-03	2.54e-01
Polycarbonate Production	Sulfur dioxide	secondary	6.70e-03	2.27e-01
Steel Prod., cold-rolled, semi-finished	Nitrogen dioxide	secondary	4.59e-03	1.55e-01
PET Resin Production	Sulfur oxides	secondary	3.99e-03	1.35e-01
Styrene-butadiene Copolymer Prod.	Sulfur oxides	secondary	2.50e-03	8.43e-02
Styrene-butadiene Copolymer Prod.	Nitrogen oxides	secondary	2.14e-03	7.23e-02
Aluminum Prod.	Nitrogen dioxide	secondary	1.86e-03	6.28e-02
PET Resin Production	Nitrogen oxides	secondary	1.21e-03	4.08e-02
Natural Gas Prod.	Hydrochloric acid	secondary	8.57e-04	2.90e-02
Natural Gas Prod.	Nitrous oxide	secondary	5.65e-04	1.91e-02
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	3.82e-04	1.29e-02
Steel Prod., cold-rolled, semi-finished	Nitrous oxide	secondary	2.67e-04	9.01e-03
Natural Gas Prod.	Hydrofluoric acid	secondary	1.95e-04	6.58e-03
Steel Prod., cold-rolled, semi-finished	Hydrochloric acid	secondary	1.93e-04	6.51e-03
Aluminum Prod.	Hydrofluoric acid	secondary	1.43e-04	4.84e-03
Aluminum Prod.	Hydrochloric acid	secondary	1.28e-04	4.31e-03
PMMA Sheet Prod.	Hydrochloric acid	secondary	5.74e-05	1.94e-03
Polycarbonate Production	Hydrochloric acid	secondary	4.99e-05	1.69e-03
Aluminum Prod.	Nitrous oxide	secondary	3.60e-05	1.22e-03
PET Resin Production	Hydrochloric acid	secondary	2.80e-05	9.45e-04
PMMA Sheet Prod.	Ammonia	secondary	1.51e-05	5.12e-04
Steel Prod., cold-rolled, semi-finished	Hydrofluoric acid	secondary	1.48e-05	5.02e-04
Steel Prod., cold-rolled, semi-finished	Hydrogen sulfide	secondary	1.25e-05	4.23e-04
Natural Gas Prod.	Hydrogen sulfide	secondary	8.84e-06	2.99e-04
Aluminum Prod.	Ammonia	secondary	6.30e-06	2.13e-04
Styrene-butadiene Copolymer Prod.	Hydrochloric acid	secondary	5.73e-06	1.94e-04
PMMA Sheet Prod.	Hydrofluoric acid	secondary	5.52e-06	1.87e-04
Polycarbonate Production	Hydrofluoric acid	secondary	3.30e-06	1.12e-04
PMMA Sheet Prod.	Hydrogen sulfide	secondary	2.88e-06	9.75e-05
Aluminum Prod.	Hydrogen sulfide	secondary	2.64e-06	8.91e-05
Polycarbonate Production	Hydrogen sulfide	secondary	1.94e-06	6.55e-05
PET Resin Production	Hydrofluoric acid	secondary	1.45e-06	4.91e-05
Styrene-butadiene Copolymer Prod.	Hydrofluoric acid	secondary	2.89e-07	9.78e-06
Polycarbonate Production	Nitrous oxide	secondary	1.81e-07	6.10e-06
PET Resin Production	Ammonia	secondary	1.71e-07	5.77e-06
PET Resin Production	Hydrogen sulfide	secondary	1.71e-07	5.77e-06
Styrene-butadiene Copolymer Prod.	Ammonia	secondary	1.70e-07	5.75e-06
Styrene-butadiene Copolymer Prod.	Hydrogen sulfide	secondary	1.70e-07	5.75e-06
Polycarbonate Production	Sulfuric acid	secondary	1.68e-07	5.66e-06
PMMA Sheet Prod.	Nitrous oxide	secondary	1.34e-07	4.54e-06
PMMA Sheet Prod.	Sulfuric acid	secondary	1.25e-07	4.21e-06
PET Resin Production	Nitrous oxide	secondary	6.35e-08	2.15e-06
Styrene-butadiene Copolymer Prod.	Nitrous oxide	secondary	6.33e-08	2.14e-06

Table M-20. LCD LCIA Results for the Acidification Impact Category

Process Group	Material	LCI Data Type	Acidification (kg SO2 Equivalents)	% of Total
PET Resin Production	Sulfuric acid	secondary	5.90e-08	1.99e-06
Styrene-butadiene Copolymer Prod.	Sulfuric acid	secondary	5.88e-08	1.99e-06
Total Materials Processing			**5.76e-01**	**1.95e+01**
Manufacturing Life-cycle Stage				
Monitor/module	Nitrogen oxides	primary	3.84e-01	1.30e+01
Japanese Electric Grid	Sulfur dioxide	model/secondary	2.90e-01	9.80e+00
Monitor/module	Ammonia	primary	1.17e-01	3.96e+00
Japanese Electric Grid	Nitrogen oxides	model/secondary	9.57e-02	3.23e+00
Monitor/module	Hydrofluoric acid	primary	8.33e-02	2.82e+00
Monitor/module	Hydrochloric acid	primary	5.33e-02	1.80e+00
LPG Production	Sulfur oxides	secondary	3.85e-02	1.30e+00
Backlight	Nitrogen oxides	primary	2.06e-02	6.97e-01
LPG Production	Nitrogen oxides	secondary	1.92e-02	6.50e-01
Natural Gas Prod.	Nitrogen oxides	secondary	1.03e-02	3.48e-01
US electric grid	Sulfur dioxide	model/secondary	4.83e-03	1.63e-01
Japanese Electric Grid	Hydrochloric acid	model/secondary	4.06e-03	1.37e-01
US electric grid	Nitrogen oxides	model/secondary	1.60e-03	5.39e-02
LCD glass mfg.	Nitrogen oxides	primary	1.43e-03	4.84e-02
Monitor/module	Sulfur oxides	primary	1.12e-03	3.77e-02
Japanese Electric Grid	Hydrofluoric acid	model/secondary	9.23e-04	3.12e-02
LPG Production	Nitrous oxide	secondary	5.45e-04	1.84e-02
Natural Gas Prod.	Ammonia	secondary	4.64e-04	1.57e-02
Natural Gas Prod.	Sulfur oxides	secondary	4.35e-04	1.47e-02
Fuel Oil #4 Prod.	Sulfur oxides	secondary	3.77e-04	1.28e-02
LPG Production	Hydrochloric acid	secondary	3.39e-04	1.15e-02
Panel components	Nitrogen oxides	primary	2.88e-04	9.73e-03
LPG Production	Hydrogen sulfide	secondary	2.77e-04	9.35e-03
Japanese Electric Grid	Nitrous oxide	model/secondary	2.63e-04	8.89e-03
LPG Production	Ammonia	secondary	1.96e-04	6.64e-03
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	1.94e-04	6.54e-03
Fuel Oil #6 Prod.	Sulfur oxides	secondary	1.86e-04	6.29e-03
US electric grid	Hydrochloric acid	model/secondary	1.83e-04	6.20e-03
Monitor/module	Nitric acid	primary	1.37e-04	4.63e-03
Fuel Oil #2 Prod.	Sulfur oxides	secondary	1.14e-04	3.84e-03
Fuel Oil #6 Prod.	Nitrogen oxides	secondary	9.76e-05	3.30e-03
LPG Production	Hydrofluoric acid	secondary	7.71e-05	2.60e-03
Fuel Oil #2 Prod.	Nitrogen oxides	secondary	5.74e-05	1.94e-03
Monitor/module	Phosphoric acid	primary	4.75e-05	1.61e-03
US electric grid	Hydrofluoric acid	model/secondary	4.17e-05	1.41e-03
Natural Gas Prod.	Hydrochloric acid	secondary	1.94e-05	6.54e-04
Natural Gas Prod.	Nitrous oxide	secondary	1.27e-05	4.31e-04
Panel components	Hydrochloric acid	primary	6.44e-06	2.18e-04
Fuel Oil #4 Prod.	Nitrous oxide	secondary	6.20e-06	2.10e-04
US electric grid	Nitrous oxide	model/secondary	4.61e-06	1.56e-04
Natural Gas Prod.	Hydrofluoric acid	secondary	4.40e-06	1.49e-04
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	3.64e-06	1.23e-04
Fuel Oil #6 Prod.	Nitrous oxide	secondary	3.46e-06	1.17e-04
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	3.43e-06	1.16e-04
LCD glass mfg.	Sulfur oxides	primary	2.35e-06	7.96e-05

Table M-20. LCD LCIA Results for the Acidification Impact Category

Process Group	Material	LCI Data Type	Acidification (kg SO2 Equivalents)	% of Total
Fuel Oil #6 Prod.	Hydrogen sulfide	secondary	2.03e-06	6.87e-05
Fuel Oil #6 Prod.	Hydrochloric acid	secondary	1.94e-06	6.56e-05
Fuel Oil #4 Prod.	Ammonia	secondary	1.72e-06	5.83e-05
Fuel Oil #2 Prod.	Nitrous oxide	secondary	1.69e-06	5.73e-05
Fuel Oil #2 Prod.	Hydrochloric acid	secondary	1.04e-06	3.50e-05
Fuel Oil #2 Prod.	Hydrogen sulfide	secondary	8.88e-07	3.00e-05
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	8.28e-07	2.80e-05
Fuel Oil #6 Prod.	Ammonia	secondary	7.50e-07	2.53e-05
Fuel Oil #2 Prod.	Ammonia	secondary	5.63e-07	1.90e-05
Fuel Oil #6 Prod.	Hydrofluoric acid	secondary	4.41e-07	1.49e-05
Fuel Oil #2 Prod.	Hydrofluoric acid	secondary	2.35e-07	7.95e-06
Natural Gas Prod.	Hydrogen sulfide	secondary	1.99e-07	6.74e-06
Total Manufacturing			**1.13e+00**	**3.82e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Sulfur dioxide	model/secondary	9.30e-01	3.14e+01
US electric grid	Nitrogen oxides	model/secondary	3.08e-01	1.04e+01
US electric grid	Hydrochloric acid	model/secondary	3.53e-02	1.19e+00
US electric grid	Hydrofluoric acid	model/secondary	8.03e-03	2.71e-01
US electric grid	Nitrous oxide	model/secondary	8.88e-04	3.00e-02
Total Use, Maintenance, and Repair			**1.28e+00**	**4.33e+01**
End-of-life Life-cycle Stage				
LCD landfilling	Nitrogen dioxide	primary	3.12e-04	1.06e-02
US electric grid	Sulfur dioxide	model/secondary	1.77e-04	5.97e-03
LCD landfilling	Sulfur dioxide	primary	6.74e-05	2.28e-03
US electric grid	Nitrogen oxides	model/secondary	5.83e-05	1.97e-03
LCD incineration	Sulfur dioxide	secondary	5.23e-05	1.77e-03
US electric grid	Hydrochloric acid	model/secondary	6.71e-06	2.27e-04
LPG Production	Sulfur oxides	secondary	3.16e-06	1.07e-04
LPG Production	Nitrogen oxides	secondary	1.58e-06	5.34e-05
US electric grid	Hydrofluoric acid	model/secondary	1.52e-06	5.15e-05
LCD landfilling	Hydrochloric acid	primary	2.17e-07	7.33e-06
US electric grid	Nitrous oxide	model/secondary	1.68e-07	5.69e-06
LCD landfilling	Hydrogen sulfide	primary	1.04e-07	3.52e-06
LPG Production	Nitrous oxide	secondary	4.47e-08	1.51e-06
LPG Production	Hydrochloric acid	secondary	2.78e-08	9.41e-07
LPG Production	Hydrogen sulfide	secondary	2.27e-08	7.67e-07
LPG Production	Ammonia	secondary	1.61e-08	5.45e-07
LPG Production	Hydrofluoric acid	secondary	6.33e-09	2.14e-07
Natural Gas Prod.	Hydrogen sulfide	secondary	-4.19e-08	-1.42e-06
Natural Gas Prod.	Hydrofluoric acid	secondary	-9.23e-07	-3.12e-05
LCD incineration	Hydrogen sulfide	secondary	-9.64e-07	-3.26e-05
Natural Gas Prod.	Nitrous oxide	secondary	-2.68e-06	-9.04e-05
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	-3.81e-06	-1.29e-04
Natural Gas Prod.	Hydrochloric acid	secondary	-4.06e-06	-1.37e-04
Fuel Oil #4 Prod.	Ammonia	secondary	-7.95e-06	-2.69e-04
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	-1.58e-05	-5.35e-04
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	-1.68e-05	-5.67e-04
LCD incineration	Ammonia	secondary	-2.53e-05	-8.56e-04
Fuel Oil #4 Prod.	Nitrous oxide	secondary	-2.86e-05	-9.66e-04
Natural Gas Prod.	Sulfur oxides	secondary	-9.13e-05	-3.08e-03

Table M-20. LCD LCIA Results for the Acidification Impact Category

Process Group	Material	LCI Data Type	Acidification (kg SO2 Equivalents)	% of Total
Natural Gas Prod.	Ammonia	secondary	-9.75e-05	-3.29e-03
LCD incineration	Hydrofluoric acid	secondary	-2.31e-04	-7.81e-03
LCD incineration	Nitrous oxide	secondary	-4.72e-04	-1.60e-02
LCD incineration	Hydrochloric acid	secondary	-5.91e-04	-2.00e-02
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	-8.92e-04	-3.01e-02
Fuel Oil #4 Prod.	Sulfur oxides	secondary	-1.74e-03	-5.88e-02
Natural Gas Prod.	Nitrogen oxides	secondary	-2.16e-03	-7.30e-02
LCD incineration	Nitrogen oxides	secondary	-6.52e-03	-2.20e-01
LCD incineration	Sulfur oxides	secondary	-1.75e-02	-5.91e-01
Total End-of-life			**-2.97e-02**	**-1.00e+00**
Total All Life-cycle Stages			**2.96e+00**	**1.00e+02**

Table M-21. CRT LCIA Results for the Air Particulates Impact Category

Process Group	Materials	LCI Data Type	Air Particulates (kg)	% of total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	PM	secondary	1.05e-01	3.48e+01
Aluminum Prod.	PM	secondary	8.90e-03	2.96e+00
Polycarbonate Production	PM	secondary	6.46e-03	2.15e+00
Invar	PM	secondary	2.76e-03	9.15e-01
Ferrite mfg.	PM	secondary	1.72e-03	5.72e-01
ABS Production	PM	secondary	1.27e-03	4.22e-01
Styrene-butadiene Copolymer Prod.	PM	secondary	9.93e-04	3.30e-01
Lead	PM	secondary	8.41e-04	2.79e-01
Polystyrene Prod., high-impact	PM	secondary	3.02e-04	1.00e-01
Total Materials Processing			**1.28e-01**	**4.25e+01**
Manufacturing Life-cycle Stage				
LPG Production	PM	secondary	1.29e-01	4.28e+01
Japanese Electric Grid	PM-10	model/secondary	2.00e-03	6.64e-01
Fuel Oil #6 Prod.	PM	secondary	9.24e-04	3.07e-01
US electric grid	PM-10	model/secondary	9.22e-04	3.06e-01
Natural Gas Prod.	PM	secondary	4.14e-04	1.38e-01
Fuel Oil #2 Prod.	PM	secondary	3.96e-04	1.31e-01
LPG Production	PM-10	secondary	2.25e-04	7.47e-02
Glass/frit	PM	primary	1.09e-04	3.63e-02
Fuel Oil #4 Prod.	PM	secondary	4.05e-05	1.34e-02
Fuel Oil #6 Prod.	PM-10	secondary	2.33e-06	7.74e-04
Fuel Oil #2 Prod.	PM-10	secondary	7.42e-07	2.47e-04
Glass/frit	PM	primary	6.67e-07	2.21e-04
Fuel Oil #4 Prod.	PM-10	secondary	8.70e-08	2.89e-05
Natural Gas Prod.	PM-10	secondary	4.94e-09	1.64e-06
Total Manufacturing			**1.34e-01**	**4.45e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	PM-10	model/secondary	5.78e-02	1.92e+01
Total Use, Maintenance and Repair			**5.78e-02**	**1.92e+01**
End-of-life Life-cycle Stage				
CRT landfilling	PM	primary	2.08e-04	6.92e-02
US electric grid	PM-10	model/secondary	5.78e-06	1.92e-03
LPG Production	PM	secondary	1.11e-06	3.70e-04
LPG Production	PM-10	secondary	1.94e-09	6.45e-07
Natural Gas Prod.	PM-10	secondary	-2.48e-09	-8.23e-07
CRT Incineration	PM-10	secondary	-6.30e-08	-2.09e-05
Fuel Oil #4 Prod.	PM-10	secondary	-9.35e-07	-3.11e-04
Natural Gas Prod.	PM	secondary	-2.08e-04	-6.90e-02
Fuel Oil #4 Prod.	PM	secondary	-4.35e-04	-1.44e-01
CRT Incineration	PM	secondary	-1.83e-02	-6.09e+00
Total End-of-life			**-1.88e-02**	**-6.23e+00**
Total All Life-cycle Stages			**3.01e-01**	**1.00e+02**

Table M-22. LCD LCIA Results for the Air Particulates Impact Category

Process Group	Materials	LCI Data Type	Air Particulates (kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	PM	secondary	5.14e-02	4.48e+01
Natural Gas Prod.	PM	secondary	2.89e-02	2.52e+01
Polycarbonate Production	PM	secondary	3.61e-03	3.15e+00
Aluminum Prod.	PM	secondary	3.31e-03	2.89e+00
PMMA Sheet Prod.	PM	secondary	3.22e-03	2.81e+00
PET Resin Production	PM	secondary	6.99e-04	6.10e-01
Styrene-butadiene Copolymer Prod.	PM	secondary	4.34e-04	3.79e-01
Natural Gas Prod.	PM-10	secondary	3.45e-07	3.01e-04
Total Materials Processing			**9.16e-02**	**7.99e+01**
Manufacturing Life-cycle Stage				
Japanese Electric Grid	PM-10	model/secondary	6.72e-03	5.87e+00
LPG Production	PM	secondary	6.19e-03	5.40e+00
Natural Gas Prod.	PM	secondary	6.53e-04	5.69e-01
US electric grid	PM-10	model/secondary	1.12e-04	9.76e-02
Fuel Oil #4 Prod.	PM	secondary	6.24e-05	5.44e-02
Fuel Oil #6 Prod.	PM	secondary	3.15e-05	2.75e-02
Panel components	PM	primary	2.74e-05	2.39e-02
Fuel Oil #2 Prod.	PM	secondary	1.85e-05	1.61e-02
Monitor/module	PM	primary	1.10e-05	9.58e-03
LPG Production	PM-10	secondary	1.08e-05	9.42e-03
LCD glass mfg.	PM	primary	5.06e-06	4.41e-03
Fuel Oil #4 Prod.	PM-10	secondary	1.34e-07	1.17e-04
Fuel Oil #6 Prod.	PM-10	secondary	7.94e-08	6.92e-05
Fuel Oil #2 Prod.	PM-10	secondary	3.47e-08	3.02e-05
Natural Gas Prod.	PM-10	secondary	7.79e-09	6.79e-06
Total Manufacturing			**1.38e-02**	**1.21e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	PM-10	model/secondary	2.16e-02	1.88e+01
Total Use, Maintenance and Repair			**2.16e-02**	**1.88e+01**
End-of-life Life-cycle Stage				
LCD landfilling	PM	primary	5.02e-05	4.38e-02
US electric grid	PM-10	model/secondary	4.09e-06	3.57e-03
LPG Production	PM	secondary	5.08e-07	4.43e-04
Natural Gas Prod.	PM-10	secondary	-1.63e-09	-1.43e-06
LCD incineration	PM-10	secondary	-4.08e-08	-3.56e-05
Fuel Oil #4 Prod.	PM-10	secondary	-6.18e-07	-5.39e-04
Natural Gas Prod.	PM	secondary	-1.37e-04	-1.20e-01
Fuel Oil #4 Prod.	PM	secondary	-2.87e-04	-2.51e-01
LCD incineration	PM	secondary	-1.20e-02	-1.05e+01
Total End-of-life			**-1.24e-02**	**-1.08e+01**
Total All Life-cycle Stages			**1.15e-01**	**1.00e+02**

Table M-23. CRT LCIA Results for the Water Eutrophication Impact Category

Process Group	Material	LCI Data Type	Water Eutrophication (kg Phosphate Equivalents)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Other nitrogen	secondary	1.80e-04	3.73e-01
Steel Prod., cold-rolled, semi-finished	COD	secondary	1.61e-04	3.34e-01
Aluminum Prod.	Phosphate (PO43-)	secondary	9.44e-05	1.96e-01
Polycarbonate Production	Phosphate (PO43-)	secondary	4.84e-05	1.00e-01
ABS Production	Ammonia	secondary	3.70e-05	7.67e-02
Lead	Phosphate (PO43-)	secondary	2.79e-05	5.79e-02
ABS Production	COD	secondary	2.05e-05	4.25e-02
Polycarbonate Production	COD	secondary	2.03e-05	4.22e-02
ABS Production	Other nitrogen	secondary	1.78e-05	3.69e-02
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	1.68e-05	3.48e-02
Aluminum Prod.	Other nitrogen	secondary	1.23e-05	2.56e-02
Steel Prod., cold-rolled, semi-finished	Phosphorus (yellow or white)	secondary	1.20e-05	2.48e-02
Aluminum Prod.	Nitrogen	secondary	1.10e-05	2.28e-02
Invar	Other nitrogen	secondary	5.96e-06	1.24e-02
Invar	COD	secondary	5.80e-06	1.20e-02
Ferrite mfg.	COD	secondary	5.66e-06	1.18e-02
Invar	Ammonia	secondary	4.91e-06	1.02e-02
Aluminum Prod.	Nitrate	secondary	4.56e-06	9.47e-03
Styrene-butadiene Copolymer Prod.	COD	secondary	4.10e-06	8.50e-03
Lead	Nitrogen	secondary	3.77e-06	7.83e-03
Polycarbonate Production	Nitrogen	secondary	3.49e-06	7.24e-03
Lead	Other nitrogen	secondary	3.06e-06	6.36e-03
Ferrite mfg.	Phosphate (PO43-)	secondary	3.04e-06	6.31e-03
ABS Production	Nitrate	secondary	3.01e-06	6.24e-03
Styrene-butadiene Copolymer Prod.	Other nitrogen	secondary	1.74e-06	3.61e-03
Invar	Nitrates/nitrites	secondary	1.62e-06	3.37e-03
Ferrite mfg.	Ammonia	secondary	1.58e-06	3.29e-03
Steel Prod., cold-rolled, semi-finished	Phosphate (PO43-)	secondary	1.44e-06	2.98e-03
Ferrite mfg.	Other nitrogen	secondary	1.27e-06	2.65e-03
Polystyrene Prod., high-impact	COD	secondary	1.20e-06	2.48e-03
Aluminum Prod.	COD	secondary	1.18e-06	2.44e-03
Styrene-butadiene Copolymer Prod.	Ammonia ions	secondary	1.17e-06	2.42e-03
Lead	Nitrate	secondary	9.00e-07	1.87e-03
Polycarbonate Production	Ammonia	secondary	7.11e-07	1.48e-03
Steel Prod., cold-rolled, semi-finished	Nitrates/nitrites	secondary	6.71e-07	1.39e-03
Polystyrene Prod., high-impact	Nitrogen	secondary	5.08e-07	1.05e-03
Ferrite mfg.	Nitrate	secondary	4.04e-07	8.38e-04
Polystyrene Prod., high-impact	Ammonia	secondary	3.10e-07	6.44e-04
Lead	COD	secondary	2.92e-07	6.07e-04
Styrene-butadiene Copolymer Prod.	Nitrate	secondary	2.90e-07	6.01e-04
Ferrite mfg.	Phosphorus (yellow or white)	secondary	5.76e-08	1.20e-04
Invar	Phosphorus (yellow or white)	secondary	4.85e-08	1.01e-04
ABS Production	Phosphate (PO43-)	secondary	4.62e-08	9.59e-05
Polycarbonate Production	Nitrate	secondary	4.62e-08	9.58e-05
Polystyrene Prod., high-impact	Nitrate	secondary	3.02e-08	6.27e-05
Total Materials Processing			**7.22e-04**	**1.50e+00**
Manufacturing Life-cycle Stage				

Table M-23. CRT LCIA Results for the Water Eutrophication Impact Category

Process Group	Material	LCI Data Type	Water Eutrophication (kg Phosphate Equivalents)	% of Total
LPG Production	COD	secondary	3.49e-02	7.24e+01
LPG Production	Ammonia ions	secondary	9.04e-03	1.88e+01
CRT tube mfg.	Nitrogen	primary	3.02e-03	6.26e+00
CRT tube mfg.	COD	primary	1.59e-04	3.30e-01
CRT tube mfg.	Phosphorus (yellow or white)	primary	1.54e-04	3.21e-01
Fuel Oil #6 Prod.	COD	secondary	1.18e-04	2.45e-01
Fuel Oil #2 Prod.	COD	secondary	9.79e-05	2.03e-01
Fuel Oil #6 Prod.	Ammonia ions	secondary	3.01e-05	6.24e-02
Fuel Oil #2 Prod.	Ammonia ions	secondary	2.51e-05	5.21e-02
Fuel Oil #4 Prod.	COD	secondary	7.96e-06	1.65e-02
LPG Production	Nitrate	secondary	6.06e-06	1.26e-02
Fuel Oil #4 Prod.	Ammonia ions	secondary	2.04e-06	4.23e-03
CRT tube mfg.	Phosphate as P2O5	primary	1.62e-06	3.36e-03
Natural Gas Prod.	COD	secondary	7.15e-07	1.49e-03
Glass/frit	Nitrates/nitrites	primary	3.95e-07	8.21e-04
Glass/frit	COD	primary	1.81e-07	3.75e-04
Natural Gas Prod.	Ammonia ions	secondary	1.11e-07	2.30e-04
Fuel Oil #6 Prod.	Nitrate	secondary	2.43e-08	5.04e-05
Fuel Oil #2 Prod.	Nitrate	secondary	1.73e-08	3.58e-05
LPG Production	Other nitrogen	secondary	6.62e-09	1.37e-05
Natural Gas Prod.	Nitrate	secondary	1.50e-09	3.12e-06
Fuel Oil #4 Prod.	Nitrate	secondary	1.47e-09	3.05e-06
Fuel Oil #6 Prod.	Other nitrogen	secondary	2.24e-11	4.65e-08
Fuel Oil #2 Prod.	Other nitrogen	secondary	1.86e-11	3.85e-08
Fuel Oil #4 Prod.	Other nitrogen	secondary	1.51e-12	3.13e-09
Natural Gas Prod.	Other nitrogen	secondary	1.34e-13	2.78e-10
Total Manufacturing			**4.76e-02**	**9.87e+01**
Use, Maintenance and Repair Life-cycle Stage				
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
CRT landfilling	COD	primary	2.13e-06	4.43e-03
CRT landfilling	Ammonia	primary	4.62e-07	9.59e-04
LPG Production	COD	secondary	3.01e-07	6.25e-04
LPG Production	Ammonia ions	secondary	7.80e-08	1.62e-04
LPG Production	Nitrate	secondary	5.23e-11	1.09e-07
LPG Production	Other nitrogen	secondary	5.71e-14	1.19e-10
Natural Gas Prod.	Other nitrogen	secondary	-6.71e-14	-1.39e-10
CRT Incineration	Other nitrogen	secondary	-1.04e-12	-2.16e-09
Fuel Oil #4 Prod.	Other nitrogen	secondary	-1.62e-11	-3.37e-08
Natural Gas Prod.	Nitrate	secondary	-7.54e-10	-1.57e-06
Fuel Oil #4 Prod.	Nitrate	secondary	-1.58e-08	-3.27e-05
Natural Gas Prod.	Ammonia ions	secondary	-5.56e-08	-1.15e-04
CRT Incineration	Nitrate	secondary	-1.80e-07	-3.73e-04
Natural Gas Prod.	COD	secondary	-3.59e-07	-7.45e-04
CRT Incineration	Ammonia	secondary	-1.80e-06	-3.74e-03
CRT Incineration	COD	secondary	-3.21e-06	-6.65e-03
Fuel Oil #4 Prod.	Ammonia ions	secondary	-2.19e-05	-4.55e-02

Table M-23. CRT LCIA Results for the Water Eutrophication Impact Category

Process Group	Material	LCI Data Type	Water Eutrophication (kg Phosphate Equivalents)	% of Total
Fuel Oil #4 Prod.	COD	secondary	-8.56e-05	-1.78e-01
Total End-of-life			**-1.10e-04**	**-2.29e-01**
Total All Manufacturing Stages			**4.82e-02**	**1.00e+02**

Table M-24. LCD LCIA Results for the Water Eutrophication Impact Category

Process Group	Material	LCI Data Type	Water Eutrophication (kg Phosphate Equivalents)	% of Total
Materials Processing Life-cycle Stage				
PMMA Sheet Prod.	Ammonia	secondary	1.97e-04	3.97e-01
Steel Prod., cold-rolled, semi-finished	Other nitrogen	secondary	8.81e-05	1.78e-01
Steel Prod., cold-rolled, semi-finished	COD	secondary	7.89e-05	1.59e-01
Natural Gas Prod.	COD	secondary	5.00e-05	1.01e-01
PMMA Sheet Prod.	Phosphate (PO43-)	secondary	4.86e-05	9.80e-02
Aluminum Prod.	Phosphate (PO43-)	secondary	3.51e-05	7.09e-02
Polycarbonate Production	Phosphate (PO43-)	secondary	2.70e-05	5.45e-02
PMMA Sheet Prod.	COD	secondary	2.19e-05	4.43e-02
Polycarbonate Production	COD	secondary	1.13e-05	2.29e-02
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	8.21e-06	1.66e-02
Natural Gas Prod.	Ammonia ions	secondary	7.75e-06	1.56e-02
PMMA Sheet Prod.	Nitrates/nitrites	secondary	7.67e-06	1.55e-02
Steel Prod., cold-rolled, semi-finished	Phosphorus (yellow or white)	secondary	5.86e-06	1.18e-02
Aluminum Prod.	Other nitrogen	secondary	4.60e-06	9.27e-03
PET Resin Production	COD	secondary	4.39e-06	8.86e-03
Aluminum Prod.	Nitrogen	secondary	4.09e-06	8.25e-03
Polycarbonate Production	Nitrogen	secondary	1.95e-06	3.93e-03
Styrene-butadiene Copolymer Prod.	COD	secondary	1.79e-06	3.61e-03
Aluminum Prod.	Nitrate	secondary	1.70e-06	3.43e-03
PMMA Sheet Prod.	Other nitrogen	secondary	9.66e-07	1.95e-03
Styrene-butadiene Copolymer Prod.	Other nitrogen	secondary	7.60e-07	1.53e-03
Steel Prod., cold-rolled, semi-finished	Phosphate (PO43-)	secondary	7.03e-07	1.42e-03
Styrene-butadiene Copolymer Prod.	Ammonia ions	secondary	5.11e-07	1.03e-03
Aluminum Prod.	COD	secondary	4.38e-07	8.83e-04
Polycarbonate Production	Ammonia	secondary	3.97e-07	8.01e-04
Steel Prod., cold-rolled, semi-finished	Nitrates/nitrites	secondary	3.29e-07	6.63e-04
Styrene-butadiene Copolymer Prod.	Nitrate	secondary	1.27e-07	2.55e-04
Natural Gas Prod.	Nitrate	secondary	1.05e-07	2.12e-04
PET Resin Production	Other nitrogen	secondary	3.81e-08	7.69e-05
Polycarbonate Production	Nitrate	secondary	2.58e-08	5.20e-05
PET Resin Production	Ammonia ions	secondary	2.33e-08	4.70e-05
PET Resin Production	Nitrate	secondary	9.08e-09	1.83e-05
Natural Gas Prod.	Other nitrogen	secondary	9.34e-12	1.88e-08
Total Materials Processing			**6.10e-04**	**1.23e+00**
Manufacturing Life-cycle Stage				
Monitor/module	Nitrogen	primary	3.33e-02	6.72e+01
Monitor/module	Phosphorus (yellow or white)	primary	1.32e-02	2.66e+01
LPG Production	COD	secondary	1.67e-03	3.38e+00
LPG Production	Ammonia ions	secondary	4.34e-04	8.75e-01
Panel components	Nitrogen	primary	2.40e-04	4.84e-01
Panel components	Phosphorus (yellow or white)	primary	7.60e-05	1.53e-01
Monitor/module	COD	primary	5.91e-05	1.19e-01
Panel components	COD	primary	4.86e-05	9.81e-02
Fuel Oil #4 Prod.	COD	secondary	1.23e-05	2.47e-02
Fuel Oil #2 Prod.	COD	secondary	4.57e-06	9.22e-03
Fuel Oil #6 Prod.	COD	secondary	4.02e-06	8.11e-03
Fuel Oil #4 Prod.	Ammonia ions	secondary	3.14e-06	6.33e-03
Fuel Oil #2 Prod.	Ammonia ions	secondary	1.17e-06	2.36e-03

Table M-24. LCD LCIA Results for the Water Eutrophication Impact Category

Process Group	Material	LCI Data Type	Water Eutrophication (kg Phosphate Equivalents)	% of Total
Natural Gas Prod.	COD	secondary	1.13e-06	2.28e-03
Fuel Oil #6 Prod.	Ammonia ions	secondary	1.02e-06	2.07e-03
LPG Production	Nitrate	secondary	2.91e-07	5.86e-04
Natural Gas Prod.	Ammonia ions	secondary	1.75e-07	3.53e-04
LCD glass mfg.	Nitrate	primary	1.83e-08	3.70e-05
LCD glass mfg.	COD	primary	8.36e-09	1.69e-05
Natural Gas Prod.	Nitrate	secondary	2.37e-09	4.78e-06
Fuel Oil #4 Prod.	Nitrate	secondary	2.26e-09	4.56e-06
Fuel Oil #6 Prod.	Nitrate	secondary	8.26e-10	1.67e-06
Fuel Oil #2 Prod.	Nitrate	secondary	8.06e-10	1.63e-06
LPG Production	Other nitrogen	secondary	3.17e-10	6.41e-07
Fuel Oil #4 Prod.	Other nitrogen	secondary	2.33e-12	4.69e-09
Fuel Oil #2 Prod.	Other nitrogen	secondary	8.67e-13	1.75e-09
Fuel Oil #6 Prod.	Other nitrogen	secondary	7.62e-13	1.54e-09
Natural Gas Prod.	Other nitrogen	secondary	2.11e-13	4.25e-10
Total Manufacturing			**4.90e-02**	**9.89e+01**
Use, Maintenance and Repair Life-cycle Stage				
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
LCD landfilling	COD	primary	5.14e-07	1.04e-03
LPG Production	COD	secondary	1.37e-07	2.77e-04
LCD landfilling	Ammonia	primary	1.11e-07	2.25e-04
LPG Production	Ammonia ions	secondary	3.56e-08	7.19e-05
LPG Production	Nitrate	secondary	2.39e-11	4.81e-08
LPG Production	Other nitrogen	secondary	2.61e-14	5.26e-11
Natural Gas Prod.	Other nitrogen	secondary	-4.43e-14	-8.93e-11
LCD incineration	Other nitrogen	secondary	-6.75e-13	-1.36e-09
Fuel Oil #4 Prod.	Other nitrogen	secondary	-1.07e-11	-2.16e-08
Natural Gas Prod.	Nitrate	secondary	-4.98e-10	-1.00e-06
Fuel Oil #4 Prod.	Nitrate	secondary	-1.04e-08	-2.10e-05
Natural Gas Prod.	Ammonia ions	secondary	-3.67e-08	-7.41e-05
LCD incineration	Nitrate	secondary	-1.17e-07	-2.35e-04
Natural Gas Prod.	COD	secondary	-2.37e-07	-4.78e-04
LCD incineration	Ammonia	secondary	-1.40e-06	-2.83e-03
LCD incineration	COD	secondary	-3.16e-06	-6.38e-03
Fuel Oil #4 Prod.	Ammonia ions	secondary	-1.45e-05	-2.92e-02
Fuel Oil #4 Prod.	COD	secondary	-5.65e-05	-1.14e-01
Total End-of-life			**-7.51e-05**	**-1.52e-01**
Total All Life-cycle Stages			**4.96e-02**	**1.00e+02**

Table M-25. CRT LCIA Results for the Water Quality, BOD Impact Category

Process Group	Material	LCI Data Type	BOD (kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	BOD	secondary	2.51e-04	1.29e-01
Polycarbonate Production	BOD	secondary	8.68e-05	4.45e-02
Styrene-butadiene Copolymer Prod.	BOD	secondary	1.65e-05	8.48e-03
ABS Production	BOD	secondary	1.40e-05	7.17e-03
Polystyrene Prod., high-impact	BOD	secondary	6.80e-06	3.49e-03
Invar	BOD	secondary	6.65e-06	3.41e-03
Ferrite mfg.	BOD	secondary	4.74e-06	2.43e-03
Aluminum Prod.	BOD	secondary	4.03e-06	2.06e-03
Lead	BOD	secondary	2.48e-06	1.27e-03
Total Materials Processing			**3.93e-04**	**2.02e-01**
Manufacturing Life-cycle Stage				
LPG Production	BOD	secondary	1.88e-01	9.61e+01
CRT tube mfg.	BOD	primary	6.39e-03	3.28e+00
Fuel Oil #6 Prod.	BOD	secondary	6.34e-04	3.25e-01
Fuel Oil #2 Prod.	BOD	secondary	5.26e-04	2.70e-01
Fuel Oil #4 Prod.	BOD	secondary	4.28e-05	2.19e-02
Glass/frit	BOD	primary	8.20e-06	4.21e-03
Natural Gas Prod.	BOD	secondary	4.00e-06	2.05e-03
Total Manufacturing			**1.95e-01**	**1.00e+02**
Use, Maintenance and Repair Life-cycle Stage				
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
CRT landfilling	BOD	primary	1.17e-05	5.98e-03
LPG Production	BOD	secondary	1.62e-06	8.30e-04
Natural Gas Prod.	BOD	secondary	-2.01e-06	-1.03e-03
CRT Incineration	BOD	secondary	-1.70e-05	-8.74e-03
Fuel Oil #4 Prod.	BOD	secondary	-4.60e-04	-2.36e-01
Total End-of-life			**-4.65e-04**	**-2.39e-01**
Total All Life-cycle Stages			**1.95e-01**	**1.00e+02**

Table M-26. LCD LCIA Results for the Water Quality, BOD Impact Category

Process Group	Material	LCI Data Type	BOD (kg)	% of Total
Materials Processing Life-cycle Stage				
Natural Gas Prod.	BOD	secondary	2.80e-04	9.88e-01
PMMA Sheet Prod.	BOD	secondary	2.30e-04	8.12e-01
Steel Prod., cold-rolled, semi-finished	BOD	secondary	1.23e-04	4.34e-01
PET Resin Production	BOD	secondary	8.17e-05	2.88e-01
Polycarbonate Production	BOD	secondary	4.85e-05	1.71e-01
Styrene-butadiene Copolymer Prod.	BOD	secondary	7.23e-06	2.55e-02
Aluminum Prod.	BOD	secondary	1.50e-06	5.29e-03
Total Materials Processing			**7.72e-04**	**2.72e+00**
Manufacturing Life-cycle Stage				
Monitor/module	BOD	primary	1.74e-02	6.15e+01
LPG Production	BOD	secondary	9.00e-03	3.18e+01
Panel components	BOD	primary	1.34e-03	4.74e+00
Fuel Oil #4 Prod.	BOD	secondary	6.59e-05	2.33e-01
Fuel Oil #2 Prod.	BOD	secondary	2.46e-05	8.67e-02
Fuel Oil #6 Prod.	BOD	secondary	2.16e-05	7.62e-02
Natural Gas Prod.	BOD	secondary	6.31e-06	2.23e-02
LCD glass mfg.	BOD	primary	3.80e-07	1.34e-03
Total Manufacturing			**2.79e-02**	**9.84e+01**
Use, Maintenance and Repair Life-cycle Stage				
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
LCD landfilling	BOD	primary	2.81e-06	9.91e-03
LPG Production	BOD	secondary	7.39e-07	2.61e-03
Natural Gas Prod.	BOD	secondary	-1.33e-06	-4.68e-03
LCD incineration	BOD	secondary	-1.70e-05	-5.99e-02
Fuel Oil #4 Prod.	BOD	secondary	-3.04e-04	-1.07e+00
Total End-of-life			**-3.18e-04**	**-1.12e+00**
Total All Life-cycle Stages			**2.83e-02**	**1.00e+02**

Table M-27. CRT LCIA Results for the Water Quality, TSS Impact Category

Process Group	Material	LCI Data Type	Total Suspended Solids (kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Suspended solids	secondary	2.04e-03	2.34e-01
Aluminum Prod.	Suspended solids	secondary	1.74e-03	1.99e-01
Polycarbonate Production	Suspended solids	secondary	1.11e-03	1.27e-01
ABS Production	Suspended solids	secondary	1.02e-03	1.16e-01
Invar	Suspended solids	secondary	8.30e-04	9.49e-02
Lead	Suspended solids	secondary	3.80e-04	4.34e-02
Styrene-butadiene Copolymer Prod.	Suspended solids	secondary	3.06e-04	3.50e-02
Ferrite mfg.	Suspended solids	secondary	2.45e-04	2.81e-02
Polystyrene Prod., high-impact	Suspended solids	secondary	5.14e-05	5.88e-03
Total Materials Processing			**7.72e-03**	**8.83e-01**
Manufacturing Life-cycle Stage				
LPG Production	Suspended solids	secondary	8.51e-01	9.74e+01
Glass/frit	Suspended solids	primary	7.23e-03	8.26e-01
CRT tube mfg.	Suspended solids	primary	4.63e-03	5.30e-01
Fuel Oil #6 Prod.	Suspended solids	secondary	2.88e-03	3.29e-01
Fuel Oil #2 Prod.	Suspended solids	secondary	2.39e-03	2.73e-01
Fuel Oil #4 Prod.	Suspended solids	secondary	1.94e-04	2.22e-02
Japanese Electric Grid	Suspended solids	model/secondary	2.27e-05	2.60e-03
Natural Gas Prod.	Suspended solids	secondary	1.72e-05	1.97e-03
Total Manufacturing			**8.69e-01**	**9.94e+01**
Use, Maintenance and Repair Life-cycle Stage				
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
CRT landfilling	Suspended solids	primary	5.52e-05	6.31e-03
LPG Production	Suspended solids	secondary	7.35e-06	8.40e-04
Natural Gas Prod.	Suspended solids	secondary	-8.64e-06	-9.88e-04
CRT Incineration	Suspended solids	secondary	-7.55e-05	-8.63e-03
Fuel Oil #4 Prod.	Suspended solids	secondary	-2.09e-03	-2.39e-01
Total End-of-life			**-2.11e-03**	**-2.41e-01**
Total All Life-cycle Stages			**8.74e-01**	**1.00e+02**

Table M-28. LCD LCIA Results for the Water Quality, TSS Impact Category

Process Group	Material	LCI Data Type	Total Suspended Solids (kg)	% of Total
Materials Processing Life-cycle Stage				
PMMA Sheet Prod.	Suspended solids	secondary	1.34e-03	2.18e+00
Natural Gas Prod.	Suspended solids	secondary	1.20e-03	1.96e+00
Steel Prod., cold-rolled, semi-finished	Suspended solids	secondary	1.00e-03	1.63e+00
Aluminum Prod.	Suspended solids	secondary	6.48e-04	1.05e+00
Polycarbonate Production	Suspended solids	secondary	6.19e-04	1.01e+00
Styrene-butadiene Copolymer Prod.	Suspended solids	secondary	1.34e-04	2.18e-01
PET Resin Production	Suspended solids	secondary	3.45e-05	5.61e-02
Total Materials Processing			**4.98e-03**	**8.10e+00**
Manufacturing Life-cycle Stage				
LPG Production	Suspended solids	secondary	4.09e-02	6.64e+01
Monitor/module	Suspended solids	primary	1.55e-02	2.52e+01
Panel components	Suspended solids	primary	6.46e-04	1.05e+00
LCD glass mfg.	Suspended solids	primary	3.35e-04	5.44e-01
Fuel Oil #4 Prod.	Suspended solids	secondary	2.99e-04	4.86e-01
Fuel Oil #2 Prod.	Suspended solids	secondary	1.12e-04	1.81e-01
Fuel Oil #6 Prod.	Suspended solids	secondary	9.81e-05	1.59e-01
Japanese Electric Grid	Suspended solids	model/secondary	7.63e-05	1.24e-01
Natural Gas Prod.	Suspended solids	secondary	2.72e-05	4.42e-02
Total Manufacturing			**5.80e-02**	**9.42e+01**
Use, Maintenance and Repair Life-cycle Stage				
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
LCD landfilling	Suspended solids	primary	1.33e-05	2.16e-02
LPG Production	Suspended solids	secondary	3.35e-06	5.45e-03
Natural Gas Prod.	Suspended solids	secondary	-5.71e-06	-9.28e-03
LCD incineration	Suspended solids	secondary	-7.69e-05	-1.25e-01
Fuel Oil #4 Prod.	Suspended solids	secondary	-1.38e-03	-2.24e+00
Total End-of-life			**-1.44e-03**	**-2.35e+00**
Total All Life-cycle Stages			**6.15e-02**	**1.00e+02**

Table M-29. CRT LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Plutonium-241 (isotope)	secondary	2.40e+07	6.23e+01
Invar	Plutonium-241 (isotope)	secondary	6.80e+06	1.77e+01
Ferrite mfg.	Plutonium-241 (isotope)	secondary	6.64e+06	1.72e+01
Steel Prod., cold-rolled, semi-finished	Plutonium-240 (isotope)	secondary	1.04e+05	2.69e-01
Steel Prod., cold-rolled, semi-finished	Cesium-135 (isotope)	secondary	9.38e+04	2.43e-01
Steel Prod., cold-rolled, semi-finished	Radon-222 (isotope)	secondary	8.77e+04	2.28e-01
Steel Prod., cold-rolled, semi-finished	Plutonium-239 (isotope)	secondary	7.29e+04	1.89e-01
Invar	Plutonium-240 (isotope)	secondary	2.94e+04	7.62e-02
Ferrite mfg.	Plutonium-240 (isotope)	secondary	2.87e+04	7.44e-02
Invar	Cesium-135 (isotope)	secondary	2.65e+04	6.89e-02
Ferrite mfg.	Cesium-135 (isotope)	secondary	2.59e+04	6.73e-02
Invar	Radon-222 (isotope)	secondary	2.48e+04	6.45e-02
Ferrite mfg.	Radon-222 (isotope)	secondary	2.42e+04	6.30e-02
Invar	Plutonium-239 (isotope)	secondary	2.06e+04	5.36e-02
Ferrite mfg.	Plutonium-239 (isotope)	secondary	2.01e+04	5.23e-02
Steel Prod., cold-rolled, semi-finished	Strontium-90 (isotope)	secondary	1.40e+04	3.64e-02
Invar	Strontium-90 (isotope)	secondary	3.97e+03	1.03e-02
Ferrite mfg.	Strontium-90 (isotope)	secondary	3.87e+03	1.01e-02
Steel Prod., cold-rolled, semi-finished	Tritium-3 (isotope)	secondary	2.50e+03	6.50e-03
Steel Prod., cold-rolled, semi-finished	radioactive gas (unspecified)	secondary	1.83e+03	4.76e-03
Steel Prod., cold-rolled, semi-finished	Xenon-133 (isotope)	secondary	1.56e+03	4.04e-03
Ferrite mfg.	Radioactive substance (unspecified)	secondary	8.77e+02	2.28e-03
Steel Prod., cold-rolled, semi-finished	Radium-226 (isotope)	secondary	8.66e+02	2.25e-03
Invar	Tritium-3 (isotope)	secondary	7.09e+02	1.84e-03
Ferrite mfg.	Tritium-3 (isotope)	secondary	6.92e+02	1.80e-03
Invar	radioactive gas (unspecified)	secondary	5.19e+02	1.35e-03
Steel Prod., cold-rolled, semi-finished	Thorium-230 (isotope)	secondary	5.15e+02	1.34e-03
Ferrite mfg.	radioactive gas (unspecified)	secondary	5.07e+02	1.32e-03
Invar	Xenon-133 (isotope)	secondary	4.41e+02	1.15e-03
Ferrite mfg.	Xenon-133 (isotope)	secondary	4.30e+02	1.12e-03
Steel Prod., cold-rolled, semi-finished	Plutonium-242 (isotope)	secondary	3.91e+02	1.02e-03
Steel Prod., cold-rolled, semi-finished	Curium-244 (isotope)	secondary	3.90e+02	1.01e-03
Steel Prod., cold-rolled, semi-finished	Uranium-234 (isotope)	secondary	3.15e+02	8.19e-04
Ferrite mfg.	Radium-226 (isotope)	secondary	2.39e+02	6.21e-04
Steel Prod., cold-rolled, semi-finished	Americium-241 (isotope)	secondary	1.92e+02	4.99e-04
Ferrite mfg.	Thorium-230 (isotope)	secondary	1.42e+02	3.70e-04
Steel Prod., cold-rolled, semi-finished	Krypton-85 (isotope)	secondary	1.11e+02	2.89e-04
Invar	Plutonium-242 (isotope)	secondary	1.11e+02	2.88e-04
Invar	Curium-244 (isotope)	secondary	1.10e+02	2.87e-04
Ferrite mfg.	Plutonium-242 (isotope)	secondary	1.08e+02	2.81e-04
Ferrite mfg.	Curium-244 (isotope)	secondary	1.08e+02	2.80e-04
Invar	Radium-226 (isotope)	secondary	1.04e+02	2.71e-04
Steel Prod., cold-rolled, semi-finished	Uranium-238 (isotope)	secondary	9.28e+01	2.41e-04
Invar	Uranium-234 (isotope)	secondary	8.74e+01	2.27e-04
Ferrite mfg.	Uranium-234 (isotope)	secondary	8.72e+01	2.26e-04
Steel Prod., cold-rolled, semi-finished	Samarium-151 (isotope)	secondary	8.67e+01	2.25e-04
Steel Prod., cold-rolled, semi-finished	Neptunium-237 (isotope)	secondary	6.02e+01	1.56e-04
Invar	Americium-241 (isotope)	secondary	5.44e+01	1.41e-04
Ferrite mfg.	Americium-241 (isotope)	secondary	5.31e+01	1.38e-04
Invar	Krypton-85 (isotope)	secondary	3.15e+01	8.18e-05

Table M-29. CRT LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
Ferrite mfg.	Krypton-85 (isotope)	secondary	3.07e+01	7.99e-05
Ferrite mfg.	Uranium-238 (isotope)	secondary	2.56e+01	6.66e-05
Invar	Samarium-151 (isotope)	secondary	2.45e+01	6.37e-05
Invar	Uranium-238 (isotope)	secondary	2.45e+01	6.35e-05
Ferrite mfg.	Samarium-151 (isotope)	secondary	2.40e+01	6.22e-05
Steel Prod., cold-rolled, semi-finished	Carbon-14 (isotope)	secondary	1.91e+01	4.95e-05
Invar	Neptunium-237 (isotope)	secondary	1.71e+01	4.43e-05
Ferrite mfg.	Neptunium-237 (isotope)	secondary	1.66e+01	4.32e-05
Invar	Radioactive substance (unspecified)	secondary	8.13e+00	2.11e-05
Steel Prod., cold-rolled, semi-finished	Radium-222 (isotope)	secondary	6.66e+00	1.73e-05
Steel Prod., cold-rolled, semi-finished	Uranium-235 (isotope)	secondary	5.85e+00	1.52e-05
Invar	Carbon-14 (isotope)	secondary	5.40e+00	1.40e-05
Ferrite mfg.	Carbon-14 (isotope)	secondary	5.27e+00	1.37e-05
Invar	Thorium-230 (isotope)	secondary	5.10e+00	1.33e-05
Steel Prod., cold-rolled, semi-finished	Americium-243 (isotope)	secondary	4.19e+00	1.09e-05
Steel Prod., cold-rolled, semi-finished	Technetium-99M (isotope)	secondary	2.86e+00	7.43e-06
Steel Prod., cold-rolled, semi-finished	Thorium-228 (isotope)	secondary	2.49e+00	6.48e-06
Steel Prod., cold-rolled, semi-finished	Radon-220 (isotope)	secondary	2.03e+00	5.26e-06
Invar	Radium-222 (isotope)	secondary	1.91e+00	4.95e-06
Ferrite mfg.	Radium-222 (isotope)	secondary	1.86e+00	4.83e-06
Invar	Uranium-234 (isotope)	secondary	1.86e+00	4.83e-06
Invar	Uranium-238 (isotope)	secondary	1.80e+00	4.67e-06
Ferrite mfg.	Uranium-235 (isotope)	secondary	1.62e+00	4.20e-06
Invar	Uranium-235 (isotope)	secondary	1.58e+00	4.10e-06
Steel Prod., cold-rolled, semi-finished	Radium-228 (isotope)	secondary	1.30e+00	3.37e-06
Invar	Americium-243 (isotope)	secondary	1.19e+00	3.08e-06
Ferrite mfg.	Americium-243 (isotope)	secondary	1.16e+00	3.00e-06
Steel Prod., cold-rolled, semi-finished	Polonium-210 (isotope)	secondary	1.13e+00	2.92e-06
Invar	Technetium-99M (isotope)	secondary	8.10e-01	2.10e-06
Ferrite mfg.	Technetium-99M (isotope)	secondary	7.91e-01	2.05e-06
Invar	Thorium-228 (isotope)	secondary	7.52e-01	1.95e-06
Ferrite mfg.	Thorium-228 (isotope)	secondary	7.34e-01	1.91e-06
Steel Prod., cold-rolled, semi-finished	Lead-210 (isotope)	secondary	6.54e-01	1.70e-06
Steel Prod., cold-rolled, semi-finished	Radium-224 (isotope)	secondary	6.05e-01	1.57e-06
Invar	Radon-220 (isotope)	secondary	5.80e-01	1.51e-06
Ferrite mfg.	Radon-220 (isotope)	secondary	5.66e-01	1.47e-06
Invar	Radium-228 (isotope)	secondary	3.90e-01	1.01e-06
Ferrite mfg.	Radium-228 (isotope)	secondary	3.81e-01	9.89e-07
Steel Prod., cold-rolled, semi-finished	Zirconium-93 (isotope)	secondary	3.76e-01	9.77e-07
Invar	Polonium-210 (isotope)	secondary	3.21e-01	8.35e-07
Steel Prod., cold-rolled, semi-finished	Cesium-137 (isotope)	secondary	3.19e-01	8.27e-07
Ferrite mfg.	Polonium-210 (isotope)	secondary	3.14e-01	8.15e-07
Steel Prod., cold-rolled, semi-finished	Protactinium-234 (isotope)	secondary	2.01e-01	5.23e-07
Steel Prod., cold-rolled, semi-finished	Thorium-234 (isotope)	secondary	2.01e-01	5.23e-07
Steel Prod., cold-rolled, semi-finished	Silver-110M (isotope)	secondary	1.88e-01	4.88e-07
Invar	Lead-210 (isotope)	secondary	1.87e-01	4.85e-07
Invar	Radium-224 (isotope)	secondary	1.83e-01	4.75e-07
Ferrite mfg.	Lead-210 (isotope)	secondary	1.82e-01	4.73e-07
Ferrite mfg.	Radium-224 (isotope)	secondary	1.78e-01	4.63e-07
Steel Prod., cold-rolled, semi-finished	Potassium-40 (isotope)	secondary	1.75e-01	4.54e-07
Invar	Radium-226 (isotope)	secondary	1.41e-01	3.66e-07

Table M-29. CRT LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
Invar	Thorium-230 (isotope)	secondary	1.41e-01	3.66e-07
Steel Prod., cold-rolled, semi-finished	Cobalt-58 (isotope)	secondary	1.26e-01	3.27e-07
Steel Prod., cold-rolled, semi-finished	Tin-126 (isotope)	secondary	1.18e-01	3.07e-07
Invar	Zirconium-93 (isotope)	secondary	1.07e-01	2.77e-07
Ferrite mfg.	Zirconium-93 (isotope)	secondary	1.04e-01	2.70e-07
Ferrite mfg.	Cesium-137 (isotope)	secondary	8.80e-02	2.29e-07
Steel Prod., cold-rolled, semi-finished	Cobalt-60 (isotope)	secondary	7.90e-02	2.05e-07
Invar	Uranium-235 (isotope)	secondary	7.81e-02	2.03e-07
Invar	Cesium-137 (isotope)	secondary	7.42e-02	1.93e-07
Steel Prod., cold-rolled, semi-finished	Selenium-79 (isotope)	secondary	6.76e-02	1.75e-07
Steel Prod., cold-rolled, semi-finished	Radioactive aerosols and halogenes (unspecified)	secondary	5.74e-02	1.49e-07
Invar	Protactinium-234 (isotope)	secondary	5.70e-02	1.48e-07
Invar	Thorium-234 (isotope)	secondary	5.70e-02	1.48e-07
Ferrite mfg.	Protactinium-234 (isotope)	secondary	5.57e-02	1.45e-07
Ferrite mfg.	Thorium-234 (isotope)	secondary	5.57e-02	1.45e-07
Invar	Silver-110M (isotope)	secondary	5.32e-02	1.38e-07
Ferrite mfg.	Silver-110M (isotope)	secondary	5.19e-02	1.35e-07
Invar	Potassium-40 (isotope)	secondary	4.99e-02	1.30e-07
Ferrite mfg.	Potassium-40 (isotope)	secondary	4.87e-02	1.27e-07
Steel Prod., cold-rolled, semi-finished	Thorium-232 (isotope)	secondary	4.65e-02	1.21e-07
Steel Prod., cold-rolled, semi-finished	Curium-245 (isotope)	secondary	4.35e-02	1.13e-07
Steel Prod., cold-rolled, semi-finished	Antimony-124 (isotope)	secondary	4.33e-02	1.12e-07
Steel Prod., cold-rolled, semi-finished	Cesium-134 (isotope)	secondary	3.88e-02	1.01e-07
Invar	Cobalt-58 (isotope)	secondary	3.57e-02	9.26e-08
Ferrite mfg.	Cobalt-58 (isotope)	secondary	3.48e-02	9.04e-08
Invar	Tin-126 (isotope)	secondary	3.35e-02	8.69e-08
Ferrite mfg.	Tin-126 (isotope)	secondary	3.27e-02	8.48e-08
Invar	Cobalt-60 (isotope)	secondary	2.24e-02	5.81e-08
Ferrite mfg.	Cobalt-60 (isotope)	secondary	2.18e-02	5.67e-08
Steel Prod., cold-rolled, semi-finished	Palladium-107 (isotope)	secondary	2.11e-02	5.49e-08
Invar	Selenium-79 (isotope)	secondary	1.91e-02	4.97e-08
Ferrite mfg.	Selenium-79 (isotope)	secondary	1.87e-02	4.85e-08
Invar	Radioactive aerosols and halogenes (unspecified)	secondary	1.63e-02	4.22e-08
Invar	Cesium-137 (isotope)	secondary	1.60e-02	4.16e-08
Ferrite mfg.	Radioactive aerosols and halogenes (unspecified)	secondary	1.59e-02	4.12e-08
Invar	Thorium-232 (isotope)	secondary	1.33e-02	3.45e-08
Ferrite mfg.	Thorium-232 (isotope)	secondary	1.30e-02	3.37e-08
Invar	Curium-245 (isotope)	secondary	1.23e-02	3.20e-08
Invar	Antimony-124 (isotope)	secondary	1.23e-02	3.18e-08
Ferrite mfg.	Curium-245 (isotope)	secondary	1.20e-02	3.12e-08
Ferrite mfg.	Antimony-124 (isotope)	secondary	1.20e-02	3.11e-08
Invar	Cesium-134 (isotope)	secondary	1.10e-02	2.85e-08
Ferrite mfg.	Cesium-134 (isotope)	secondary	1.07e-02	2.79e-08
Steel Prod., cold-rolled, semi-finished	Iodine-131 (isotope)	secondary	9.03e-03	2.34e-08
Steel Prod., cold-rolled, semi-finished	Iodine-133 (isotope)	secondary	8.35e-03	2.17e-08
Steel Prod., cold-rolled, semi-finished	Manganese-54 (isotope)	secondary	6.26e-03	1.63e-08
Steel Prod., cold-rolled, semi-finished	Iodine-129 (isotope)	secondary	6.14e-03	1.59e-08
Invar	Palladium-107 (isotope)	secondary	5.98e-03	1.55e-08

Table M-29. CRT LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
Ferrite mfg.	Palladium-107 (isotope)	secondary	5.84e-03	1.52e-08
Steel Prod., cold-rolled, semi-finished	Radioactive substance (unspecified)	secondary	3.20e-03	8.31e-09
Invar	Iodine-131 (isotope)	secondary	2.56e-03	6.64e-09
Ferrite mfg.	Iodine-131 (isotope)	secondary	2.49e-03	6.48e-09
Invar	Iodine-133 (isotope)	secondary	2.36e-03	6.14e-09
Ferrite mfg.	Iodine-133 (isotope)	secondary	2.31e-03	5.99e-09
Invar	Manganese-54 (isotope)	secondary	1.77e-03	4.60e-09
Invar	Iodine-129 (isotope)	secondary	1.74e-03	4.52e-09
Ferrite mfg.	Manganese-54 (isotope)	secondary	1.73e-03	4.49e-09
Ferrite mfg.	Iodine-129 (isotope)	secondary	1.70e-03	4.41e-09
Total Materials Processing			**3.80e+07**	**9.88e+01**
Manufacturing Life-cycle Stage				0.00e+00
Japanese Electric Grid	Xenon-133M (isotope)	model/secondary	1.96e+04	5.08e-02
US electric grid	Xenon-133 (isotope)	model/secondary	4.98e+03	1.29e-02
Japanese Electric Grid	Tritium-3 (isotope)	model/secondary	2.35e+03	6.10e-03
Japanese Electric Grid	Krypton-85 (isotope)	model/secondary	1.66e+03	4.32e-03
Japanese Electric Grid	Xenon-133 (isotope)	model/secondary	1.30e+03	3.38e-03
Japanese Electric Grid	Argon-41 (isotope)	model/secondary	1.00e+03	2.60e-03
LPG Production	Radioactive substance (unspecified)	secondary	9.21e+02	2.39e-03
Japanese Electric Grid	Xenon-135 (isotope)	model/secondary	7.39e+02	1.92e-03
US electric grid	Tritium-3 (isotope)	model/secondary	5.98e+02	1.55e-03
US electric grid	Krypton-85 (isotope)	model/secondary	4.23e+02	1.10e-03
US electric grid	Xenon-133M (isotope)	model/secondary	3.31e+02	8.59e-04
US electric grid	Argon-41 (isotope)	model/secondary	2.55e+02	6.62e-04
US electric grid	Xenon-135 (isotope)	model/secondary	1.88e+02	4.88e-04
Japanese Electric Grid	Krypton-88 (isotope)	model/secondary	1.41e+02	3.65e-04
Japanese Electric Grid	Xenon-131M (isotope)	model/secondary	1.36e+02	3.52e-04
Japanese Electric Grid	Krypton-85M (isotope)	model/secondary	8.06e+01	2.09e-04
Japanese Electric Grid	Iodine-133 (isotope)	model/secondary	7.03e+01	1.83e-04
US electric grid	Cobalt-58 (isotope)	model/secondary	5.49e+01	1.42e-04
Japanese Electric Grid	Xenon-138 (isotope)	model/secondary	4.68e+01	1.21e-04
US electric grid	Krypton-88 (isotope)	model/secondary	3.58e+01	9.29e-05
US electric grid	Xenon-131M (isotope)	model/secondary	3.45e+01	8.95e-05
Japanese Electric Grid	Krypton-87 (isotope)	model/secondary	3.00e+01	7.79e-05
US electric grid	Krypton-85M (isotope)	model/secondary	2.05e+01	5.32e-05
US electric grid	Iodine-133 (isotope)	model/secondary	1.79e+01	4.65e-05
Japanese Electric Grid	Xenon-135M (isotope)	model/secondary	1.41e+01	3.66e-05
US electric grid	Xenon-138 (isotope)	model/secondary	1.19e+01	3.09e-05
US electric grid	Krypton-87 (isotope)	model/secondary	7.62e+00	1.98e-05
US electric grid	Xenon-135M (isotope)	model/secondary	3.59e+00	9.32e-06
Fuel Oil #6 Prod.	Radioactive substance (unspecified)	secondary	3.12e+00	8.09e-06
Fuel Oil #2 Prod.	Radioactive substance (unspecified)	secondary	2.59e+00	6.71e-06
Japanese Electric Grid	Rubidium-88 (isotope)	model/secondary	3.29e-01	8.55e-07
Fuel Oil #4 Prod.	Radioactive substance (unspecified)	secondary	2.10e-01	5.46e-07
US electric grid	Rubidium-88 (isotope)	model/secondary	8.37e-02	2.17e-07
Japanese Electric Grid	Iodine-134 (isotope)	model/secondary	7.98e-02	2.07e-07
Japanese Electric Grid	Iodine-131 (isotope)	model/secondary	7.58e-02	1.97e-07
Japanese Electric Grid	Chromium-51 (isotope)	model/secondary	6.29e-02	1.63e-07
Japanese Electric Grid	Cesium-137 (isotope)	model/secondary	2.40e-02	6.24e-08
US electric grid	Iodine-134 (isotope)	model/secondary	2.03e-02	5.27e-08
US electric grid	Iodine-131 (isotope)	model/secondary	1.93e-02	5.01e-08

Table M-29. CRT LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
Natural Gas Prod.	Radioactive substance (unspecified)	secondary	1.86e-02	4.84e-08
Japanese Electric Grid	Cobalt-60 (isotope)	model/secondary	1.62e-02	4.21e-08
US electric grid	Chromium-51 (isotope)	model/secondary	1.60e-02	4.15e-08
Japanese Electric Grid	Iodine-132 (isotope)	model/secondary	1.54e-02	4.00e-08
US electric grid	Cesium-137 (isotope)	model/secondary	6.11e-03	1.59e-08
US electric grid	Cobalt-60 (isotope)	model/secondary	4.13e-03	1.07e-08
Japanese Electric Grid	Iodine-135 (isotope)	model/secondary	4.01e-03	1.04e-08
US electric grid	Iodine-132 (isotope)	model/secondary	3.92e-03	1.02e-08
Japanese Electric Grid	Cesium-134 (isotope)	model/secondary	3.18e-03	8.27e-09
Japanese Electric Grid	Cobalt-58 (isotope)	model/secondary	2.16e-03	5.60e-09
US electric grid	Iodine-135 (isotope)	model/secondary	1.02e-03	2.65e-09
Japanese Electric Grid	Manganese-54 (isotope)	model/secondary	8.92e-04	2.32e-09
US electric grid	Cesium-134 (isotope)	model/secondary	8.09e-04	2.10e-09
US electric grid	Manganese-54 (isotope)	model/secondary	2.27e-04	5.89e-10
Japanese Electric Grid	Cobalt-57 (isotope)	model/secondary	1.69e-04	4.39e-10
Japanese Electric Grid	Bromine-89 (isotope)	model/secondary	1.16e-04	3.01e-10
Japanese Electric Grid	Zirconium-95 (isotope)	model/secondary	9.16e-05	2.38e-10
Japanese Electric Grid	Bromine-90 (isotope)	model/secondary	4.72e-05	1.22e-10
US electric grid	Cobalt-57 (isotope)	model/secondary	4.30e-05	1.12e-10
Japanese Electric Grid	Niobium-95 (isotope)	model/secondary	3.54e-05	9.20e-11
US electric grid	Bromine-89 (isotope)	model/secondary	2.95e-05	7.66e-11
US electric grid	Zirconium-95 (isotope)	model/secondary	2.33e-05	6.05e-11
US electric grid	Bromine-90 (isotope)	model/secondary	1.20e-05	3.11e-11
US electric grid	Niobium-95 (isotope)	model/secondary	9.01e-06	2.34e-11
Japanese Electric Grid	Technetium-99M (isotope)	model/secondary	4.75e-06	1.23e-11
US electric grid	Technetium-99M (isotope)	model/secondary	1.21e-06	3.14e-12
Japanese Electric Grid	Silver-110M (isotope)	model/secondary	1.06e-06	2.75e-12
US electric grid	Silver-110M (isotope)	model/secondary	2.69e-07	6.98e-13
Total Manufacturing			**3.50e+04**	**9.10e-02**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Xenon-133 (isotope)	model/secondary	3.12e+05	8.10e-01
US electric grid	Tritium-3 (isotope)	model/secondary	3.74e+04	9.72e-02
US electric grid	Krypton-85 (isotope)	model/secondary	2.65e+04	6.88e-02
US electric grid	Xenon-133M (isotope)	model/secondary	2.07e+04	5.38e-02
US electric grid	Argon-41 (isotope)	model/secondary	1.60e+04	4.15e-02
US electric grid	Xenon-135 (isotope)	model/secondary	1.18e+04	3.06e-02
US electric grid	Cobalt-58 (isotope)	model/secondary	3.44e+03	8.93e-03
US electric grid	Krypton-88 (isotope)	model/secondary	2.24e+03	5.82e-03
US electric grid	Xenon-131M (isotope)	model/secondary	2.16e+03	5.61e-03
US electric grid	Krypton-85M (isotope)	model/secondary	1.28e+03	3.33e-03
US electric grid	Iodine-133 (isotope)	model/secondary	1.12e+03	2.91e-03
US electric grid	Xenon-138 (isotope)	model/secondary	7.45e+02	1.93e-03
US electric grid	Krypton-87 (isotope)	model/secondary	4.78e+02	1.24e-03
US electric grid	Xenon-135M (isotope)	model/secondary	2.25e+02	5.84e-04
US electric grid	Rubidium-88 (isotope)	model/secondary	5.25e+00	1.36e-05
US electric grid	Iodine-134 (isotope)	model/secondary	1.27e+00	3.30e-06
US electric grid	Iodine-131 (isotope)	model/secondary	1.21e+00	3.14e-06
US electric grid	Chromium-51 (isotope)	model/secondary	1.00e+00	2.60e-06
US electric grid	Cesium-137 (isotope)	model/secondary	3.83e-01	9.93e-07
US electric grid	Cobalt-60 (isotope)	model/secondary	2.59e-01	6.72e-07

Table M-29. CRT LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
US electric grid	Iodine-132 (isotope)	model/secondary	2.45e-01	6.37e-07
US electric grid	Iodine-135 (isotope)	model/secondary	6.39e-02	1.66e-07
US electric grid	Cesium-134 (isotope)	model/secondary	5.07e-02	1.32e-07
US electric grid	Manganese-54 (isotope)	model/secondary	1.42e-02	3.69e-08
US electric grid	Cobalt-57 (isotope)	model/secondary	2.69e-03	6.99e-09
US electric grid	Bromine-89 (isotope)	model/secondary	1.85e-03	4.80e-09
US electric grid	Zirconium-95 (isotope)	model/secondary	1.46e-03	3.79e-09
US electric grid	Bromine-90 (isotope)	model/secondary	7.51e-04	1.95e-09
US electric grid	Niobium-95 (isotope)	model/secondary	5.65e-04	1.47e-09
US electric grid	Technetium-99M (isotope)	model/secondary	7.57e-05	1.97e-10
US electric grid	Silver-110M (isotope)	model/secondary	1.68e-05	4.37e-11
Total Use, Maintenance and Repair			**4.36e+05**	**1.13e+00**
End-of-life Manufacturing Stage				
US electric grid	Xenon-133 (isotope)	model/secondary	3.12e+01	8.10e-05
US electric grid	Tritium-3 (isotope)	model/secondary	3.75e+00	9.73e-06
US electric grid	Krypton-85 (isotope)	model/secondary	2.65e+00	6.88e-06
US electric grid	Xenon-133M (isotope)	model/secondary	2.07e+00	5.38e-06
US electric grid	Argon-41 (isotope)	model/secondary	1.60e+00	4.15e-06
US electric grid	Xenon-135 (isotope)	model/secondary	1.18e+00	3.06e-06
US electric grid	Cobalt-58 (isotope)	model/secondary	3.44e-01	8.93e-07
US electric grid	Krypton-88 (isotope)	model/secondary	2.24e-01	5.82e-07
US electric grid	Xenon-131M (isotope)	model/secondary	2.16e-01	5.61e-07
US electric grid	Krypton-85M (isotope)	model/secondary	1.28e-01	3.33e-07
US electric grid	Iodine-133 (isotope)	model/secondary	1.12e-01	2.91e-07
US electric grid	Xenon-138 (isotope)	model/secondary	7.45e-02	1.94e-07
US electric grid	Krypton-87 (isotope)	model/secondary	4.78e-02	1.24e-07
US electric grid	Xenon-135M (isotope)	model/secondary	2.25e-02	5.84e-08
LPG Production	Radioactive substance (unspecified)	secondary	7.95e-03	2.07e-08
US electric grid	Rubidium-88 (isotope)	model/secondary	5.25e-04	1.36e-09
US electric grid	Iodine-134 (isotope)	model/secondary	1.27e-04	3.30e-10
US electric grid	Iodine-131 (isotope)	model/secondary	1.21e-04	3.14e-10
US electric grid	Chromium-51 (isotope)	model/secondary	1.00e-04	2.60e-10
US electric grid	Cesium-137 (isotope)	model/secondary	3.83e-05	9.94e-11
US electric grid	Cobalt-60 (isotope)	model/secondary	2.59e-05	6.72e-11
US electric grid	Iodine-132 (isotope)	model/secondary	2.46e-05	6.38e-11
US electric grid	Iodine-135 (isotope)	model/secondary	6.39e-06	1.66e-11
US electric grid	Cesium-134 (isotope)	model/secondary	5.07e-06	1.32e-11
US electric grid	Manganese-54 (isotope)	model/secondary	1.42e-06	3.69e-12
US electric grid	Cobalt-57 (isotope)	model/secondary	2.69e-07	7.00e-13
US electric grid	Bromine-89 (isotope)	model/secondary	1.85e-07	4.80e-13
US electric grid	Zirconium-95 (isotope)	model/secondary	1.46e-07	3.79e-13
US electric grid	Bromine-90 (isotope)	model/secondary	7.52e-08	1.95e-13
US electric grid	Niobium-95 (isotope)	model/secondary	5.65e-08	1.47e-13
US electric grid	Technetium-99M (isotope)	model/secondary	7.58e-09	1.97e-14
US electric grid	Silver-110M (isotope)	model/secondary	1.68e-09	4.38e-15
Natural Gas Prod.	Radioactive substance (unspecified)	secondary	-9.34e-03	-2.43e-08
CRT Incineration	Radioactive substance (unspecified)	secondary	-1.45e-01	-3.76e-07
Fuel Oil #4 Prod.	Radioactive substance (unspecified)	secondary	-2.26e+00	-5.87e-06
Total End-of-life			**4.12e+01**	**1.07e-04**
Total All Life-cycle Stages			**3.85e+07**	**1.00e+02**

Table M-30. LCD LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Plutonium-241 (isotope)	secondary	1.18e+07	9.64e+01
Steel Prod., cold-rolled, semi-finished	Plutonium-240 (isotope)	secondary	5.08e+04	4.16e-01
Steel Prod., cold-rolled, semi-finished	Cesium-135 (isotope)	secondary	4.59e+04	3.76e-01
Steel Prod., cold-rolled, semi-finished	Radon-222 (isotope)	secondary	4.30e+04	3.52e-01
Steel Prod., cold-rolled, semi-finished	Plutonium-239 (isotope)	secondary	3.57e+04	2.93e-01
Steel Prod., cold-rolled, semi-finished	Strontium-90 (isotope)	secondary	6.86e+03	5.62e-02
Steel Prod., cold-rolled, semi-finished	Tritium-3 (isotope)	secondary	1.23e+03	1.00e-02
Steel Prod., cold-rolled, semi-finished	radioactive gas (unspecified)	secondary	8.98e+02	7.36e-03
Steel Prod., cold-rolled, semi-finished	Xenon-133 (isotope)	secondary	7.63e+02	6.25e-03
Steel Prod., cold-rolled, semi-finished	Radium-226 (isotope)	secondary	4.24e+02	3.48e-03
Steel Prod., cold-rolled, semi-finished	Thorium-230 (isotope)	secondary	2.53e+02	2.07e-03
Steel Prod., cold-rolled, semi-finished	Plutonium-242 (isotope)	secondary	1.92e+02	1.57e-03
Steel Prod., cold-rolled, semi-finished	Curium-244 (isotope)	secondary	1.91e+02	1.57e-03
Steel Prod., cold-rolled, semi-finished	Uranium-234 (isotope)	secondary	1.55e+02	1.27e-03
Steel Prod., cold-rolled, semi-finished	Americium-241 (isotope)	secondary	9.42e+01	7.72e-04
Steel Prod., cold-rolled, semi-finished	Krypton-85 (isotope)	secondary	5.45e+01	4.47e-04
Steel Prod., cold-rolled, semi-finished	Uranium-238 (isotope)	secondary	4.55e+01	3.72e-04
Steel Prod., cold-rolled, semi-finished	Samarium-151 (isotope)	secondary	4.25e+01	3.48e-04
Steel Prod., cold-rolled, semi-finished	Neptunium-237 (isotope)	secondary	2.95e+01	2.42e-04
Steel Prod., cold-rolled, semi-finished	Carbon-14 (isotope)	secondary	9.35e+00	7.66e-05
Steel Prod., cold-rolled, semi-finished	Radium-222 (isotope)	secondary	3.26e+00	2.67e-05
Steel Prod., cold-rolled, semi-finished	Uranium-235 (isotope)	secondary	2.87e+00	2.35e-05
Steel Prod., cold-rolled, semi-finished	Americium-243 (isotope)	secondary	2.05e+00	1.68e-05
Steel Prod., cold-rolled, semi-finished	Technetium-99M (isotope)	secondary	1.40e+00	1.15e-05
Natural Gas Prod.	Radioactive substance (unspecified)	secondary	1.30e+00	1.07e-05
Steel Prod., cold-rolled, semi-finished	Thorium-228 (isotope)	secondary	1.22e+00	1.00e-05
Steel Prod., cold-rolled, semi-finished	Radon-220 (isotope)	secondary	9.93e-01	8.13e-06
Steel Prod., cold-rolled, semi-finished	Radium-228 (isotope)	secondary	6.36e-01	5.21e-06
Steel Prod., cold-rolled, semi-finished	Polonium-210 (isotope)	secondary	5.52e-01	4.52e-06
Steel Prod., cold-rolled, semi-finished	Lead-210 (isotope)	secondary	3.21e-01	2.63e-06
Steel Prod., cold-rolled, semi-finished	Radium-224 (isotope)	secondary	2.97e-01	2.43e-06
Steel Prod., cold-rolled, semi-finished	Zirconium-93 (isotope)	secondary	1.84e-01	1.51e-06
Steel Prod., cold-rolled, semi-finished	Cesium-137 (isotope)	secondary	1.56e-01	1.28e-06
Steel Prod., cold-rolled, semi-finished	Protactinium-234 (isotope)	secondary	9.87e-02	8.09e-07
Steel Prod., cold-rolled, semi-finished	Thorium-234 (isotope)	secondary	9.87e-02	8.09e-07
Steel Prod., cold-rolled, semi-finished	Silver-110M (isotope)	secondary	9.21e-02	7.54e-07
Steel Prod., cold-rolled, semi-finished	Potassium-40 (isotope)	secondary	8.57e-02	7.02e-07
Steel Prod., cold-rolled, semi-finished	Cobalt-58 (isotope)	secondary	6.17e-02	5.06e-07
Steel Prod., cold-rolled, semi-finished	Tin-126 (isotope)	secondary	5.79e-02	4.74e-07
Steel Prod., cold-rolled, semi-finished	Cobalt-60 (isotope)	secondary	3.87e-02	3.17e-07
Steel Prod., cold-rolled, semi-finished	Selenium-79 (isotope)	secondary	3.31e-02	2.71e-07
Steel Prod., cold-rolled, semi-finished	Radioactive aerosols and halogenes (unspecified)	secondary	2.81e-02	2.30e-07
Steel Prod., cold-rolled, semi-finished	Thorium-232 (isotope)	secondary	2.28e-02	1.87e-07
Steel Prod., cold-rolled, semi-finished	Curium-245 (isotope)	secondary	2.13e-02	1.75e-07
Steel Prod., cold-rolled, semi-finished	Antimony-124 (isotope)	secondary	2.12e-02	1.74e-07
Steel Prod., cold-rolled, semi-finished	Cesium-134 (isotope)	secondary	1.90e-02	1.56e-07
Steel Prod., cold-rolled, semi-finished	Palladium-107 (isotope)	secondary	1.04e-02	8.48e-08

Table M-30. LCD LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
Steel Prod., cold-rolled, semi-finished	Iodine-131 (isotope)	secondary	4.42e-03	3.62e-08
Steel Prod., cold-rolled, semi-finished	Iodine-133 (isotope)	secondary	4.09e-03	3.35e-08
Steel Prod., cold-rolled, semi-finished	Manganese-54 (isotope)	secondary	3.07e-03	2.51e-08
Steel Prod., cold-rolled, semi-finished	Iodine-129 (isotope)	secondary	3.01e-03	2.47e-08
Steel Prod., cold-rolled, semi-finished	Radioactive substance (unspecified)	secondary	1.57e-03	1.28e-08
Total Materials Processing			**1.20e+07**	**9.79e+01**
Manufacturing Life-cycle Stage				
Japanese Electric Grid	Xenon-133M (isotope)	model/secondary	6.58e+04	5.39e-01
Japanese Electric Grid	Tritium-3 (isotope)	model/secondary	7.90e+03	6.48e-02
Japanese Electric Grid	Krypton-85 (isotope)	model/secondary	5.59e+03	4.58e-02
Japanese Electric Grid	Xenon-133 (isotope)	model/secondary	4.37e+03	3.58e-02
Japanese Electric Grid	Argon-41 (isotope)	model/secondary	3.37e+03	2.76e-02
Japanese Electric Grid	Xenon-135 (isotope)	model/secondary	2.48e+03	2.04e-02
US electric grid	Xenon-133 (isotope)	model/secondary	6.04e+02	4.95e-03
Japanese Electric Grid	Krypton-88 (isotope)	model/secondary	4.73e+02	3.88e-03
Japanese Electric Grid	Xenon-131M (isotope)	model/secondary	4.56e+02	3.74e-03
Japanese Electric Grid	Krypton-85M (isotope)	model/secondary	2.71e+02	2.22e-03
Japanese Electric Grid	Iodine-133 (isotope)	model/secondary	2.37e+02	1.94e-03
Japanese Electric Grid	Xenon-138 (isotope)	model/secondary	1.57e+02	1.29e-03
Japanese Electric Grid	Krypton-87 (isotope)	model/secondary	1.01e+02	8.26e-04
US electric grid	Tritium-3 (isotope)	model/secondary	7.25e+01	5.94e-04
US electric grid	Krypton-85 (isotope)	model/secondary	5.13e+01	4.20e-04
Japanese Electric Grid	Xenon-135M (isotope)	model/secondary	4.74e+01	3.89e-04
LPG Production	Radioactive substance (unspecified)	secondary	4.42e+01	3.62e-04
US electric grid	Xenon-133M (isotope)	model/secondary	4.01e+01	3.29e-04
US electric grid	Argon-41 (isotope)	model/secondary	3.09e+01	2.53e-04
US electric grid	Xenon-135 (isotope)	model/secondary	2.28e+01	1.87e-04
US electric grid	Cobalt-58 (isotope)	model/secondary	6.65e+00	5.45e-05
US electric grid	Krypton-88 (isotope)	model/secondary	4.34e+00	3.56e-05
US electric grid	Xenon-131M (isotope)	model/secondary	4.18e+00	3.43e-05
US electric grid	Krypton-85M (isotope)	model/secondary	2.48e+00	2.04e-05
US electric grid	Iodine-133 (isotope)	model/secondary	2.17e+00	1.78e-05
US electric grid	Xenon-138 (isotope)	model/secondary	1.44e+00	1.18e-05
Japanese Electric Grid	Rubidium-88 (isotope)	model/secondary	1.11e+00	9.07e-06
US electric grid	Krypton-87 (isotope)	model/secondary	9.25e-01	7.58e-06
US electric grid	Xenon-135M (isotope)	model/secondary	4.35e-01	3.57e-06
Fuel Oil #4 Prod.	Radioactive substance (unspecified)	secondary	3.24e-01	2.65e-06
Japanese Electric Grid	Iodine-134 (isotope)	model/secondary	2.68e-01	2.20e-06
Japanese Electric Grid	Iodine-131 (isotope)	model/secondary	2.55e-01	2.09e-06
Japanese Electric Grid	Chromium-51 (isotope)	model/secondary	2.11e-01	1.73e-06
Fuel Oil #2 Prod.	Radioactive substance (unspecified)	secondary	1.21e-01	9.88e-07
Fuel Oil #6 Prod.	Radioactive substance (unspecified)	secondary	1.06e-01	8.69e-07
Japanese Electric Grid	Cesium-137 (isotope)	model/secondary	8.08e-02	6.62e-07
Japanese Electric Grid	Cobalt-60 (isotope)	model/secondary	5.46e-02	4.47e-07
Japanese Electric Grid	Iodine-132 (isotope)	model/secondary	5.18e-02	4.24e-07
Natural Gas Prod.	Radioactive substance (unspecified)	secondary	2.94e-02	2.41e-07
Japanese Electric Grid	Iodine-135 (isotope)	model/secondary	1.35e-02	1.10e-07
Japanese Electric Grid	Cesium-134 (isotope)	model/secondary	1.07e-02	8.77e-08
US electric grid	Rubidium-88 (isotope)	model/secondary	1.02e-02	8.32e-08
Japanese Electric Grid	Cobalt-58 (isotope)	model/secondary	7.26e-03	5.94e-08
Japanese Electric Grid	Manganese-54 (isotope)	model/secondary	3.00e-03	2.46e-08

Table M-30. LCD LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
US electric grid	Iodine-134 (isotope)	model/secondary	2.46e-03	2.02e-08
US electric grid	Iodine-131 (isotope)	model/secondary	2.34e-03	1.92e-08
US electric grid	Chromium-51 (isotope)	model/secondary	1.94e-03	1.59e-08
US electric grid	Cesium-137 (isotope)	model/secondary	7.41e-04	6.07e-09
Japanese Electric Grid	Cobalt-57 (isotope)	model/secondary	5.68e-04	4.66e-09
US electric grid	Cobalt-60 (isotope)	model/secondary	5.01e-04	4.10e-09
US electric grid	Iodine-132 (isotope)	model/secondary	4.75e-04	3.89e-09
Japanese Electric Grid	Bromine-89 (isotope)	model/secondary	3.90e-04	3.19e-09
Japanese Electric Grid	Zirconium-95 (isotope)	model/secondary	3.08e-04	2.52e-09
Japanese Electric Grid	Bromine-90 (isotope)	model/secondary	1.59e-04	1.30e-09
US electric grid	Iodine-135 (isotope)	model/secondary	1.24e-04	1.01e-09
Japanese Electric Grid	Niobium-95 (isotope)	model/secondary	1.19e-04	9.77e-10
US electric grid	Cesium-134 (isotope)	model/secondary	9.82e-05	8.04e-10
US electric grid	Manganese-54 (isotope)	model/secondary	2.75e-05	2.25e-10
Japanese Electric Grid	Technetium-99M (isotope)	model/secondary	1.60e-05	1.31e-10
US electric grid	Cobalt-57 (isotope)	model/secondary	5.21e-06	4.27e-11
US electric grid	Bromine-89 (isotope)	model/secondary	3.58e-06	2.93e-11
Japanese Electric Grid	Silver-110M (isotope)	model/secondary	3.56e-06	2.91e-11
US electric grid	Zirconium-95 (isotope)	model/secondary	2.82e-06	2.31e-11
US electric grid	Bromine-90 (isotope)	model/secondary	1.45e-06	1.19e-11
US electric grid	Niobium-95 (isotope)	model/secondary	1.09e-06	8.96e-12
US electric grid	Technetium-99M (isotope)	model/secondary	1.47e-07	1.20e-12
US electric grid	Silver-110M (isotope)	model/secondary	3.26e-08	2.67e-13
Total Manufacturing			**9.22e+04**	**7.55e-01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Xenon-133 (isotope)	model/secondary	1.16e+05	9.53e-01
US electric grid	Tritium-3 (isotope)	model/secondary	1.40e+04	1.14e-01
US electric grid	Krypton-85 (isotope)	model/secondary	9.88e+03	8.10e-02
US electric grid	Xenon-133M (isotope)	model/secondary	7.73e+03	6.34e-02
US electric grid	Argon-41 (isotope)	model/secondary	5.96e+03	4.88e-02
US electric grid	Xenon-135 (isotope)	model/secondary	4.39e+03	3.60e-02
US electric grid	Cobalt-58 (isotope)	model/secondary	1.28e+03	1.05e-02
US electric grid	Krypton-88 (isotope)	model/secondary	8.37e+02	6.85e-03
US electric grid	Xenon-131M (isotope)	model/secondary	8.06e+02	6.60e-03
US electric grid	Krypton-85M (isotope)	model/secondary	4.79e+02	3.92e-03
US electric grid	Iodine-133 (isotope)	model/secondary	4.18e+02	3.43e-03
US electric grid	Xenon-138 (isotope)	model/secondary	2.78e+02	2.28e-03
US electric grid	Krypton-87 (isotope)	model/secondary	1.78e+02	1.46e-03
US electric grid	Xenon-135M (isotope)	model/secondary	8.39e+01	6.87e-04
US electric grid	Rubidium-88 (isotope)	model/secondary	1.96e+00	1.60e-05
US electric grid	Iodine-134 (isotope)	model/secondary	4.74e-01	3.89e-06
US electric grid	Iodine-131 (isotope)	model/secondary	4.51e-01	3.69e-06
US electric grid	Chromium-51 (isotope)	model/secondary	3.74e-01	3.06e-06
US electric grid	Cesium-137 (isotope)	model/secondary	1.43e-01	1.17e-06
US electric grid	Cobalt-60 (isotope)	model/secondary	9.65e-02	7.91e-07
US electric grid	Iodine-132 (isotope)	model/secondary	9.16e-02	7.50e-07
US electric grid	Iodine-135 (isotope)	model/secondary	2.38e-02	1.95e-07
US electric grid	Cesium-134 (isotope)	model/secondary	1.89e-02	1.55e-07
US electric grid	Manganese-54 (isotope)	model/secondary	5.30e-03	4.35e-08

Table M-30. LCD LCIA Results for the Radioactivity Impact Category

Process Group	Material	LCI Data Type	Radioactivity (Bq)	% of Total
US electric grid	Cobalt-57 (isotope)	model/secondary	1.00e-03	8.23e-09
US electric grid	Bromine-89 (isotope)	model/secondary	6.89e-04	5.65e-09
US electric grid	Zirconium-95 (isotope)	model/secondary	5.44e-04	4.46e-09
US electric grid	Bromine-90 (isotope)	model/secondary	2.80e-04	2.30e-09
US electric grid	Niobium-95 (isotope)	model/secondary	2.11e-04	1.73e-09
US electric grid	Technetium-99M (isotope)	model/secondary	2.83e-05	2.32e-10
US electric grid	Silver-110M (isotope)	model/secondary	6.29e-06	5.15e-11
Total Use, Maintenance and Repair			**1.63e+05**	**1.33e+00**
End-of-life Life-cycle Stage				
US electric grid	Xenon-133 (isotope)	model/secondary	2.21e+01	1.81e-04
US electric grid	Tritium-3 (isotope)	model/secondary	2.65e+00	2.17e-05
US electric grid	Krypton-85 (isotope)	model/secondary	1.88e+00	1.54e-05
US electric grid	Xenon-133M (isotope)	model/secondary	1.47e+00	1.20e-05
US electric grid	Argon-41 (isotope)	model/secondary	1.13e+00	9.26e-06
US electric grid	Xenon-135 (isotope)	model/secondary	8.33e-01	6.83e-06
US electric grid	Cobalt-58 (isotope)	model/secondary	2.43e-01	1.99e-06
US electric grid	Krypton-88 (isotope)	model/secondary	1.59e-01	1.30e-06
US electric grid	Xenon-131M (isotope)	model/secondary	1.53e-01	1.25e-06
US electric grid	Krypton-85M (isotope)	model/secondary	9.09e-02	7.45e-07
US electric grid	Iodine-133 (isotope)	model/secondary	7.94e-02	6.50e-07
US electric grid	Xenon-138 (isotope)	model/secondary	5.28e-02	4.32e-07
US electric grid	Krypton-87 (isotope)	model/secondary	3.38e-02	2.77e-07
US electric grid	Xenon-135M (isotope)	model/secondary	1.59e-02	1.30e-07
LPG Production	Radioactive substance (unspecified)	secondary	3.63e-03	2.97e-08
US electric grid	Rubidium-88 (isotope)	model/secondary	3.72e-04	3.04e-09
US electric grid	Iodine-134 (isotope)	model/secondary	9.00e-05	7.37e-10
US electric grid	Iodine-131 (isotope)	model/secondary	8.56e-05	7.01e-10
US electric grid	Chromium-51 (isotope)	model/secondary	7.09e-05	5.81e-10
US electric grid	Cesium-137 (isotope)	model/secondary	2.71e-05	2.22e-10
US electric grid	Cobalt-60 (isotope)	model/secondary	1.83e-05	1.50e-10
US electric grid	Iodine-132 (isotope)	model/secondary	1.74e-05	1.42e-10
US electric grid	Iodine-135 (isotope)	model/secondary	4.52e-06	3.70e-11
US electric grid	Cesium-134 (isotope)	model/secondary	3.59e-06	2.94e-11
US electric grid	Manganese-54 (isotope)	model/secondary	1.01e-06	8.25e-12
US electric grid	Cobalt-57 (isotope)	model/secondary	1.91e-07	1.56e-12
US electric grid	Bromine-89 (isotope)	model/secondary	1.31e-07	1.07e-12
US electric grid	Zirconium-95 (isotope)	model/secondary	1.03e-07	8.46e-13
US electric grid	Bromine-90 (isotope)	model/secondary	5.32e-08	4.36e-13
US electric grid	Niobium-95 (isotope)	model/secondary	4.00e-08	3.28e-13
US electric grid	Technetium-99M (isotope)	model/secondary	5.36e-09	4.39e-14
US electric grid	Silver-110M (isotope)	model/secondary	1.19e-09	9.77e-15
Natural Gas Prod.	Radioactive substance (unspecified)	secondary	-6.16e-03	-5.05e-10
LCD incineration	Radioactive substance (unspecified)	secondary	-9.39e-02	-7.69e-09
Fuel Oil #4 Prod.	Radioactive substance (unspecified)	secondary	-1.49e+00	-1.22e-07
Total End-of-life			**2.93e+01**	**2.53e-04**
Total All Life-cycle Stages			**1.22e+07**	**1.00e+02**

Table M-31. CRT LCIA Results for the Chronic Occupational Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Occupational Toxicity (tox-kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Sodium Dichromate	secondary	7.23e-01	7.74e-02
Steel Prod., cold-rolled, semi-finished	Phenolsulphonic Acid	secondary	6.24e-03	6.68e-04
Aluminum Prod.	Barium sulfate	secondary	2.28e-03	2.44e-04
Steel Prod., cold-rolled, semi-finished	Dioctyl Sebacate	secondary	2.46e-04	2.64e-05
Ferrite mfg.	Barium sulfate	secondary	2.14e-04	2.29e-05
Steel Prod., cold-rolled, semi-finished	Etoxy Naphtol Sulphonic Acid (ENSA)	secondary	1.99e-04	2.13e-05
Steel Prod., cold-rolled, semi-finished	Barium sulfate	secondary	1.90e-04	2.03e-05
ABS Production	Barium sulfate	secondary	8.47e-07	9.07e-08
Invar	Borax	secondary	5.26e-07	5.64e-08
Ferrite mfg.	Borax	secondary	5.14e-07	5.50e-08
Total Materials Processing			**7.32e-01**	**7.84e-02**
Manufacturing Life-cycle Stage				
Glass/frit	Liquified petroleum gas ("propane")	primary	7.02e+02	7.51e+01
PWB Mfg.	Sulfuric acid	model/secondary	1.26e+02	1.34e+01
CRT tube mfg.	Sulfuric acid	primary	3.84e+01	4.11e+00
Glass/frit	Barium Carbonate	primary	1.68e+01	1.80e+00
CRT tube mfg.	Fuel oil #6	primary	7.37e+00	7.89e-01
Glass/frit	Fuel oil #2	primary	2.32e+00	2.49e-01
CRT monitor assembly	PPE	primary	1.47e+00	1.57e-01
Glass/frit	Lead	primary	8.95e-01	9.58e-02
PWB Mfg.	Hydrochloric acid	model/secondary	8.78e-01	9.40e-02
PWB Mfg.	Formaldehyde	model/secondary	7.56e-01	8.09e-02
CRT tube mfg.	LNG	primary	6.71e-01	7.18e-02
CRT tube mfg.	Ammonium bifluoride	primary	4.85e-01	5.20e-02
Glass/frit.	Cerium Oxide	primary	4.53e-01	4.86e-02
Glass/frit	Strontium Carbonate	primary	3.52e-01	3.77e-02
Glass/frit	Sodium Dichromate	primary	2.88e-01	3.09e-02
CRT monitor assembly	Fuel oil #4	primary	2.74e-01	2.93e-02
PWB Mfg.	Nitric acid	model/secondary	2.72e-01	2.91e-02
CRT tube mfg.	Hydrochloric acid	primary	2.01e-01	2.15e-02
Glass/frit	Hydrofluoric acid	primary	1.58e-01	1.69e-02
PWB Mfg.	Ammonium hydroxide	model/secondary	1.55e-01	1.66e-02
CRT tube mfg.	Sulfuric acid, aluminum salt	primary	1.20e-01	1.28e-02
Glass/frit	Zircon Sand	primary	1.09e-01	1.16e-02
CRT tube mfg.	Hydrogen peroxide	primary	1.07e-01	1.14e-02
CRT monitor assembly	Triphenyl phosphate	primary	1.06e-01	1.13e-02
Glass/frit	Lead	primary	9.33e-02	9.99e-03
CRT tube mfg.	Chlorine	primary	8.07e-02	8.64e-03
CRT glass mfg.	Aluminum Oxide	primary	6.74e-02	7.22e-03
PWB Mfg.	Hydrogen peroxide	model/secondary	6.21e-02	6.65e-03
CRT monitor assembly	Tricresyl phosphate	primary	4.59e-02	4.92e-03
CRT monitor assembly	Isopropyl alcohol	primary	2.44e-02	2.61e-03
CRT tube mfg.	Nitric acid	primary	1.63e-02	1.75e-03
Glass/frit	Borax	primary	1.60e-02	1.71e-03
CRT tube mfg.	Hydrofluoric acid	primary	1.48e-02	1.58e-03
CRT tube mfg.	Boric acid	primary	1.37e-02	1.47e-03
PWB Mfg.	Glycol ethers	model/secondary	1.34e-02	1.43e-03
CRT tube mfg.	Red Phosphor (Y2O2S)	primary	9.31e-03	9.96e-04

Table M-31. CRT LCIA Results for the Chronic Occupational Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Occupational Toxicity (tox-kg)	% of Total
CRT monitor assembly	Phosphate ester	primary	8.41e-03	9.00e-04
CRT tube mfg.	Polyvinyl alcohol	primary	8.11e-03	8.69e-04
CRT tube mfg.	Blue Phosphor (ZnS)	primary	7.67e-03	8.22e-04
CRT tube mfg.	Green Phosphor (ZnS)	primary	6.68e-03	7.15e-04
CRT tube mfg.	Chromium (VI)	primary	5.68e-03	6.09e-04
CRT tube mfg.	Sodium Metabisulfite	primary	4.67e-03	5.00e-04
CRT tube mfg.	Dimethyl Formamide	primary	3.84e-03	4.11e-04
CRT tube mfg.	Isopentylacetate	primary	3.49e-03	3.74e-04
CRT tube mfg.	Blue Phosphor (ZnS.Ag.Al)	primary	3.34e-03	3.57e-04
CRT tube mfg.	Ammonium hydroxide	primary	2.81e-03	3.01e-04
CRT tube mfg.	Green Phosphor (ZnS.Cu.Al)	primary	2.68e-03	2.87e-04
CRT tube mfg.	Red Phosphor (Y2O2S.Eu)	primary	2.67e-03	2.86e-04
CRT tube mfg.	Amyl acetate (mixed isomers)	primary	2.41e-03	2.58e-04
CRT tube mfg.	Ammonium fluoride	primary	1.78e-03	1.91e-04
CRT tube mfg.	Toluene	primary	8.02e-04	8.59e-05
CRT tube mfg.	Sodium Persulfate	primary	7.08e-04	7.58e-05
CRT tube mfg.	Ammonium Oxalate Monohydrate	primary	6.32e-04	6.77e-05
Japanese Electric Grid	Uranium, yellowcake	model/secondary	6.07e-04	6.50e-05
CRT tube mfg.	Sodium Hypochlorite	primary	5.24e-04	5.61e-05
CRT tube mfg.	Polyvinyl Pyrrolidone (PVP)	primary	5.22e-04	5.59e-05
CRT tube mfg.	Periodic Acid	primary	4.53e-04	4.85e-05
CRT tube mfg.	Ammonia	primary	3.24e-04	3.47e-05
CRT monitor assembly	2,2,4-trimethylpentane	primary	3.01e-04	3.22e-05
US electric grid	Uranium, yellowcake	model/secondary	1.55e-04	1.66e-05
CRT tube mfg.	Ammonium Dichromate	primary	6.99e-05	7.49e-06
CRT tube mfg.	Sodium Dichromate Dihydrate (VI)	primary	6.19e-05	6.63e-06
CRT tube mfg.	Acetone	primary	3.77e-05	4.03e-06
CRT monitor assembly	Fluorocarbon resin	primary	3.75e-05	4.02e-06
CRT tube mfg.	Xylene (mixed isomers)	primary	3.19e-05	3.42e-06
CRT monitor assembly	Cyclohexane	primary	8.61e-06	9.22e-07
Total Manufacturing			**9.00e+02**	**9.64e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Natural gas	model/secondary	2.80e+01	3.00e+00
US electric grid	Petroleum (in gournd)	model/secondary	7.60e+00	8.14e-01
US electric grid	Uranium, yellowcake	model/secondary	9.70e-03	1.04e-03
Total Use, Maintenance and Repair			**3.56e+01**	**3.81e+00**
End-of-life Life-cycle Stage				
CRT landfilling	Fuel oil #4	primary	3.86e-02	4.13e-03
CRT Recycling	Liquified petroleum gas ("propane")	primary	6.06e-03	6.48e-04
US electric grid	Uranium, yellowcake	model/secondary	9.71e-07	1.04e-07
CRT Incineration	Fuel oil #4	secondary	-2.88e+00	-3.08e-01
Total End-of-life			**-2.83e+00**	**-3.03e-01**
Total All Life-cycle Stages			**9.34e+02**	**1.00e+02**

Table M-32. LCD LCIA Results for the Chronic Occupational Health Effects Impact Category

Process Group	Materials	LCI Data Type	Chronic Occupational Toxicity (tox-kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Sodium Dichromate	secondary	3.54e-01	5.09e-02
Steel Prod., cold-rolled, semi-finished	Phenolsulphonic Acid	secondary	3.06e-03	4.40e-04
Aluminum Prod.	Barium sulfate	secondary	8.47e-04	1.22e-04
Steel Prod., cold-rolled, semi-finished	Dioctyl Sebacate	secondary	1.21e-04	1.73e-05
Steel Prod., cold-rolled, semi-finished	Etoxy Naphtol Sulphonic Acid (ENSA)	secondary	9.76e-05	1.40e-05
Steel Prod., cold-rolled, semi-finished	Barium sulfate	secondary	9.30e-05	1.34e-05
PMMA Sheet Prod.	Barium sulfate	secondary	2.42e-05	3.47e-06
PMMA Sheet Prod.	Ferromanganese (Fe, Mn, C)	secondary	7.67e-07	1.10e-07
Total Materials Processing			**3.59e-01**	**5.15e-02**
Manufacturing Life-cycle Stage				
Monitor/module	LNG	primary	3.95e+02	5.67e+01
Monitor/module	Sulfuric acid	primary	1.58e+02	2.26e+01
PWB Mfg.	Sulfuric acid	model/secondary	5.54e+01	7.96e+00
LCD glass mfg.	Liquified petroleum gas ("propane")	primary	3.25e+01	4.67e+00
Monitor/module	Phosphine	primary	1.23e+01	1.77e+00
Panel components	Sulfuric acid	primary	1.09e+01	1.56e+00
Monitor/module	Dimethylsulfoxide	primary	7.96e+00	1.14e+00
Monitor/module	Ethanol amine	primary	4.32e+00	6.21e-01
Panel components	Tetrahydrofuran	primary	1.32e+00	1.89e-01
Monitor/module	Liquified petroleum gas ("propane")	primary	1.17e+00	1.67e-01
LCD glass mfg.	Barium Carbonate	primary	7.79e-01	1.12e-01
Monitor/module	Kerosene	primary	5.95e-01	8.56e-02
Monitor/module	Ammonium bifluoride	primary	5.62e-01	8.07e-02
Monitor/module	Fuel oil #4	primary	4.22e-01	6.06e-02
Monitor/module	Isopropyl alcohol	primary	4.19e-01	6.02e-02
PWB Mfg.	Hydrochloric acid	model/secondary	3.87e-01	5.57e-02
Panel components	Kerosene	primary	3.35e-01	4.82e-02
PWB Mfg.	Formaldehyde	model/secondary	3.33e-01	4.79e-02
Monitor/module	Tetramethyl ammonium hydroxide	primary	2.57e-01	3.70e-02
Panel components	Fuel oil #6	primary	2.51e-01	3.61e-02
Monitor/module	Nitrogen fluoride	primary	2.16e-01	3.11e-02
Monitor/module	Hydrochloric acid	primary	1.97e-01	2.83e-02
Monitor/module	Phosphoric acid	primary	1.90e-01	2.73e-02
Monitor/module	2-(2-butoxyethoxy)-ethanol	primary	1.81e-01	2.60e-02
Monitor/module	N-Butylacetate	primary	1.64e-01	2.35e-02
Monitor/module	Molybdenum	primary	1.52e-01	2.18e-02
PWB Mfg.	Nitric acid	model/secondary	1.20e-01	1.72e-02
LCD glass mfg.	Fuel oil #2	primary	1.08e-01	1.55e-02
Monitor/module	Hydrofluoric acid	primary	8.42e-02	1.21e-02
PWB Mfg.	Ammonium hydroxide	model/secondary	6.85e-02	9.84e-03
Monitor/module	Ammonia	primary	4.22e-02	6.06e-03
Monitor/module	Sulfur hexafluoride	primary	3.24e-02	4.66e-03
Monitor/module	Propylene glycol monomethyl ether acetate	primary	3.12e-02	4.49e-03
Monitor/module	Chlorine	primary	3.11e-02	4.46e-03
PWB Mfg.	Hydrogen peroxide	model/secondary	2.74e-02	3.94e-03
Monitor/module	Nitric acid	primary	2.49e-02	3.58e-03
Monitor/module	Ammonium fluoride	primary	2.28e-02	3.28e-03

Table M-32. LCD LCIA Results for the Chronic Occupational Health Effects Impact Category

Process Group	Materials	LCI Data Type	Chronic Occupational Toxicity (tox-kg)	% of Total
LCD glass mfg.	Cerium Oxide	primary	2.10e-02	3.02e-03
Monitor/module	Isopropyl alcohol	primary	1.88e-02	2.70e-03
Monitor/module	Acetone	primary	1.74e-02	2.49e-03
LCD glass mfg.	Strontium Carbonate	primary	1.63e-02	2.34e-03
Monitor/module	Glycol ethers	primary	1.23e-02	1.76e-03
Monitor/module	1-Methoxy-2-propanol	primary	1.21e-02	1.74e-03
Monitor/module	Titanium	primary	1.16e-02	1.66e-03
Panel components	Polyvinyl alcohol	primary	8.61e-03	1.24e-03
Panel components	Perchloric acid	primary	7.64e-03	1.10e-03
Monitor/module	1-methyl-2-pyrrolidinone	primary	7.37e-03	1.06e-03
LCD glass mfg.	Hydrofluoric acid	primary	7.33e-03	1.05e-03
Monitor/module	Acetic acid	primary	6.79e-03	9.76e-04
Monitor/module	Propylene glycol	primary	6.26e-03	9.00e-04
Panel components	Hydrochloric acid	primary	5.90e-03	8.47e-04
PWB Mfg.	Glycol ethers	model/secondary	5.89e-03	8.46e-04
LCD glass mfg.	Zircon Sand	primary	5.03e-03	7.23e-04
Panel components	Toluene	primary	4.60e-03	6.61e-04
Panel components	Heptane	primary	4.33e-03	6.22e-04
Monitor/module	2-ethoxyl ethylacetate	primary	3.55e-03	5.10e-04
LCD glass mfg.	Aluminum Oxide	primary	3.12e-03	4.49e-04
Monitor/module	Nitrous oxide	primary	2.71e-03	3.90e-04
Monitor/module	Perfluoromethane	primary	2.57e-03	3.70e-04
Monitor/module	Monosilane	primary	2.25e-03	3.23e-04
Panel components	Orthoboric acid	primary	2.12e-03	3.05e-04
Panel components	Hydrochloric acid	primary	2.07e-03	2.97e-04
Japanese Electric Grid	Uranium, yellowcake	model/secondary	2.04e-03	2.94e-04
Monitor/module	Cresol-formaldehyde resin	primary	1.66e-03	2.38e-04
Panel components	Acetone	primary	1.22e-03	1.75e-04
Monitor/module	Indium tin oxide	primary	1.05e-03	1.51e-04
Monitor/module	Polyethylene mono(nonylphenyl) ether glycol	primary	9.39e-04	1.35e-04
Panel components	Fuel oil #2	primary	8.15e-04	1.17e-04
Panel components	3,4-difluorobromobenzene	primary	7.31e-04	1.05e-04
Panel components	4-pentylphenol	primary	6.84e-04	9.83e-05
Panel components	4-bromophenol	primary	6.53e-04	9.38e-05
Monitor/module	LCD material (confidential)	primary	6.21e-04	8.93e-05
Monitor/module	1,4-butanolide	primary	5.31e-04	7.63e-05
Panel components	3,4,5-trifluorobromobenzene	primary	5.29e-04	7.60e-05
Monitor/module	Hexamethyldisilizane	primary	5.16e-04	7.42e-05
Panel components	4-4(-propylcyclohexyl)cyclohexanone	primary	4.35e-04	6.26e-05
Panel components	4-propionylphenol	primary	3.89e-04	5.59e-05
Monitor/module	Hydrogen peroxide	primary	2.93e-04	4.22e-05
Panel components	HCFC-225ca	primary	2.74e-04	3.93e-05
Panel components	HCFC-225cb	primary	2.74e-04	3.93e-05
Panel components	Borax	primary	1.83e-04	2.62e-05
Panel components	Cyclohexane	primary	1.78e-04	2.56e-05
Panel components	4-ethylphenol	primary	1.40e-04	2.01e-05
Monitor/module	Xylene (mixed isomers)	primary	1.04e-04	1.50e-05
Backlight	Diethyl ether	primary	9.50e-05	1.37e-05
Panel components	Methyl ethyl ketone	primary	4.61e-05	6.62e-06

Table M-32. LCD LCIA Results for the Chronic Occupational Health Effects Impact Category

Process Group	Materials	LCI Data Type	Chronic Occupational Toxicity (tox-kg)	% of Total
Monitor/module	Triallyl isocyanurate	primary	3.09e-05	4.44e-06
Monitor/module	2,2,4-trimethylpentane	primary	3.05e-05	4.38e-06
US electric grid	Uranium, yellowcake	model/secondary	1.88e-05	2.70e-06
Monitor/module	Ammonium hydroxide	primary	1.03e-05	1.48e-06
Backlight	LNG	primary	8.33e-06	1.20e-06
Monitor/module	2-(2-butoxyethoxy)-ethanol acetate	primary	8.18e-06	1.18e-06
Monitor/module	Sodium dihydrogen phosphate dihydrate	primary	8.12e-06	1.17e-06
Backlight	Mercury	primary	3.99e-06	5.73e-07
Monitor/module	Fluorocarbon resin	primary	3.38e-06	4.86e-07
Monitor/module	Cyclohexane	primary	9.30e-07	1.34e-07
Monitor/module	Methyl ethyl ketone	primary	7.00e-07	1.01e-07
Monitor/module	Aluminum (elemental)	primary	1.70e-11	2.45e-12
Total Manufacturing			**6.84e+02**	**9.83e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Natural gas	model/secondary	1.04e+01	1.50e+00
US electric grid	Petroleum (in ground)	model/secondary	2.84e+00	4.08e-01
US electric grid	Uranium, yellowcake	model/secondary	3.62e-03	5.20e-04
Total Use, Maintenance and Repair			**1.33e+01**	**1.91e+00**
End-of-life Life-cycle Stage				
LCD landfilling	Fuel oil #4	primary	9.29e-03	1.34e-03
LCD recycling	Liquified petroleum gas ("propane")	primary	2.76e-03	3.97e-04
US electric grid	Uranium, yellowcake	model/secondary	6.87e-07	9.87e-08
LCD incineration	Fuel oil #4	secondary	-1.95e+00	-2.80e-01
Total End-of-life			**-1.94e+00**	**-2.79e-01**
Total All Life-cycle Stages			**6.96e+02**	**1.00e+02**

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Materials Processing Life-cycle Stage				
Invar	Sulfur dioxide	secondary	1.65e+02	8.33e+00
Steel Prod., cold-rolled, semi-finished	Sulfur dioxide	secondary	2.54e+01	1.28e+00
Aluminum Prod.	Sulfur dioxide	secondary	1.38e+01	6.97e-01
Polycarbonate Production	Sulfur dioxide	secondary	7.93e+00	4.01e-01
Lead	Sulfur dioxide	secondary	4.57e+00	2.31e-01
ABS Production	Sulfur dioxide	secondary	2.80e+00	1.41e-01
Ferrite mfg.	Sulfur dioxide	secondary	2.35e+00	1.19e-01
Lead	Arsenic	secondary	2.21e+00	1.11e-01
Polystyrene Prod., high-impact	Sulfur dioxide	secondary	1.20e+00	6.05e-02
Aluminum Prod.	Titanium tetrachloride	secondary	7.20e-01	3.64e-02
Steel Prod., cold-rolled, semi-finished	Carbon monoxide	secondary	3.00e-01	1.51e-02
Invar	Titanium tetrachloride	secondary	2.56e-01	1.29e-02
Lead	Titanium tetrachloride	secondary	2.10e-01	1.06e-02
Steel Prod., cold-rolled, semi-finished	PM	secondary	2.10e-01	1.06e-02
Aluminum Prod.	Manganese cmpds	secondary	1.62e-01	8.18e-03
Invar	Manganese cmpds	secondary	1.50e-01	7.56e-03
Aluminum Prod.	Vanadium	secondary	1.07e-01	5.43e-03
Ferrite mfg.	Manganese cmpds	secondary	9.39e-02	4.74e-03
Invar	Carbon monoxide	secondary	7.60e-02	3.84e-03
Invar	Vanadium	secondary	7.40e-02	3.74e-03
Ferrite mfg.	Carbon monoxide	secondary	6.32e-02	3.19e-03
Steel Prod., cold-rolled, semi-finished	Vanadium	secondary	5.15e-02	2.60e-03
Aluminum Prod.	Arsenic cmpds	secondary	4.75e-02	2.40e-03
Lead	Manganese cmpds	secondary	4.60e-02	2.33e-03
Polycarbonate Production	Carbon monoxide	secondary	4.48e-02	2.27e-03
Polycarbonate Production	Methane	secondary	4.06e-02	2.05e-03
Polycarbonate Production	Nitrogen dioxide	secondary	3.88e-02	1.96e-03
Invar	Arsenic	secondary	3.21e-02	1.62e-03
Ferrite mfg.	Arsenic	secondary	2.90e-02	1.46e-03
Steel Prod., cold-rolled, semi-finished	Nitrogen dioxide	secondary	2.80e-02	1.41e-03
Lead	Zinc (elemental)	secondary	2.42e-02	1.22e-03
Ferrite mfg.	Titanium tetrachloride	secondary	2.36e-02	1.19e-03
Invar	Zinc (elemental)	secondary	2.28e-02	1.15e-03
Ferrite mfg.	Zinc (elemental)	secondary	2.21e-02	1.12e-03
Steel Prod., cold-rolled, semi-finished	Methane	secondary	2.18e-02	1.10e-03
ABS Production	Carbon monoxide	secondary	2.17e-02	1.10e-03
Lead	Vanadium	secondary	2.09e-02	1.06e-03
Lead	Carbon monoxide	secondary	2.04e-02	1.03e-03
Steel Prod., cold-rolled, semi-finished	Fluorides (F-)	secondary	1.92e-02	9.70e-04
Aluminum Prod.	Carbon monoxide	secondary	1.86e-02	9.41e-04
Aluminum Prod.	PM	secondary	1.78e-02	8.99e-04
Styrene-butadiene Copolymer Prod.	Carbon monoxide	secondary	1.73e-02	8.74e-04
Invar	Arsenic cmpds	secondary	1.69e-02	8.53e-04
Aluminum Prod.	Methane	secondary	1.61e-02	8.13e-04
Steel Prod., cold-rolled, semi-finished	Manganese cmpds	secondary	1.49e-02	7.53e-04
Ferrite mfg.	Vanadium	secondary	1.45e-02	7.33e-04
Aluminum Prod.	Nitrogen dioxide	secondary	1.43e-02	7.21e-04
Styrene-butadiene Copolymer Prod.	Nitrogen oxides	secondary	1.40e-02	7.07e-04
Lead	Arsenic cmpds	secondary	1.38e-02	6.98e-04

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Styrene-butadiene Copolymer Prod.	Methane	secondary	1.37e-02	6.94e-04
Polycarbonate Production	PM	secondary	1.29e-02	6.53e-04
Invar	Methane	secondary	1.15e-02	5.82e-04
Styrene-butadiene Copolymer Prod.	Sulfur oxides	secondary	1.14e-02	5.77e-04
Aluminum Prod.	Barium cmpds	secondary	1.04e-02	5.28e-04
ABS Production	Methane	secondary	1.02e-02	5.14e-04
Invar	Nitrogen dioxide	secondary	1.01e-02	5.12e-04
ABS Production	Nitrogen dioxide	secondary	9.32e-03	4.71e-04
Lead	Nitrogen dioxide	secondary	8.37e-03	4.23e-04
Aluminum Prod.	Selenium	secondary	6.29e-03	3.18e-04
Ferrite mfg.	Methane	secondary	5.71e-03	2.88e-04
Invar	PM	secondary	5.51e-03	2.78e-04
Lead	Methane	secondary	5.04e-03	2.55e-04
Steel Prod., cold-rolled, semi-finished	Arsenic	secondary	4.52e-03	2.28e-04
Invar	Barium cmpds	secondary	4.31e-03	2.18e-04
Steel Prod., cold-rolled, semi-finished	Phosphorus (yellow or white)	secondary	4.07e-03	2.06e-04
Ferrite mfg.	Nitrogen dioxide	secondary	4.05e-03	2.05e-04
Polystyrene Prod., high-impact	Nitrogen dioxide	secondary	3.63e-03	1.83e-04
Ferrite mfg.	PM	secondary	3.44e-03	1.74e-04
Polystyrene Prod., high-impact	Methane	secondary	3.33e-03	1.68e-04
Aluminum Prod.	Aluminum (+3)	secondary	3.18e-03	1.60e-04
Lead	Lead	secondary	3.16e-03	1.60e-04
ABS Production	Hydrochloric acid	secondary	2.93e-03	1.48e-04
Lead	Barium cmpds	secondary	2.71e-03	1.37e-04
ABS Production	PM	secondary	2.54e-03	1.28e-04
Polystyrene Prod., high-impact	Carbon monoxide	secondary	2.45e-03	1.24e-04
Invar	Selenium	secondary	2.32e-03	1.17e-04
Steel Prod., cold-rolled, semi-finished	Hydrochloric acid	secondary	2.05e-03	1.03e-04
Styrene-butadiene Copolymer Prod.	PM	secondary	1.99e-03	1.00e-04
Invar	Hydrochloric acid	secondary	1.85e-03	9.35e-05
Lead	Selenium	secondary	1.84e-03	9.27e-05
Aluminum Prod.	Hydrochloric acid	secondary	1.78e-03	9.02e-05
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	1.76e-03	8.89e-05
Steel Prod., cold-rolled, semi-finished	Barium cmpds	secondary	1.73e-03	8.75e-05
Lead	PM	secondary	1.68e-03	8.50e-05
Ferrite mfg.	Arsenic cmpds	secondary	1.64e-03	8.28e-05
ABS Production	Formaldehyde	secondary	1.60e-03	8.09e-05
Steel Prod., cold-rolled, semi-finished	Nitrous oxide	secondary	1.55e-03	7.85e-05
Steel Prod., cold-rolled, semi-finished	Arsenic cmpds	secondary	1.54e-03	7.76e-05
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	1.26e-03	6.38e-05
Aluminum Prod.	Cadmium cmpds	secondary	1.17e-03	5.92e-05
Invar	Aluminum (+3)	secondary	1.14e-03	5.76e-05
Lead	Hydrochloric acid	secondary	1.07e-03	5.41e-05
Steel Prod., cold-rolled, semi-finished	Silicon	secondary	1.01e-03	5.12e-05
Invar	Copper	secondary	9.89e-04	4.99e-05
Lead	Aluminum (+3)	secondary	9.25e-04	4.67e-05
Invar	Benzene	secondary	9.18e-04	4.64e-05
Steel Prod., cold-rolled, semi-finished	Titanium tetrachloride	secondary	8.33e-04	4.21e-05
Ferrite mfg.	Barium cmpds	secondary	7.81e-04	3.95e-05

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Ferrite mfg.	Hydrochloric acid	secondary	6.93e-04	3.50e-05
Polystyrene Prod., high-impact	PM	secondary	6.05e-04	3.05e-05
Ferrite mfg.	Benzene	secondary	5.86e-04	2.96e-05
Aluminum Prod.	Benzene	secondary	5.70e-04	2.88e-05
Steel Prod., cold-rolled, semi-finished	Ethane	secondary	4.92e-04	2.48e-05
ABS Production	Hydrofluoric acid	secondary	4.87e-04	2.46e-05
Aluminum Prod.	Hydrofluoric acid	secondary	4.81e-04	2.43e-05
Polycarbonate Production	Hydrochloric acid	secondary	4.65e-04	2.35e-05
Aluminum Prod.	Barium sulfate	secondary	4.54e-04	2.29e-05
Invar	Silicon	secondary	4.52e-04	2.28e-05
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	4.15e-04	2.10e-05
ABS Production	Aromatic hydrocarbons	secondary	3.81e-04	1.93e-05
Steel Prod., cold-rolled, semi-finished	Titanium	secondary	3.30e-04	1.67e-05
Polycarbonate Production	Sulfuric acid	secondary	3.18e-04	1.60e-05
ABS Production	Ammonia	secondary	3.07e-04	1.55e-05
Steel Prod., cold-rolled, semi-finished	Selenium	secondary	3.00e-04	1.51e-05
Lead	Benzene	secondary	2.99e-04	1.51e-05
Ferrite mfg.	Silicon	secondary	2.97e-04	1.50e-05
Invar	Phosphorus (yellow or white)	secondary	2.89e-04	1.46e-05
Ferrite mfg.	Selenium	secondary	2.86e-04	1.44e-05
Ferrite mfg.	Phosphorus (yellow or white)	secondary	2.85e-04	1.44e-05
Aluminum Prod.	Nitrous oxide	secondary	2.76e-04	1.40e-05
Aluminum Prod.	Perfluoromethane	secondary	2.59e-04	1.31e-05
Polycarbonate Production	Mercury compounds	secondary	2.44e-04	1.23e-05
ABS Production	Ethane	secondary	2.37e-04	1.20e-05
Aluminum Prod.	Titanium	secondary	2.30e-04	1.16e-05
Aluminum Prod.	Zinc (elemental)	secondary	2.30e-04	1.16e-05
Aluminum Prod.	Silicon	secondary	2.19e-04	1.10e-05
Steel Prod., cold-rolled, semi-finished	Zinc (elemental)	secondary	2.16e-04	1.09e-05
Invar	Titanium	secondary	2.16e-04	1.09e-05
Steel Prod., cold-rolled, semi-finished	Tin (Sn++, Sn4+)	secondary	2.09e-04	1.05e-05
Steel Prod., cold-rolled, semi-finished	Molybdenum	secondary	1.88e-04	9.50e-06
Aluminum Prod.	Copper (+1 & +2)	secondary	1.80e-04	9.10e-06
Aluminum Prod.	Strontium (Sr II)	secondary	1.70e-04	8.57e-06
Invar	Ethane	secondary	1.65e-04	8.35e-06
Polycarbonate Production	Aromatic hydrocarbons	secondary	1.64e-04	8.30e-06
Ferrite mfg.	Ethane	secondary	1.61e-04	8.15e-06
Invar	Formaldehyde	secondary	1.60e-04	8.09e-06
Ferrite mfg.	Formaldehyde	secondary	1.56e-04	7.90e-06
Invar	Molybdenum	secondary	1.52e-04	7.69e-06
ABS Production	Sulfuric acid	secondary	1.46e-04	7.36e-06
Lead	Silicon	secondary	1.43e-04	7.20e-06
Styrene-butadiene Copolymer Prod.	Sulfuric acid	secondary	1.42e-04	7.19e-06
Invar	Nitrates/nitrites	secondary	1.37e-04	6.91e-06
Styrene-butadiene Copolymer Prod.	Aromatic hydrocarbons	secondary	1.36e-04	6.86e-06
Invar	Cadmium cmpds	secondary	1.27e-04	6.42e-06
Steel Prod., cold-rolled, semi-finished	Barium	secondary	1.23e-04	6.22e-06
Lead	Barium sulfate	secondary	1.15e-04	5.79e-06
ABS Production	Mercury compounds	secondary	1.12e-04	5.64e-06
Ferrite mfg.	Aluminum (+3)	secondary	1.12e-04	5.63e-06

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Styrene-butadiene Copolymer Prod.	Mercury compounds	secondary	1.09e-04	5.51e-06
ABS Production	Aluminum (+3)	secondary	1.02e-04	5.14e-06
Steel Prod., cold-rolled, semi-finished	Antimony	secondary	9.54e-05	4.82e-06
Invar	Copper (+1 & +2)	secondary	9.43e-05	4.77e-06
Invar	Nickel	secondary	9.29e-05	4.69e-06
Ferrite mfg.	Titanium	secondary	9.23e-05	4.66e-06
Polycarbonate Production	Fluorides (F-)	secondary	9.20e-05	4.65e-06
Aluminum Prod.	Nitrate	secondary	9.13e-05	4.61e-06
Invar	Strontium (Sr II)	secondary	8.79e-05	4.44e-06
Steel Prod., cold-rolled, semi-finished	Boron	secondary	8.57e-05	4.33e-06
Steel Prod., cold-rolled, semi-finished	Strontium (Sr II)	secondary	7.92e-05	4.00e-06
Invar	Lead	secondary	7.24e-05	3.66e-06
Ferrite mfg.	Lead	secondary	6.92e-05	3.50e-06
Styrene-butadiene Copolymer Prod.	Hydrochloric acid	secondary	6.82e-05	3.45e-06
Invar	Barium	secondary	6.53e-05	3.30e-06
Lead	Ethane	secondary	6.32e-05	3.19e-06
Steel Prod., cold-rolled, semi-finished	Silver compounds	secondary	6.17e-05	3.12e-06
Invar	Tin (Sn++, Sn4+)	secondary	6.07e-05	3.07e-06
Polystyrene Prod., high-impact	Aromatic hydrocarbons	secondary	6.05e-05	3.05e-06
ABS Production	Nitrate	secondary	6.01e-05	3.04e-06
Steel Prod., cold-rolled, semi-finished	Nitrates/nitrites	secondary	5.66e-05	2.86e-06
Invar	Hydrofluoric acid	secondary	5.37e-05	2.72e-06
Ferrite mfg.	Molybdenum	secondary	5.24e-05	2.65e-06
Lead	Copper (+1 & +2)	secondary	5.20e-05	2.63e-06
Steel Prod., cold-rolled, semi-finished	Chromium (VI)	secondary	5.17e-05	2.61e-06
Invar	Ammonia	secondary	5.01e-05	2.53e-06
Invar	Zinc (+2)	secondary	4.87e-05	2.46e-06
Invar	Boron	secondary	4.85e-05	2.45e-06
Steel Prod., cold-rolled, semi-finished	Acetylene	secondary	4.66e-05	2.35e-06
Steel Prod., cold-rolled, semi-finished	Mercury compounds	secondary	4.53e-05	2.29e-06
Lead	Cadmium	secondary	4.52e-05	2.29e-06
Styrene-butadiene Copolymer Prod.	Fluorides (F-)	secondary	4.12e-05	2.08e-06
Lead	Nitrous oxide	secondary	4.06e-05	2.05e-06
Aluminum Prod.	Barium	secondary	3.91e-05	1.98e-06
Steel Prod., cold-rolled, semi-finished	Hydrofluoric acid	secondary	3.79e-05	1.91e-06
Ferrite mfg.	Barium	secondary	3.73e-05	1.89e-06
Ferrite mfg.	Zinc (+2)	secondary	3.69e-05	1.86e-06
Aluminum Prod.	Zinc (+2)	secondary	3.48e-05	1.76e-06
Invar	Barium sulfate	secondary	3.46e-05	1.75e-06
Steel Prod., cold-rolled, semi-finished	Barium sulfate	secondary	3.43e-05	1.73e-06
Lead	Strontium (Sr II)	secondary	3.40e-05	1.72e-06
Ferrite mfg.	Barium sulfate	secondary	3.38e-05	1.71e-06
Steel Prod., cold-rolled, semi-finished	Aluminum (+3)	secondary	3.15e-05	1.59e-06
Lead	Barium	secondary	2.88e-05	1.46e-06
Aluminum Prod.	Aromatic hydrocarbons	secondary	2.83e-05	1.43e-06
Lead	Copper	secondary	2.82e-05	1.42e-06
Lead	Hydrofluoric acid	secondary	2.73e-05	1.38e-06
Steel Prod., cold-rolled, semi-finished	Hydrogen sulfide	secondary	2.72e-05	1.37e-06
Aluminum Prod.	Nickel cmpds	secondary	2.71e-05	1.37e-06
Invar	Antimony	secondary	2.70e-05	1.37e-06

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Cadmium cmpds	secondary	2.70e-05	1.36e-06
Ferrite mfg.	Antimony	secondary	2.64e-05	1.33e-06
Ferrite mfg.	Boron	secondary	2.58e-05	1.30e-06
Ferrite mfg.	Strontium (Sr II)	secondary	2.57e-05	1.30e-06
Aluminum Prod.	Nickel	secondary	2.52e-05	1.28e-06
Steel Prod., cold-rolled, semi-finished	Aluminum (elemental)	secondary	2.47e-05	1.25e-06
Aluminum Prod.	Ammonia	secondary	2.45e-05	1.24e-06
Polystyrene Prod., high-impact	Hydrochloric acid	secondary	2.42e-05	1.22e-06
Aluminum Prod.	Copper	secondary	2.38e-05	1.20e-06
Invar	Nickel cmpds	secondary	2.15e-05	1.09e-06
Ferrite mfg.	Nitrous oxide	secondary	2.12e-05	1.07e-06
ABS Production	Hydrogen sulfide	secondary	2.02e-05	1.02e-06
Lead	Ammonia	secondary	1.88e-05	9.49e-07
Invar	Silver compounds	secondary	1.86e-05	9.42e-07
Ferrite mfg.	Silver compounds	secondary	1.82e-05	9.20e-07
Aluminum Prod.	Fluoride	secondary	1.82e-05	9.19e-07
Lead	Nitrate	secondary	1.80e-05	9.10e-07
Aluminum Prod.	Lead cmpds	secondary	1.74e-05	8.81e-07
Steel Prod., cold-rolled, semi-finished	Pentane	secondary	1.70e-05	8.57e-07
Invar	Aromatic hydrocarbons	secondary	1.67e-05	8.44e-07
Lead	Boron	secondary	1.66e-05	8.37e-07
Aluminum Prod.	Vanadium (V3+, V5+)	secondary	1.63e-05	8.23e-07
Ferrite mfg.	Ammonia	secondary	1.62e-05	8.20e-07
Invar	Aluminum (elemental)	secondary	1.52e-05	7.70e-07
Aluminum Prod.	Nitrites	secondary	1.47e-05	7.40e-07
Invar	Hydrogen sulfide	secondary	1.45e-05	7.34e-07
Invar	Chromium (VI)	secondary	1.45e-05	7.31e-07
Aluminum Prod.	Perfluoroethane	secondary	1.44e-05	7.28e-07
Steel Prod., cold-rolled, semi-finished	Aromatic hydrocarbons	secondary	1.43e-05	7.24e-07
Aluminum Prod.	Chromium (VI)	secondary	1.39e-05	7.03e-07
Invar	Cadmium	secondary	1.34e-05	6.77e-07
Invar	Acetylene	secondary	1.32e-05	6.68e-07
Ferrite mfg.	Acetylene	secondary	1.29e-05	6.52e-07
Ferrite mfg.	Hydrofluoric acid	secondary	1.27e-05	6.44e-07
Steel Prod., cold-rolled, semi-finished	Copper	secondary	1.22e-05	6.17e-07
Steel Prod., cold-rolled, semi-finished	Nickel	secondary	1.16e-05	5.84e-07
Ferrite mfg.	Cadmium	secondary	1.11e-05	5.61e-07
Aluminum Prod.	Aluminum (elemental)	secondary	1.05e-05	5.32e-07
Polycarbonate Production	Copper (+1 & +2)	secondary	1.04e-05	5.24e-07
Ferrite mfg.	Hydrogen sulfide	secondary	1.03e-05	5.22e-07
Lead	Zinc (+2)	secondary	9.93e-06	5.02e-07
Aluminum Prod.	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	9.88e-06	4.99e-07
Polycarbonate Production	Phenol	secondary	9.34e-06	4.72e-07
Invar	Pentane	secondary	8.97e-06	4.53e-07
Lead	Fluoride	secondary	8.91e-06	4.50e-07
Steel Prod., cold-rolled, semi-finished	Hexane	secondary	8.86e-06	4.48e-07
Invar	Fluoride	secondary	8.80e-06	4.45e-07
Ferrite mfg.	Pentane	secondary	8.76e-06	4.43e-07
Steel Prod., cold-rolled, semi-finished	Copper (+1 & +2)	secondary	8.59e-06	4.34e-07
Lead	Aluminum (elemental)	secondary	8.16e-06	4.12e-07

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Ferrite mfg.	Nitrate	secondary	8.08e-06	4.08e-07
Lead	Nickel cmpds	secondary	7.95e-06	4.01e-07
Ferrite mfg.	Aluminum (elemental)	secondary	7.77e-06	3.92e-07
Invar	Benzo[a]pyrene	secondary	7.72e-06	3.90e-07
Aluminum Prod.	Hydrogen sulfide	secondary	7.53e-06	3.80e-07
Polycarbonate Production	Hydrofluoric acid	secondary	7.39e-06	3.73e-07
Aluminum Prod.	Acetic acid	secondary	7.33e-06	3.71e-07
Lead	Nickel	secondary	6.71e-06	3.39e-07
Ferrite mfg.	Chromium (VI)	secondary	6.52e-06	3.30e-07
Invar	Nitrites	secondary	6.45e-06	3.26e-07
Invar	Acetic acid	secondary	6.08e-06	3.07e-07
Invar	Vanadium (V3+, V5+)	secondary	6.00e-06	3.03e-07
Invar	Lead cmpds	secondary	5.96e-06	3.01e-07
Ferrite mfg.	Copper (+1 & +2)	secondary	5.96e-06	3.01e-07
Ferrite mfg.	Cadmium cmpds	secondary	5.94e-06	3.00e-07
Lead	Hydrogen sulfide	secondary	5.93e-06	3.00e-07
Polycarbonate Production	Ammonia	secondary	5.86e-06	2.96e-07
Lead	Chromium (VI)	secondary	5.80e-06	2.93e-07
Styrene-butadiene Copolymer Prod.	Nitrate	secondary	5.79e-06	2.93e-07
Lead	Lead cmpds	secondary	5.50e-06	2.78e-07
ABS Production	Heptane	secondary	5.02e-06	2.53e-07
ABS Production	Copper (+1 & +2)	secondary	4.75e-06	2.40e-07
Lead	Vanadium (V3+, V5+)	secondary	4.75e-06	2.40e-07
Styrene-butadiene Copolymer Prod.	Copper (+1 & +2)	secondary	4.64e-06	2.35e-07
Ferrite mfg.	Copper	secondary	4.55e-06	2.30e-07
Ferrite mfg.	Aromatic hydrocarbons	secondary	4.52e-06	2.29e-07
Steel Prod., cold-rolled, semi-finished	Bromine	secondary	4.06e-06	2.05e-07
Polycarbonate Production	Halogenated hydrocarbons (unspecified)	secondary	3.69e-06	1.87e-07
Polycarbonate Production	Hydrogen sulfide	secondary	3.69e-06	1.87e-07
Steel Prod., cold-rolled, semi-finished	Acetic acid	secondary	3.56e-06	1.80e-07
Invar	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	3.45e-06	1.74e-07
Aluminum Prod.	Cadmium	secondary	3.36e-06	1.70e-07
Steel Prod., cold-rolled, semi-finished	Boric acid	secondary	3.30e-06	1.67e-07
Ferrite mfg.	Nickel	secondary	3.26e-06	1.65e-07
Lead	Nitrites	secondary	3.10e-06	1.57e-07
Steel Prod., cold-rolled, semi-finished	Strontium	secondary	3.01e-06	1.52e-07
Lead	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	2.99e-06	1.51e-07
Invar	Cobalt (Co I, Co II, Co III)	secondary	2.88e-06	1.46e-07
Aluminum Prod.	Triethylene glycol	secondary	2.69e-06	1.36e-07
Invar	Hexane	secondary	2.58e-06	1.30e-07
Polystyrene Prod., high-impact	Ammonia	secondary	2.56e-06	1.29e-07
Ferrite mfg.	Hexane	secondary	2.51e-06	1.27e-07
Aluminum Prod.	Lead	secondary	2.40e-06	1.21e-07
Steel Prod., cold-rolled, semi-finished	Lead	secondary	2.20e-06	1.11e-07
Invar	Boron (B III)	secondary	2.18e-06	1.10e-07
Lead	Bromine	secondary	2.16e-06	1.09e-07
Invar	Triethylene glycol	secondary	2.14e-06	1.08e-07
Steel Prod., cold-rolled, semi-finished	Triethylene glycol	secondary	2.12e-06	1.07e-07
Ferrite mfg.	Triethylene glycol	secondary	2.09e-06	1.05e-07
Lead	Triethylene glycol	secondary	2.01e-06	1.01e-07

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Cadmium	secondary	1.98e-06	1.00e-07
Invar	Methanol	secondary	1.87e-06	9.43e-08
Polycarbonate Production	Chlorine	secondary	1.85e-06	9.33e-08
Ferrite mfg.	Fluoride	secondary	1.85e-06	9.33e-08
Lead	Cobalt (Co I, Co II, Co III)	secondary	1.84e-06	9.28e-08
Aluminum Prod.	Toluene	secondary	1.81e-06	9.15e-08
Steel Prod., cold-rolled, semi-finished	Lead cmpds	secondary	1.77e-06	8.92e-08
Steel Prod., cold-rolled, semi-finished	Uranium	secondary	1.71e-06	8.65e-08
Styrene-butadiene Copolymer Prod.	Aluminum (+3)	secondary	1.65e-06	8.36e-08
Invar	Strontium	secondary	1.59e-06	8.04e-08
Ferrite mfg.	Acetic acid	secondary	1.52e-06	7.67e-08
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	1.52e-06	7.67e-08
Lead	Mercury	secondary	1.51e-06	7.64e-08
Invar	Bromium (Br)	secondary	1.42e-06	7.16e-08
Ferrite mfg.	Bromine	secondary	1.38e-06	6.99e-08
Aluminum Prod.	Xylene (mixed isomers)	secondary	1.38e-06	6.96e-08
Lead	Boron (B III)	secondary	1.31e-06	6.63e-08
ABS Production	Chlorine	secondary	1.27e-06	6.42e-08
Lead	Acetic acid	secondary	1.27e-06	6.41e-08
Steel Prod., cold-rolled, semi-finished	Ethylene	secondary	1.23e-06	6.20e-08
Steel Prod., cold-rolled, semi-finished	Cyanide (-1)	secondary	1.21e-06	6.10e-08
Steel Prod., cold-rolled, semi-finished	Methanol	secondary	1.19e-06	6.03e-08
Ferrite mfg.	Nickel cmpds	secondary	1.13e-06	5.72e-08
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	1.12e-06	5.67e-08
Steel Prod., cold-rolled, semi-finished	Naphthalene	secondary	1.11e-06	5.63e-08
Invar	Toluene	secondary	1.10e-06	5.55e-08
Steel Prod., cold-rolled, semi-finished	Zinc (+2)	secondary	1.06e-06	5.36e-08
Ferrite mfg.	Lead cmpds	secondary	1.04e-06	5.25e-08
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	9.70e-07	4.90e-08
Invar	Boric acid	secondary	9.35e-07	4.72e-08
Steel Prod., cold-rolled, semi-finished	Heptane	secondary	9.33e-07	4.72e-08
Polycarbonate Production	Aluminum (+3)	secondary	9.23e-07	4.67e-08
Polycarbonate Production	Ethanethiol	secondary	9.23e-07	4.67e-08
Polycarbonate Production	Lead	secondary	9.23e-07	4.67e-08
Polycarbonate Production	Nitrate	secondary	9.23e-07	4.67e-08
Polycarbonate Production	Nitrous oxide	secondary	9.23e-07	4.67e-08
Polycarbonate Production	Zinc (+2)	secondary	9.23e-07	4.67e-08
Ferrite mfg.	Boric acid	secondary	9.13e-07	4.61e-08
Lead	Manganese	secondary	8.47e-07	4.28e-08
Steel Prod., cold-rolled, semi-finished	Nickel cmpds	secondary	8.46e-07	4.27e-08
Ferrite mfg.	Strontium	secondary	8.38e-07	4.23e-08
Styrene-butadiene Copolymer Prod.	Chlorine	secondary	8.27e-07	4.18e-08
Styrene-butadiene Copolymer Prod.	Hydrofluoric acid	secondary	8.27e-07	4.18e-08
Aluminum Prod.	Cobalt	secondary	8.23e-07	4.16e-08
Steel Prod., cold-rolled, semi-finished	Cobalt	secondary	8.10e-07	4.09e-08
Lead	Mercury compounds	secondary	7.89e-07	3.99e-08
Invar	Xylene (mixed isomers)	secondary	7.67e-07	3.88e-08
Aluminum Prod.	Strontium	secondary	7.60e-07	3.84e-08
Steel Prod., cold-rolled, semi-finished	Beryllium	secondary	7.21e-07	3.64e-08
ABS Production	Nickel cmpds	secondary	7.16e-07	3.62e-08

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Ferrite mfg.	Vanadium (V3+, V5+)	secondary	6.83e-07	3.45e-08
Aluminum Prod.	Phenol	secondary	6.39e-07	3.23e-08
Invar	Manganese	secondary	6.32e-07	3.19e-08
Polystyrene Prod., high-impact	Nitrate	secondary	6.05e-07	3.05e-08
Invar	Ethylene	secondary	6.01e-07	3.03e-08
Steel Prod., cold-rolled, semi-finished	Vanadium (V3+, V5+)	secondary	5.94e-07	3.00e-08
ABS Production	Phenol	secondary	5.88e-07	2.97e-08
Ferrite mfg.	Ethylene	secondary	5.79e-07	2.92e-08
Styrene-butadiene Copolymer Prod.	Ammonia	secondary	5.62e-07	2.84e-08
Steel Prod., cold-rolled, semi-finished	Benzo[a]pyrene	secondary	5.60e-07	2.83e-08
Ferrite mfg.	Toluene	secondary	5.31e-07	2.68e-08
ABS Production	HALON-1301	secondary	5.12e-07	2.59e-08
Styrene-butadiene Copolymer Prod.	Phenol	secondary	4.92e-07	2.49e-08
Invar	Uranium	secondary	4.89e-07	2.47e-08
Ferrite mfg.	Uranium	secondary	4.77e-07	2.41e-08
Steel Prod., cold-rolled, semi-finished	Boron (B III)	secondary	4.70e-07	2.37e-08
Polycarbonate Production	Mercury	secondary	4.62e-07	2.33e-08
Ferrite mfg.	Nitrites	secondary	4.48e-07	2.26e-08
Invar	Phenol	secondary	4.41e-07	2.23e-08
ABS Production	Ethanethiol	secondary	4.24e-07	2.14e-08
ABS Production	Fluoride	secondary	4.24e-07	2.14e-08
ABS Production	Halogenated hydrocarbons (unspecified)	secondary	4.24e-07	2.14e-08
ABS Production	Lead	secondary	4.24e-07	2.14e-08
ABS Production	Nitrous oxide	secondary	4.24e-07	2.14e-08
ABS Production	Zinc (+2)	secondary	4.24e-07	2.14e-08
Styrene-butadiene Copolymer Prod.	Halogenated hydrocarbons (unspecified)	secondary	4.14e-07	2.09e-08
Styrene-butadiene Copolymer Prod.	Hydrogen sulfide	secondary	4.14e-07	2.09e-08
Styrene-butadiene Copolymer Prod.	Lead	secondary	4.14e-07	2.09e-08
Styrene-butadiene Copolymer Prod.	Nitrous oxide	secondary	4.14e-07	2.09e-08
Styrene-butadiene Copolymer Prod.	Zinc (+2)	secondary	4.14e-07	2.09e-08
Aluminum Prod.	HALON-1301	secondary	3.61e-07	1.82e-08
Steel Prod., cold-rolled, semi-finished	Manganese	secondary	3.60e-07	1.82e-08
Ferrite mfg.	Xylene (mixed isomers)	secondary	3.50e-07	1.77e-08
Ferrite mfg.	Methanol	secondary	3.36e-07	1.70e-08
Invar	Cyanide (-1)	secondary	2.89e-07	1.46e-08
Invar	Heptane	secondary	2.83e-07	1.43e-08
Invar	Acetaldehyde	secondary	2.79e-07	1.41e-08
Ferrite mfg.	Heptane	secondary	2.76e-07	1.40e-08
Lead	Xylene (mixed isomers)	secondary	2.54e-07	1.29e-08
Aluminum Prod.	1,2-Dichlorotetrafluoroethane	secondary	2.49e-07	1.26e-08
Steel Prod., cold-rolled, semi-finished	Rubidium ion (Rb+)	secondary	2.42e-07	1.22e-08
Ferrite mfg.	Cobalt	secondary	2.40e-07	1.21e-08
Invar	Mercury	secondary	2.12e-07	1.07e-08
ABS Production	Mercury	secondary	2.12e-07	1.07e-08
Styrene-butadiene Copolymer Prod.	Mercury	secondary	2.07e-07	1.05e-08
Ferrite mfg.	Cyanide (-1)	secondary	2.05e-07	1.04e-08
Invar	Beryllium	secondary	2.05e-07	1.04e-08
Aluminum Prod.	Mercury	secondary	2.02e-07	1.02e-08
Ferrite mfg.	Beryllium	secondary	2.00e-07	1.01e-08
Ferrite mfg.	Phenol	secondary	1.95e-07	9.87e-09

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Aluminum Prod.	Cyanide (-1)	secondary	1.89e-07	9.57e-09
Steel Prod., cold-rolled, semi-finished	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	1.81e-07	9.17e-09
Polystyrene Prod., high-impact	Phenol	secondary	1.80e-07	9.09e-09
Steel Prod., cold-rolled, semi-finished	Morpholine	secondary	1.79e-07	9.05e-09
Steel Prod., cold-rolled, semi-finished	Propylene	secondary	1.77e-07	8.94e-09
Ferrite mfg.	Cobalt (Co I, Co II, Co III)	secondary	1.76e-07	8.88e-09
Lead	Methanol	secondary	1.62e-07	8.21e-09
Steel Prod., cold-rolled, semi-finished	Acetaldehyde	secondary	1.62e-07	8.18e-09
Ferrite mfg.	Mercury	secondary	1.62e-07	8.16e-09
Ferrite mfg.	Benzo[a]pyrene	secondary	1.55e-07	7.85e-09
Ferrite mfg.	Boron (B III)	secondary	1.55e-07	7.83e-09
ABS Production	Ethylene	secondary	1.52e-07	7.68e-09
Invar	HALON-1301	secondary	1.52e-07	7.68e-09
Lead	Cobalt	secondary	1.46e-07	7.39e-09
Lead	Phenol	secondary	1.37e-07	6.94e-09
Invar	Ethylbenzene	secondary	1.37e-07	6.90e-09
Invar	Acetone	secondary	1.36e-07	6.88e-09
Lead	Aromatic hydrocarbons	secondary	1.36e-07	6.86e-09
Aluminum Prod.	Chromium (III)	secondary	1.31e-07	6.62e-09
Ferrite mfg.	Manganese	secondary	1.19e-07	6.00e-09
Steel Prod., cold-rolled, semi-finished	Fluorine	secondary	1.14e-07	5.78e-09
Steel Prod., cold-rolled, semi-finished	Lanthanum	secondary	1.07e-07	5.43e-09
Invar	1,2-Dichlorotetrafluoroethane	secondary	1.03e-07	5.22e-09
Lead	Cyanide (-1)	secondary	9.76e-08	4.93e-09
Invar	Nitrous oxide	secondary	9.70e-08	4.90e-09
Lead	Ethylene	secondary	9.43e-08	4.77e-09
Lead	Toluene	secondary	8.24e-08	4.16e-09
Steel Prod., cold-rolled, semi-finished	Acetone	secondary	7.91e-08	3.99e-09
Invar	Rubidium ion (Rb+)	secondary	7.31e-08	3.69e-09
Ferrite mfg.	Rubidium ion (Rb+)	secondary	7.14e-08	3.61e-09
Lead	HALON-1301	secondary	6.78e-08	3.42e-09
Invar	Sulfuric acid	secondary	5.99e-08	3.03e-09
Ferrite mfg.	Sulfuric acid	secondary	5.85e-08	2.95e-09
Steel Prod., cold-rolled, semi-finished	Thorium	secondary	5.77e-08	2.91e-09
Invar	Mercury compounds	secondary	5.58e-08	2.82e-09
Ferrite mfg.	Mercury compounds	secondary	5.45e-08	2.75e-09
Steel Prod., cold-rolled, semi-finished	Ethylbenzene	secondary	5.25e-08	2.65e-09
Ferrite mfg.	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	5.09e-08	2.57e-09
Invar	Morpholine	secondary	5.07e-08	2.56e-09
Steel Prod., cold-rolled, semi-finished	HALON-1301	secondary	5.04e-08	2.55e-09
Invar	Propylene	secondary	5.03e-08	2.54e-09
Ferrite mfg.	Morpholine	secondary	4.95e-08	2.50e-09
Ferrite mfg.	Propylene	secondary	4.91e-08	2.48e-09
Invar	Chromium (III)	secondary	4.79e-08	2.42e-09
Lead	Ethylbenzene	secondary	4.72e-08	2.39e-09
Ferrite mfg.	Acetaldehyde	secondary	4.63e-08	2.34e-09
Lead	Chromium (III)	secondary	3.86e-08	1.95e-09
Lead	Acetaldehyde	secondary	3.59e-08	1.81e-09
Steel Prod., cold-rolled, semi-finished	Tin	secondary	3.35e-08	1.69e-09
Steel Prod., cold-rolled, semi-finished	Mercury	secondary	3.26e-08	1.65e-09

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Invar	Fluorine	secondary	3.24e-08	1.64e-09
Steel Prod., cold-rolled, semi-finished	Phosphorus pentoxide	secondary	3.22e-08	1.63e-09
Ferrite mfg.	Fluorine	secondary	3.16e-08	1.60e-09
Invar	Lanthanum	secondary	3.06e-08	1.55e-09
Ferrite mfg.	Lanthanum	secondary	2.99e-08	1.51e-09
Steel Prod., cold-rolled, semi-finished	Hydrazine	secondary	2.65e-08	1.34e-09
Steel Prod., cold-rolled, semi-finished	Scandium	secondary	2.61e-08	1.32e-09
Steel Prod., cold-rolled, semi-finished	Chlorine	secondary	2.28e-08	1.15e-09
Ferrite mfg.	Acetone	secondary	2.23e-08	1.13e-09
Ferrite mfg.	Ethylbenzene	secondary	1.94e-08	9.80e-10
Ferrite mfg.	HALON-1301	secondary	1.90e-08	9.62e-10
Steel Prod., cold-rolled, semi-finished	Thallium	secondary	1.78e-08	8.99e-10
Lead	Acetone	secondary	1.72e-08	8.67e-10
Invar	Thorium	secondary	1.65e-08	8.32e-10
Ferrite mfg.	Thorium	secondary	1.61e-08	8.12e-10
Steel Prod., cold-rolled, semi-finished	Zirconium	secondary	1.37e-08	6.94e-10
Lead	Benzo[a]pyrene	secondary	1.23e-08	6.22e-10
Invar	Tin	secondary	9.53e-09	4.82e-10
Invar	Phosphorus pentoxide	secondary	9.39e-09	4.74e-10
Ferrite mfg.	Tin	secondary	9.31e-09	4.70e-10
Ferrite mfg.	Phosphorus pentoxide	secondary	9.16e-09	4.63e-10
Invar	Trichlorofluoromethane	secondary	8.09e-09	4.09e-10
Invar	Hydrogen cyanide	secondary	7.58e-09	3.83e-10
Invar	Hydrazine	secondary	7.51e-09	3.79e-10
Invar	Scandium	secondary	7.47e-09	3.77e-10
Ferrite mfg.	Hydrogen cyanide	secondary	7.40e-09	3.74e-10
Ferrite mfg.	Hydrazine	secondary	7.33e-09	3.70e-10
Ferrite mfg.	Scandium	secondary	7.29e-09	3.68e-10
Invar	Perfluoromethane	secondary	5.70e-09	2.88e-10
Steel Prod., cold-rolled, semi-finished	Nitrites	secondary	5.63e-09	2.84e-10
Ferrite mfg.	Perfluoromethane	secondary	5.57e-09	2.81e-10
Steel Prod., cold-rolled, semi-finished	Chromium (III)	secondary	5.29e-09	2.67e-10
Invar	Thallium	secondary	5.10e-09	2.58e-10
Ferrite mfg.	Chromium (III)	secondary	5.01e-09	2.53e-10
Ferrite mfg.	Thallium	secondary	4.98e-09	2.52e-10
Invar	Zirconium	secondary	3.94e-09	1.99e-10
Steel Prod., cold-rolled, semi-finished	Edetic acid (EDTA)	secondary	3.86e-09	1.95e-10
Ferrite mfg.	Zirconium	secondary	3.84e-09	1.94e-10
Invar	Hypochlorous acid	secondary	3.54e-09	1.79e-10
Steel Prod., cold-rolled, semi-finished	Hypochlorous acid	secondary	3.52e-09	1.78e-10
Ferrite mfg.	Hypochlorous acid	secondary	3.46e-09	1.75e-10
Steel Prod., cold-rolled, semi-finished	Cobalt (Co I, Co II, Co III)	secondary	3.14e-09	1.59e-10
Ferrite mfg.	Trichlorofluoromethane	secondary	3.01e-09	1.52e-10
ABS Production	HCFC-22	secondary	2.69e-09	1.36e-10
Invar	HFC-125	secondary	2.30e-09	1.16e-10
Ferrite mfg.	HFC-125	secondary	2.24e-09	1.13e-10
Invar	Chlorine	secondary	2.22e-09	1.12e-10
Ferrite mfg.	Chlorine	secondary	2.17e-09	1.10e-10
Invar	Dichloromethane	secondary	1.51e-09	7.61e-11
Steel Prod., cold-rolled, semi-finished	Dichloromethane	secondary	1.50e-09	7.55e-11

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Ferrite mfg.	Dichloromethane	secondary	1.47e-09	7.43e-11
Invar	Dichlorodifluoromethane	secondary	1.44e-09	7.27e-11
Invar	Edetic acid (EDTA)	secondary	1.09e-09	5.52e-11
Ferrite mfg.	Edetic acid (EDTA)	secondary	1.07e-09	5.39e-11
Invar	CFC-13	secondary	1.01e-09	5.09e-11
Steel Prod., cold-rolled, semi-finished	Isopropylpropionate	secondary	4.05e-10	2.04e-11
Ferrite mfg.	Isopropylpropionate	secondary	3.97e-10	2.01e-11
Invar	Halogenated matter (organic)	secondary	2.74e-10	1.39e-11
Ferrite mfg.	Halogenated matter (organic)	secondary	2.68e-10	1.35e-11
Steel Prod., cold-rolled, semi-finished	Lithium salts	secondary	1.98e-10	1.00e-11
Invar	Ethanethiol	secondary	1.74e-10	8.80e-12
Ferrite mfg.	Ethanethiol	secondary	1.70e-10	8.59e-12
Ferrite mfg.	Tin (Sn++, Sn4+)	secondary	1.46e-10	7.36e-12
Steel Prod., cold-rolled, semi-finished	Perfluoromethane	secondary	8.98e-11	4.54e-12
Invar	Lithium salts	secondary	5.61e-11	2.84e-12
Invar	Chloroform	secondary	5.52e-11	2.79e-12
Steel Prod., cold-rolled, semi-finished	Chloroform	secondary	5.48e-11	2.77e-12
Ferrite mfg.	Lithium salts	secondary	5.48e-11	2.77e-12
Ferrite mfg.	Chloroform	secondary	5.39e-11	2.72e-12
Lead	Acrolein	secondary	2.38e-11	1.20e-12
Lead	Benzaldehyde	secondary	1.35e-11	6.81e-13
Invar	Perfluoroethane	secondary	5.35e-12	2.70e-13
Invar	Trichloroethylene	secondary	7.98e-13	4.03e-14
Steel Prod., cold-rolled, semi-finished	Trichloroethylene	secondary	7.91e-13	4.00e-14
Ferrite mfg.	Trichloroethylene	secondary	7.79e-13	3.94e-14
Invar	Propionaldehyde	secondary	2.08e-13	1.05e-14
Steel Prod., cold-rolled, semi-finished	Propionaldehyde	secondary	2.08e-13	1.05e-14
Ferrite mfg.	Propionaldehyde	secondary	2.03e-13	1.03e-14
Steel Prod., cold-rolled, semi-finished	Benzaldehyde	secondary	6.15e-14	3.11e-15
Invar	Benzaldehyde	secondary	6.10e-14	3.08e-15
Ferrite mfg.	Benzaldehyde	secondary	5.95e-14	3.01e-15
Invar	Pentachlorobenzene	secondary	2.77e-14	1.40e-15
Steel Prod., cold-rolled, semi-finished	Tetrachloroethylene	secondary	2.20e-14	1.11e-15
Invar	Tetrachloroethylene	secondary	2.17e-14	1.10e-15
Ferrite mfg.	Tetrachloroethylene	secondary	2.12e-14	1.07e-15
Invar	Acrolein	secondary	9.90e-15	5.00e-16
Ferrite mfg.	1,2-Dichlorotetrafluoroethane	secondary	7.63e-15	3.86e-16
Invar	1,1,1-Trichloroethane	secondary	3.25e-15	1.64e-16
Steel Prod., cold-rolled, semi-finished	1,1,1-Trichloroethane	secondary	3.21e-15	1.62e-16
Ferrite mfg.	1,1,1-Trichloroethane	secondary	3.16e-15	1.60e-16
Invar	Pentachlorophenol	secondary	1.55e-15	7.84e-17
Invar	Hexachloroethane	secondary	1.24e-16	6.27e-18
Steel Prod., cold-rolled, semi-finished	Hexachloroethane	secondary	1.23e-16	6.22e-18
Ferrite mfg.	Hexachloroethane	secondary	1.21e-16	6.12e-18
Ferrite mfg.	Dichlorodifluoromethane	secondary	1.07e-16	5.39e-18
Ferrite mfg.	CFC-13	secondary	7.48e-17	3.78e-18
Invar	HCFC-22	secondary	6.78e-17	3.43e-18
Ferrite mfg.	HCFC-22	secondary	6.62e-17	3.35e-18
Total Materials Processing			**2.28e+02**	**1.15e+01**
Manufacturing Life-cycle Stage				

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Japanese Electric Grid	Sulfur dioxide	model/secondary	5.69e+01	2.88e+00
US electric grid	Sulfur dioxide	model/secondary	2.63e+01	1.33e+00
LPG Production	Carbon monoxide	secondary	5.77e+00	2.92e-01
LPG Production	Methane	secondary	1.68e+00	8.48e-02
LPG Production	Sulfur oxides	secondary	1.60e+00	8.10e-02
LPG Production	Nitrogen oxides	secondary	1.15e+00	5.79e-02
LPG Production	Vanadium	secondary	1.05e+00	5.29e-02
LPG Production	Benzene	secondary	8.58e-01	4.34e-02
Glass/frit	Fluorides (F-)	primary	5.85e-01	2.96e-02
LPG Production	PM	secondary	2.58e-01	1.30e-02
CRT tube mfg.	Carbon monoxide	primary	2.29e-01	1.16e-02
LPG Production	Arsenic	secondary	2.06e-01	1.04e-02
LPG Production	Formaldehyde	secondary	1.34e-01	6.77e-03
Natural Gas Prod.	Methane	secondary	1.00e-01	5.07e-03
Glass/frit	Nitrogen oxides	primary	8.83e-02	4.46e-03
Japanese Electric Grid	Nitrogen oxides	model/secondary	8.13e-02	4.11e-03
Natural Gas Prod.	Benzene	secondary	7.57e-02	3.83e-03
Natural Gas Prod.	Carbon monoxide	secondary	6.87e-02	3.47e-03
CRT monitor assembly	Tricresyl phosphate	primary	4.59e-02	2.32e-03
CRT tube mfg.	Phosphorus (yellow or white)	primary	4.00e-02	2.02e-03
Japanese Electric Grid	Carbon monoxide	model/secondary	3.78e-02	1.91e-03
US electric grid	Nitrogen oxides	model/secondary	3.76e-02	1.90e-03
LPG Production	Hydrochloric acid	secondary	3.68e-02	1.86e-03
LPG Production	Nitrous oxide	secondary	3.24e-02	1.64e-03
Fuel Oil #6 Prod.	Carbon monoxide	secondary	2.83e-02	1.43e-03
Japanese Electric Grid	Vanadium	model/secondary	2.27e-02	1.15e-03
US electric grid	Methane	model/secondary	2.06e-02	1.04e-03
CRT tube mfg.	Sulfur oxides	primary	1.99e-02	1.01e-03
Natural Gas Prod.	Nitrogen oxides	secondary	1.86e-02	9.42e-04
US electric grid	Carbon monoxide	model/secondary	1.74e-02	8.80e-04
Fuel Oil #2 Prod.	Carbon monoxide	secondary	1.68e-02	8.50e-04
Fuel Oil #6 Prod.	Methane	secondary	1.18e-02	5.95e-04
Fuel Oil #6 Prod.	Sulfur oxides	secondary	1.09e-02	5.53e-04
Fuel Oil #6 Prod.	Vanadium	secondary	1.08e-02	5.44e-04
Japanese Electric Grid	Arsenic	model/secondary	1.04e-02	5.27e-04
LPG Production	Phosphorus (yellow or white)	secondary	9.81e-03	4.96e-04
US electric grid	Arsenic	model/secondary	8.91e-03	4.50e-04
Fuel Oil #6 Prod.	Nitrogen oxides	secondary	8.19e-03	4.14e-04
US electric grid	Hydrochloric acid	model/secondary	7.87e-03	3.98e-04
LPG Production	Fluorides (F-)	secondary	7.54e-03	3.81e-04
LPG Production	Selenium	secondary	7.41e-03	3.75e-04
CRT tube mfg.	Fluoride	primary	6.91e-03	3.49e-04
Japanese Electric Grid	Hydrochloric acid	model/secondary	6.28e-03	3.17e-04
LPG Production	Hydrogen sulfide	secondary	6.13e-03	3.10e-04
LPG Production	Ammonia	secondary	5.91e-03	2.99e-04
Glass/frit	Fluorides (F-)	primary	5.85e-03	2.95e-04
Fuel Oil #2 Prod.	Methane	secondary	5.14e-03	2.60e-04
Fuel Oil #6 Prod.	Benzene	secondary	4.90e-03	2.48e-04
Fuel Oil #2 Prod.	Sulfur oxides	secondary	4.87e-03	2.46e-04
PWB Mfg.	Formaldehyde	model/secondary	4.45e-03	2.25e-04

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
CRT tube mfg.	Nitrogen oxides	primary	4.34e-03	2.19e-04
Japanese Electric Grid	PM-10	model/secondary	4.00e-03	2.02e-04
Fuel Oil #2 Prod.	Nitrogen oxides	secondary	3.51e-03	1.78e-04
Fuel Oil #2 Prod.	Vanadium	secondary	3.45e-03	1.74e-04
CRT tube mfg.	Dimethyl Formamide	primary	3.07e-03	1.55e-04
Fuel Oil #2 Prod.	Benzene	secondary	2.55e-03	1.29e-04
Glass/frit	Carbon monoxide	primary	2.16e-03	1.09e-04
LPG Production	Hydrofluoric acid	secondary	2.01e-03	1.01e-04
Fuel Oil #6 Prod.	PM	secondary	1.85e-03	9.34e-05
US electric grid	PM-10	model/secondary	1.84e-03	9.32e-05
Fuel Oil #6 Prod.	Arsenic	secondary	1.72e-03	8.72e-05
CRT tube mfg.	Zinc (elemental)	primary	1.65e-03	8.33e-05
LPG Production	Molybdenum	secondary	1.65e-03	8.33e-05
LPG Production	Chromium (VI)	secondary	1.58e-03	7.97e-05
LPG Production	Ethane	secondary	1.55e-03	7.84e-05
Fuel Oil #4 Prod.	Carbon monoxide	secondary	1.52e-03	7.66e-05
US electric grid	Selenium	model/secondary	1.48e-03	7.48e-05
Fuel Oil #6 Prod.	Formaldehyde	secondary	1.37e-03	6.92e-05
Japanese Electric Grid	Fluorides (F-)	model/secondary	1.32e-03	6.65e-05
Japanese Electric Grid	Selenium	model/secondary	1.27e-03	6.44e-05
LPG Production	Zinc (elemental)	secondary	1.20e-03	6.06e-05
Japanese Electric Grid	Formaldehyde	model/secondary	1.17e-03	5.91e-05
US electric grid	Vanadium	model/secondary	1.11e-03	5.63e-05
Glass/frit	Nitrogen oxides	primary	1.07e-03	5.39e-05
LPG Production	Hexane	secondary	9.02e-04	4.56e-05
Natural Gas Prod.	PM	secondary	8.28e-04	4.18e-05
Fuel Oil #2 Prod.	PM	secondary	7.92e-04	4.00e-05
LPG Production	Phenol	secondary	7.15e-04	3.61e-05
Fuel Oil #2 Prod.	Arsenic	secondary	6.52e-04	3.29e-05
LPG Production	Pentane	secondary	6.51e-04	3.29e-05
CRT tube mfg.	Toluene	primary	6.41e-04	3.24e-05
Japanese Electric Grid	Zinc (elemental)	model/secondary	6.13e-04	3.10e-05
Natural Gas Prod.	Sulfur oxides	secondary	5.51e-04	2.79e-05
Fuel Oil #4 Prod.	Methane	secondary	5.21e-04	2.63e-05
Fuel Oil #4 Prod.	Sulfur oxides	secondary	4.90e-04	2.48e-05
LPG Production	PM-10	secondary	4.50e-04	2.27e-05
Fuel Oil #2 Prod.	Formaldehyde	secondary	4.41e-04	2.23e-05
US electric grid	Hydrofluoric acid	model/secondary	4.29e-04	2.17e-05
Natural Gas Prod.	Ammonia	secondary	4.26e-04	2.15e-05
LPG Production	Nickel	secondary	4.12e-04	2.08e-05
Fuel Oil #4 Prod.	Vanadium	secondary	4.03e-04	2.04e-05
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	3.59e-04	1.81e-05
Japanese Electric Grid	Hydrofluoric acid	model/secondary	3.43e-04	1.73e-05
Japanese Electric Grid	Antimony	model/secondary	3.24e-04	1.64e-05
Natural Gas Prod.	Arsenic	secondary	3.15e-04	1.59e-05
Fuel Oil #6 Prod.	Hydrochloric acid	secondary	2.97e-04	1.50e-05
Fuel Oil #6 Prod.	Nitrous oxide	secondary	2.90e-04	1.47e-05
LPG Production	Aluminum (+3)	secondary	2.83e-04	1.43e-05
CRT tube mfg.	Nickel	primary	2.68e-04	1.35e-05
Fuel Oil #4 Prod.	Benzene	secondary	2.41e-04	1.22e-05

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Japanese Electric Grid	Nitrous oxide	model/secondary	2.24e-04	1.13e-05
Glass/frit	PM	primary	2.18e-04	1.10e-05
LPG Production	Antimony	secondary	2.14e-04	1.08e-05
Japanese Electric Grid	Methane	model/secondary	1.63e-04	8.22e-06
US electric grid	Formaldehyde	model/secondary	1.55e-04	7.82e-06
Japanese Electric Grid	Molybdenum	model/secondary	1.32e-04	6.65e-06
LPG Production	Nitrate	secondary	1.21e-04	6.12e-06
Fuel Oil #2 Prod.	Hydrochloric acid	secondary	1.15e-04	5.83e-06
US electric grid	Benzene	model/secondary	1.11e-04	5.63e-06
US electric grid	Nitrous oxide	model/secondary	1.08e-04	5.48e-06
Fuel Oil #2 Prod.	Nitrous oxide	secondary	1.04e-04	5.24e-06
CRT tube mfg.	Molybdenum	primary	1.02e-04	5.18e-06
Glass/frit	Sulfur oxides	primary	1.02e-04	5.14e-06
Fuel Oil #6 Prod.	Phosphorus (yellow or white)	secondary	9.77e-05	4.94e-06
Japanese Electric Grid	Benzene	model/secondary	9.11e-05	4.60e-06
Glass/frit	Lead	primary	8.74e-05	4.42e-06
Fuel Oil #4 Prod.	PM	secondary	8.09e-05	4.09e-06
Fuel Oil #4 Prod.	Arsenic	secondary	7.04e-05	3.56e-06
Natural Gas Prod.	Vanadium	secondary	6.96e-05	3.52e-06
Natural Gas Prod.	Hydrochloric acid	secondary	6.39e-05	3.23e-06
Fuel Oil #6 Prod.	Hydrogen sulfide	secondary	6.35e-05	3.21e-06
US electric grid	Phosphorus (yellow or white)	model/secondary	6.27e-05	3.17e-06
Fuel Oil #6 Prod.	Selenium	secondary	6.07e-05	3.07e-06
Glass/frit	Carbon monoxide	primary	6.03e-05	3.05e-06
Fuel Oil #6 Prod.	Fluorides (F-)	secondary	5.86e-05	2.96e-06
Fuel Oil #4 Prod.	Formaldehyde	secondary	5.14e-05	2.60e-06
Japanese Electric Grid	Nickel	model/secondary	4.98e-05	2.52e-06
CRT tube mfg.	Copper	primary	4.05e-05	2.04e-06
LPG Production	Copper	secondary	3.49e-05	1.76e-06
LPG Production	Methyl hydrazine	secondary	3.44e-05	1.74e-06
LPG Production	Silicon	secondary	3.38e-05	1.71e-06
Glass/frit	Nitrates/nitrites	primary	3.34e-05	1.69e-06
LPG Production	2-Chloroacetophenone	secondary	3.22e-05	1.63e-06
Fuel Oil #2 Prod.	Phosphorus (yellow or white)	secondary	3.21e-05	1.62e-06
LPG Production	Dimethylbenzanthracene	secondary	3.19e-05	1.61e-06
LPG Production	Bromomethane	secondary	3.18e-05	1.61e-06
Fuel Oil #6 Prod.	Ammonia	secondary	3.18e-05	1.61e-06
Japanese Electric Grid	Barium	model/secondary	2.94e-05	1.48e-06
US electric grid	Zinc (elemental)	model/secondary	2.89e-05	1.46e-06
Natural Gas Prod.	Formaldehyde	secondary	2.77e-05	1.40e-06
LPG Production	Naphthalene	secondary	2.61e-05	1.32e-06
CRT tube mfg.	Xylene (mixed isomers)	primary	2.55e-05	1.29e-06
LPG Production	Lead	secondary	2.47e-05	1.25e-06
US electric grid	Antimony	model/secondary	2.37e-05	1.20e-06
Fuel Oil #2 Prod.	Fluorides (F-)	secondary	2.35e-05	1.19e-06
Fuel Oil #2 Prod.	Selenium	secondary	2.33e-05	1.18e-06
Natural Gas Prod.	Nitrous oxide	secondary	2.31e-05	1.17e-06
LPG Production	Manganese	secondary	2.23e-05	1.13e-06
LPG Production	Beryllium	secondary	2.15e-05	1.08e-06
Fuel Oil #2 Prod.	Hydrogen sulfide	secondary	2.02e-05	1.02e-06

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Barium	secondary	1.86e-05	9.42e-07
Fuel Oil #2 Prod.	Ammonia	secondary	1.74e-05	8.81e-07
LPG Production	Cyanide (-1)	secondary	1.67e-05	8.45e-07
Japanese Electric Grid	Naphthalene	model/secondary	1.66e-05	8.37e-07
Fuel Oil #6 Prod.	Hydrofluoric acid	secondary	1.62e-05	8.19e-07
LPG Production	Barium cmpds	secondary	1.59e-05	8.02e-07
Fuel Oil #6 Prod.	Molybdenum	secondary	1.56e-05	7.88e-07
Natural Gas Prod.	Ethane	secondary	1.40e-05	7.06e-07
Natural Gas Prod.	Fluorides (F-)	secondary	1.36e-05	6.87e-07
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	1.23e-05	6.22e-07
Natural Gas Prod.	Selenium	secondary	1.21e-05	6.13e-07
Fuel Oil #4 Prod.	Nitrous oxide	secondary	1.15e-05	5.81e-07
Japanese Electric Grid	Chromium (VI)	model/secondary	9.99e-06	5.05e-07
LPG Production	Cadmium	secondary	9.21e-06	4.65e-07
Fuel Oil #6 Prod.	Ethane	secondary	8.87e-06	4.48e-07
US electric grid	Chromium (VI)	model/secondary	8.58e-06	4.33e-07
Natural Gas Prod.	Zinc (elemental)	secondary	8.50e-06	4.30e-07
Natural Gas Prod.	Hexane	secondary	8.11e-06	4.10e-07
US electric grid	Molybdenum	model/secondary	7.93e-06	4.01e-07
US electric grid	Methyl hydrazine	model/secondary	7.36e-06	3.72e-07
Japanese Electric Grid	Copper	model/secondary	7.14e-06	3.61e-07
US electric grid	2-Chloroacetophenone	model/secondary	6.89e-06	3.48e-07
LPG Production	Carbon disulfide	secondary	6.85e-06	3.46e-07
US electric grid	Bromomethane	model/secondary	6.81e-06	3.44e-07
Fuel Oil #6 Prod.	Zinc (elemental)	secondary	6.59e-06	3.33e-07
Fuel Oil #6 Prod.	Chromium (VI)	secondary	6.39e-06	3.23e-07
Fuel Oil #2 Prod.	Hydrofluoric acid	secondary	6.30e-06	3.18e-07
CRT tube mfg.	Lead	primary	6.03e-06	3.05e-07
Japanese Electric Grid	Methyl hydrazine	model/secondary	5.88e-06	2.97e-07
Natural Gas Prod.	Pentane	secondary	5.86e-06	2.96e-07
Japanese Electric Grid	2-Chloroacetophenone	model/secondary	5.51e-06	2.78e-07
Japanese Electric Grid	Bromomethane	model/secondary	5.44e-06	2.75e-07
Fuel Oil #2 Prod.	Molybdenum	secondary	5.33e-06	2.69e-07
LPG Production	Benzyl chloride	secondary	5.24e-06	2.65e-07
Fuel Oil #6 Prod.	Hexane	secondary	5.16e-06	2.61e-07
LPG Production	Cobalt	secondary	5.02e-06	2.54e-07
Fuel Oil #6 Prod.	PM-10	secondary	4.66e-06	2.36e-07
Fuel Oil #2 Prod.	Ethane	secondary	4.61e-06	2.33e-07
Fuel Oil #6 Prod.	Nickel	secondary	3.99e-06	2.02e-07
LPG Production	Aluminum (elemental)	secondary	3.87e-06	1.96e-07
Fuel Oil #6 Prod.	Pentane	secondary	3.72e-06	1.88e-07
Fuel Oil #4 Prod.	Phosphorus (yellow or white)	secondary	3.70e-06	1.87e-07
US electric grid	Nickel	model/secondary	3.70e-06	1.87e-07
LPG Production	Chloroform	secondary	3.70e-06	1.87e-07
CRT tube mfg.	Manganese	primary	3.60e-06	1.82e-07
US electric grid	Cyanide (-1)	model/secondary	3.58e-06	1.81e-07
Fuel Oil #2 Prod.	Zinc (elemental)	secondary	3.54e-06	1.79e-07
Natural Gas Prod.	Hydrofluoric acid	secondary	3.49e-06	1.76e-07
LPG Production	Propionaldehyde	secondary	3.42e-06	1.73e-07
Japanese Electric Grid	Cyanide (-1)	model/secondary	2.86e-06	1.44e-07

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
US electric grid	2,3,7,8-TCDD	model/secondary	2.71e-06	1.37e-07
Fuel Oil #2 Prod.	Hexane	secondary	2.68e-06	1.35e-07
Fuel Oil #4 Prod.	Selenium	secondary	2.50e-06	1.26e-07
Fuel Oil #2 Prod.	Chromium (VI)	secondary	2.48e-06	1.25e-07
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	2.47e-06	1.25e-07
Fuel Oil #6 Prod.	Phenol	secondary	2.42e-06	1.22e-07
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	2.37e-06	1.20e-07
Japanese Electric Grid	Cobalt	model/secondary	2.37e-06	1.20e-07
Natural Gas Prod.	Molybdenum	secondary	2.31e-06	1.17e-07
Japanese Electric Grid	2,3,7,8-TCDD	model/secondary	2.23e-06	1.12e-07
US electric grid	Naphthalene	model/secondary	2.19e-06	1.10e-07
Fuel Oil #2 Prod.	Phenol	secondary	2.01e-06	1.01e-07
LPG Production	Acrolein	secondary	1.94e-06	9.80e-08
Fuel Oil #2 Prod.	Pentane	secondary	1.93e-06	9.77e-08
US electric grid	Barium	model/secondary	1.86e-06	9.39e-08
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	1.77e-06	8.94e-08
Fuel Oil #4 Prod.	Ammonia	secondary	1.62e-06	8.17e-08
LPG Production	Methyl chloride	secondary	1.61e-06	8.13e-08
Japanese Electric Grid	Cadmium	model/secondary	1.60e-06	8.09e-08
Fuel Oil #2 Prod.	PM-10	secondary	1.48e-06	7.50e-08
Natural Gas Prod.	Chromium (VI)	secondary	1.48e-06	7.47e-08
US electric grid	Carbon disulfide	model/secondary	1.46e-06	7.40e-08
Fuel Oil #2 Prod.	Nickel	secondary	1.34e-06	6.77e-08
Glass/frit	PM	primary	1.33e-06	6.74e-08
Fuel Oil #6 Prod.	Antimony	secondary	1.19e-06	6.00e-08
Japanese Electric Grid	Carbon disulfide	model/secondary	1.17e-06	5.91e-08
LPG Production	Di(2-ethylhexyl)phthalate	secondary	1.16e-06	5.86e-08
US electric grid	Benzyl chloride	model/secondary	1.12e-06	5.67e-08
Fuel Oil #6 Prod.	Aluminum (+3)	secondary	9.58e-07	4.84e-08
LPG Production	Acetaldehyde	secondary	9.23e-07	4.67e-08
Japanese Electric Grid	Benzyl chloride	model/secondary	8.95e-07	4.52e-08
US electric grid	Cadmium	model/secondary	8.74e-07	4.42e-08
LPG Production	Mercury	secondary	8.69e-07	4.39e-08
Fuel Oil #2 Prod.	Aluminum (+3)	secondary	7.95e-07	4.02e-08
US electric grid	Chloroform	model/secondary	7.91e-07	4.00e-08
US electric grid	Propionaldehyde	model/secondary	7.31e-07	3.69e-08
US electric grid	Manganese	model/secondary	7.28e-07	3.68e-08
LPG Production	Cadmium cmpds	secondary	6.95e-07	3.51e-08
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	6.72e-07	3.39e-08
LPG Production	Dimethyl sulfate	secondary	6.42e-07	3.25e-08
Fuel Oil #2 Prod.	Antimony	secondary	6.34e-07	3.20e-08
Japanese Electric Grid	Chloroform	model/secondary	6.31e-07	3.19e-08
US electric grid	Fluoride	model/secondary	6.23e-07	3.15e-08
LPG Production	Toluene	secondary	6.23e-07	3.15e-08
CRT tube mfg.	Cyanide (-1)	primary	6.06e-07	3.06e-08
Fuel Oil #4 Prod.	Molybdenum	secondary	6.03e-07	3.05e-08
Japanese Electric Grid	Propionaldehyde	model/secondary	5.84e-07	2.95e-08
Glass/frit	Zinc (elemental)	primary	5.55e-07	2.81e-08
Japanese Electric Grid	Beryllium	model/secondary	4.94e-07	2.50e-08
Fuel Oil #6 Prod.	Nitrate	secondary	4.85e-07	2.45e-08

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
US electric grid	Beryllium	model/secondary	4.65e-07	2.35e-08
Natural Gas Prod.	Antimony	secondary	4.46e-07	2.25e-08
Glass/frit	Chromium	primary	4.41e-07	2.23e-08
Fuel Oil #4 Prod.	Ethane	secondary	4.36e-07	2.20e-08
US electric grid	Acrolein	model/secondary	4.15e-07	2.10e-08
US electric grid	Lead	model/secondary	4.07e-07	2.06e-08
US electric grid	Cobalt	model/secondary	3.88e-07	1.96e-08
LPG Production	1,4-Dichlorobenzene	secondary	3.62e-07	1.83e-08
US electric grid	Copper	model/secondary	3.57e-07	1.80e-08
Fuel Oil #6 Prod.	Silicon	secondary	3.50e-07	1.77e-08
Fuel Oil #2 Prod.	Nitrate	secondary	3.45e-07	1.74e-08
US electric grid	Methyl chloride	model/secondary	3.44e-07	1.74e-08
Japanese Electric Grid	Acrolein	model/secondary	3.31e-07	1.67e-08
Fuel Oil #4 Prod.	Zinc (elemental)	secondary	3.31e-07	1.67e-08
Fuel Oil #6 Prod.	Copper	secondary	3.17e-07	1.60e-08
LPG Production	Isophorone	secondary	3.10e-07	1.57e-08
Natural Gas Prod.	Dimethylbenzanthracene	secondary	2.87e-07	1.45e-08
LPG Production	Aromatic hydrocarbons	secondary	2.80e-07	1.42e-08
Fuel Oil #6 Prod.	Methyl hydrazine	secondary	2.78e-07	1.40e-08
Glass/frit	Nickel	primary	2.77e-07	1.40e-08
Japanese Electric Grid	Methyl chloride	model/secondary	2.75e-07	1.39e-08
Fuel Oil #4 Prod.	Chromium (VI)	secondary	2.64e-07	1.34e-08
Fuel Oil #6 Prod.	2-Chloroacetophenone	secondary	2.60e-07	1.31e-08
Fuel Oil #6 Prod.	Bromomethane	secondary	2.57e-07	1.30e-08
Fuel Oil #4 Prod.	Hexane	secondary	2.53e-07	1.28e-08
LPG Production	Methyl ethyl ketone	secondary	2.48e-07	1.26e-08
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	2.48e-07	1.25e-08
LPG Production	Tetrachloroethylene	secondary	2.46e-07	1.24e-08
Japanese Electric Grid	Toluene	model/secondary	2.39e-07	1.21e-08
LPG Production	1,2-Dichloroethane	secondary	2.18e-07	1.10e-08
LPG Production	Methyl methacrylate	secondary	2.12e-07	1.07e-08
Fuel Oil #6 Prod.	Lead	secondary	2.00e-07	1.01e-08
Japanese Electric Grid	Di(2-ethylhexyl)phthalate	model/secondary	1.98e-07	1.00e-08
US electric grid	Acetaldehyde	model/secondary	1.98e-07	9.98e-09
US electric grid	Hexane	model/secondary	1.92e-07	9.69e-09
LPG Production	Styrene	secondary	1.88e-07	9.48e-09
Fuel Oil #4 Prod.	Pentane	secondary	1.83e-07	9.24e-09
Fuel Oil #6 Prod.	Dimethylbenzanthracene	secondary	1.82e-07	9.22e-09
Fuel Oil #6 Prod.	Manganese	secondary	1.79e-07	9.04e-09
LPG Production	Bromoform	secondary	1.75e-07	8.85e-09
Natural Gas Prod.	Nickel	secondary	1.74e-07	8.81e-09
Fuel Oil #4 Prod.	PM-10	secondary	1.74e-07	8.79e-09
LPG Production	Dichloromethane	secondary	1.73e-07	8.74e-09
LPG Production	Chromium (III)	secondary	1.72e-07	8.67e-09
Fuel Oil #6 Prod.	Beryllium	secondary	1.71e-07	8.64e-09
Fuel Oil #4 Prod.	Phenol	secondary	1.63e-07	8.24e-09
Fuel Oil #6 Prod.	Naphthalene	secondary	1.58e-07	8.00e-09
Japanese Electric Grid	Acetaldehyde	model/secondary	1.58e-07	7.97e-09
Japanese Electric Grid	Hexane	model/secondary	1.53e-07	7.74e-09
Fuel Oil #4 Prod.	Nickel	secondary	1.53e-07	7.73e-09
LPG Production	Chlorobenzene	secondary	1.40e-07	7.08e-09

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
US electric grid	Dimethyl sulfate	model/secondary	1.37e-07	6.94e-09
Fuel Oil #6 Prod.	Cyanide (-1)	secondary	1.35e-07	6.82e-09
Natural Gas Prod.	Hydrogen sulfide	secondary	1.35e-07	6.80e-09
Natural Gas Prod.	Naphthalene	secondary	1.32e-07	6.66e-09
LPG Production	Copper (+1 & +2)	secondary	1.31e-07	6.62e-09
US electric grid	Mercury	model/secondary	1.20e-07	6.06e-09
Japanese Electric Grid	Mercury	model/secondary	1.18e-07	5.97e-09
LPG Production	2,4-Dinitrotoluene	secondary	1.12e-07	5.68e-09
Fuel Oil #2 Prod.	Copper	secondary	1.12e-07	5.65e-09
Fuel Oil #2 Prod.	Silicon	secondary	1.12e-07	5.64e-09
Japanese Electric Grid	Dimethyl sulfate	model/secondary	1.10e-07	5.54e-09
Fuel Oil #2 Prod.	Methyl hydrazine	secondary	1.08e-07	5.45e-09
LPG Production	Acetophenone	secondary	1.03e-07	5.21e-09
Fuel Oil #2 Prod.	2-Chloroacetophenone	secondary	1.01e-07	5.11e-09
Fuel Oil #2 Prod.	Bromomethane	secondary	9.99e-08	5.05e-09
Fuel Oil #6 Prod.	Barium	secondary	9.97e-08	5.04e-09
Fuel Oil #2 Prod.	Dimethylbenzanthracene	secondary	9.48e-08	4.79e-09
Fuel Oil #2 Prod.	Naphthalene	secondary	7.83e-08	3.95e-09
Fuel Oil #2 Prod.	Lead	secondary	7.76e-08	3.92e-09
Fuel Oil #6 Prod.	Cadmium	secondary	7.24e-08	3.66e-09
Fuel Oil #2 Prod.	Manganese	secondary	7.00e-08	3.53e-09
LPG Production	o-xylene	secondary	6.86e-08	3.47e-09
US electric grid	Toluene	model/secondary	6.78e-08	3.43e-09
Fuel Oil #2 Prod.	Beryllium	secondary	6.72e-08	3.39e-09
US electric grid	Isophorone	model/secondary	6.64e-08	3.36e-09
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	6.46e-08	3.26e-09
Natural Gas Prod.	Methyl hydrazine	secondary	5.97e-08	3.01e-09
Fuel Oil #4 Prod.	Antimony	secondary	5.94e-08	3.00e-09
Natural Gas Prod.	Barium	secondary	5.90e-08	2.98e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	5.59e-08	2.82e-09
LPG Production	Ethylbenzene	secondary	5.56e-08	2.81e-09
Natural Gas Prod.	Bromomethane	secondary	5.52e-08	2.79e-09
Fuel Oil #6 Prod.	Carbon disulfide	secondary	5.52e-08	2.79e-09
Fuel Oil #2 Prod.	Barium	secondary	5.49e-08	2.77e-09
Fuel Oil #6 Prod.	Barium cmpds	secondary	5.37e-08	2.71e-09
US electric grid	Methyl ethyl ketone	model/secondary	5.32e-08	2.69e-09
Japanese Electric Grid	Isophorone	model/secondary	5.30e-08	2.68e-09
Glass/frit	Barium	primary	5.29e-08	2.67e-09
Natural Gas Prod.	Copper	secondary	5.28e-08	2.67e-09
US electric grid	Tetrachloroethylene	model/secondary	5.25e-08	2.65e-09
Fuel Oil #2 Prod.	Cyanide (-1)	secondary	5.25e-08	2.65e-09
US electric grid	1,2-Dichloroethane	model/secondary	4.67e-08	2.36e-09
US electric grid	Methyl methacrylate	model/secondary	4.54e-08	2.30e-09
Fuel Oil #2 Prod.	Barium cmpds	secondary	4.45e-08	2.25e-09
Natural Gas Prod.	Lead	secondary	4.33e-08	2.19e-09
Natural Gas Prod.	Beryllium	secondary	4.27e-08	2.16e-09
Fuel Oil #6 Prod.	Cobalt	secondary	4.25e-08	2.14e-09
Japanese Electric Grid	Methyl ethyl ketone	model/secondary	4.24e-08	2.14e-09
Fuel Oil #6 Prod.	Benzyl chloride	secondary	4.23e-08	2.14e-09
Japanese Electric Grid	Tetrachloroethylene	model/secondary	4.19e-08	2.12e-09

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
US electric grid	Styrene	model/secondary	4.01e-08	2.03e-09
Fuel Oil #6 Prod.	Aluminum (elemental)	secondary	4.01e-08	2.03e-09
Natural Gas Prod.	Manganese	secondary	3.95e-08	2.00e-09
US electric grid	Bromoform	model/secondary	3.75e-08	1.89e-09
Japanese Electric Grid	1,2-Dichloroethane	model/secondary	3.73e-08	1.88e-09
US electric grid	Dichloromethane	model/secondary	3.70e-08	1.87e-09
Japanese Electric Grid	Methyl methacrylate	model/secondary	3.63e-08	1.83e-09
Japanese Electric Grid	Styrene	model/secondary	3.20e-08	1.62e-09
Natural Gas Prod.	Nitrate	secondary	3.01e-08	1.52e-09
US electric grid	Chlorobenzene	model/secondary	3.00e-08	1.51e-09
Japanese Electric Grid	Bromoform	model/secondary	2.99e-08	1.51e-09
Fuel Oil #6 Prod.	Chloroform	secondary	2.98e-08	1.51e-09
Japanese Electric Grid	Dichloromethane	model/secondary	2.95e-08	1.49e-09
Fuel Oil #4 Prod.	Nitrate	secondary	2.93e-08	1.48e-09
Natural Gas Prod.	Cyanide (-1)	secondary	2.90e-08	1.47e-09
Fuel Oil #2 Prod.	Cadmium	secondary	2.88e-08	1.45e-09
LPG Production	Methyl tert-butyl ether	secondary	2.79e-08	1.41e-09
Fuel Oil #6 Prod.	Propionaldehyde	secondary	2.76e-08	1.39e-09
US electric grid	2,4-Dinitrotoluene	model/secondary	2.40e-08	1.21e-09
Japanese Electric Grid	Chlorobenzene	model/secondary	2.39e-08	1.21e-09
LPG Production	Zinc (+2)	secondary	2.35e-08	1.19e-09
LPG Production	Phenanthrene	secondary	2.27e-08	1.15e-09
US electric grid	Acetophenone	model/secondary	2.21e-08	1.12e-09
Fuel Oil #2 Prod.	Carbon disulfide	secondary	2.15e-08	1.09e-09
LPG Production	Vinyl acetate	secondary	1.98e-08	1.00e-09
Japanese Electric Grid	Cumene hydroperoxide	model/secondary	1.95e-08	9.84e-10
LPG Production	3-Methylcholanthrene	secondary	1.92e-08	9.70e-10
Japanese Electric Grid	2,4-Dinitrotoluene	model/secondary	1.91e-08	9.67e-10
LPG Production	Ethylene dibromide	secondary	1.84e-08	9.30e-10
Japanese Electric Grid	Acetophenone	model/secondary	1.76e-08	8.91e-10
Fuel Oil #2 Prod.	Benzyl chloride	secondary	1.64e-08	8.31e-10
Natural Gas Prod.	Cadmium	secondary	1.60e-08	8.06e-10
Fuel Oil #2 Prod.	Cobalt	secondary	1.59e-08	8.03e-10
Fuel Oil #6 Prod.	Acrolein	secondary	1.57e-08	7.91e-10
Natural Gas Prod.	Phenol	secondary	1.46e-08	7.37e-10
Glass/frit	Copper	primary	1.42e-08	7.18e-10
Fuel Oil #4 Prod.	Silicon	secondary	1.31e-08	6.61e-10
Fuel Oil #6 Prod.	Methyl chloride	secondary	1.30e-08	6.56e-10
Fuel Oil #2 Prod.	Aluminum (elemental)	secondary	1.28e-08	6.45e-10
Fuel Oil #4 Prod.	Copper	secondary	1.25e-08	6.30e-10
LPG Production	2-Methylnaphthalene	secondary	1.20e-08	6.07e-10
Natural Gas Prod.	Carbon disulfide	secondary	1.19e-08	6.00e-10
US electric grid	Ethylbenzene	model/secondary	1.18e-08	5.97e-10
Fuel Oil #2 Prod.	Chloroform	secondary	1.16e-08	5.86e-10
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	1.15e-08	5.81e-10
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	1.08e-08	5.45e-10
Fuel Oil #2 Prod.	Propionaldehyde	secondary	1.07e-08	5.41e-10
Fuel Oil #4 Prod.	Bromomethane	secondary	1.07e-08	5.38e-10
LPG Production	Chlorine	secondary	1.06e-08	5.38e-10
Japanese Electric Grid	Ethylbenzene	model/secondary	1.04e-08	5.25e-10
Natural Gas Prod.	PM-10	secondary	9.88e-09	4.99e-10

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #6 Prod.	Di(2-ethylhexyl)phthalate	secondary	9.36e-09	4.73e-10
Natural Gas Prod.	Benzyl chloride	secondary	9.09e-09	4.59e-10
Fuel Oil #4 Prod.	Dimethylbenzanthracene	secondary	8.97e-09	4.53e-10
Natural Gas Prod.	Toluene	secondary	8.63e-09	4.36e-10
Fuel Oil #4 Prod.	Lead	secondary	8.28e-09	4.18e-10
LPG Production	1,1,1-Trichloroethane	secondary	7.57e-09	3.82e-10
Fuel Oil #4 Prod.	Naphthalene	secondary	7.55e-09	3.81e-10
Fuel Oil #6 Prod.	Acetaldehyde	secondary	7.45e-09	3.76e-10
Fuel Oil #4 Prod.	Manganese	secondary	7.44e-09	3.76e-10
Fuel Oil #4 Prod.	Beryllium	secondary	7.13e-09	3.60e-10
LPG Production	Acenaphthene	secondary	7.03e-09	3.55e-10
Fuel Oil #6 Prod.	Mercury	secondary	6.94e-09	3.51e-10
Natural Gas Prod.	Chloroform	secondary	6.41e-09	3.24e-10
Fuel Oil #2 Prod.	Acrolein	secondary	6.09e-09	3.08e-10
US electric grid	Methyl tert-butyl ether	model/secondary	5.96e-09	3.01e-10
Natural Gas Prod.	Propionaldehyde	secondary	5.93e-09	2.99e-10
Japanese Electric Grid	Acenaphthene	model/secondary	5.79e-09	2.92e-10
Natural Gas Prod.	Aluminum (+3)	secondary	5.72e-09	2.89e-10
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	5.60e-09	2.83e-10
LPG Production	Ethyl Chloride	secondary	5.36e-09	2.71e-10
Natural Gas Prod.	Cobalt	secondary	5.28e-09	2.67e-10
Japanese Electric Grid	Phenanthrene	model/secondary	5.21e-09	2.63e-10
Fuel Oil #6 Prod.	Dimethyl sulfate	secondary	5.18e-09	2.62e-10
Fuel Oil #4 Prod.	Barium	secondary	5.08e-09	2.57e-10
Fuel Oil #2 Prod.	Methyl chloride	secondary	5.05e-09	2.55e-10
Japanese Electric Grid	Methyl tert-butyl ether	model/secondary	4.75e-09	2.40e-10
Natural Gas Prod.	o-xylene	secondary	4.60e-09	2.32e-10
US electric grid	Phenol	model/secondary	4.54e-09	2.30e-10
LPG Production	Cumene	secondary	4.54e-09	2.29e-10
Japanese Electric Grid	Chromium (III)	model/secondary	4.48e-09	2.26e-10
LPG Production	Benzo[a]pyrene	secondary	4.28e-09	2.16e-10
US electric grid	Vinyl acetate	model/secondary	4.25e-09	2.15e-10
Fuel Oil #6 Prod.	Toluene	secondary	4.19e-09	2.12e-10
US electric grid	Phenanthrene	model/secondary	4.00e-09	2.02e-10
US electric grid	Ethylene dibromide	model/secondary	3.94e-09	1.99e-10
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	3.66e-09	1.85e-10
Fuel Oil #2 Prod.	Di(2-ethylhexyl)phthalate	secondary	3.64e-09	1.84e-10
Japanese Electric Grid	Phenol	model/secondary	3.63e-09	1.83e-10
Fuel Oil #4 Prod.	Barium cmpds	secondary	3.62e-09	1.83e-10
US electric grid	Xylene (mixed isomers)	model/secondary	3.52e-09	1.78e-10
Japanese Electric Grid	Vinyl acetate	model/secondary	3.38e-09	1.71e-10
Natural Gas Prod.	Acrolein	secondary	3.37e-09	1.70e-10
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	3.26e-09	1.65e-10
US electric grid	Chromium (III)	model/secondary	3.15e-09	1.59e-10
Japanese Electric Grid	Ethylene dibromide	model/secondary	3.14e-09	1.59e-10
Fuel Oil #4 Prod.	Cadmium	secondary	3.04e-09	1.53e-10
Fuel Oil #2 Prod.	Acetaldehyde	secondary	2.90e-09	1.46e-10
Japanese Electric Grid	Xylene (mixed isomers)	model/secondary	2.81e-09	1.42e-10
Natural Gas Prod.	Methyl chloride	secondary	2.79e-09	1.41e-10
Fuel Oil #2 Prod.	Mercury	secondary	2.72e-09	1.37e-10

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Biphenyl	secondary	2.71e-09	1.37e-10
Fuel Oil #6 Prod.	Isophorone	secondary	2.50e-09	1.27e-10
Fuel Oil #6 Prod.	Cadmium cmpds	secondary	2.35e-09	1.19e-10
LPG Production	Lead cmpds	secondary	2.33e-09	1.18e-10
Fuel Oil #4 Prod.	Carbon disulfide	secondary	2.29e-09	1.16e-10
LPG Production	Dibenzo[a,h]anthracene	secondary	2.23e-09	1.12e-10
LPG Production	Acenaphthylene	secondary	2.14e-09	1.08e-10
LPG Production	Anthracene	secondary	2.11e-09	1.07e-10
Fuel Oil #6 Prod.	1,4-Dichlorobenzene	secondary	2.07e-09	1.05e-10
Fuel Oil #2 Prod.	Dimethyl sulfate	secondary	2.02e-09	1.02e-10
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	2.01e-09	1.02e-10
Fuel Oil #6 Prod.	Methyl ethyl ketone	secondary	2.00e-09	1.01e-10
Fuel Oil #6 Prod.	Tetrachloroethylene	secondary	1.98e-09	1.00e-10
LPG Production	Nickel cmpds	secondary	1.97e-09	9.96e-11
Fuel Oil #2 Prod.	Cadmium cmpds	secondary	1.95e-09	9.85e-11
LPG Production	Benzo[a]anthracene	secondary	1.91e-09	9.63e-11
Fuel Oil #2 Prod.	Toluene	secondary	1.90e-09	9.58e-11
Natural Gas Prod.	Mercury	secondary	1.88e-09	9.51e-11
US electric grid	2,3,7,8-TCDF	model/secondary	1.86e-09	9.41e-11
Japanese Electric Grid	Dibenzo[a,h]anthracene	model/secondary	1.86e-09	9.37e-11
Glass/frit	Nickel	primary	1.80e-09	9.11e-11
Fuel Oil #6 Prod.	1,2-Dichloroethane	secondary	1.76e-09	8.90e-11
Fuel Oil #4 Prod.	Benzyl chloride	secondary	1.75e-09	8.86e-11
US electric grid	1,1,1-Trichloroethane	model/secondary	1.73e-09	8.74e-11
Fuel Oil #4 Prod.	Cobalt	secondary	1.72e-09	8.71e-11
Fuel Oil #6 Prod.	Methyl methacrylate	secondary	1.71e-09	8.66e-11
Natural Gas Prod.	Acetaldehyde	secondary	1.60e-09	8.09e-11
Fuel Oil #6 Prod.	Styrene	secondary	1.51e-09	7.65e-11
Fuel Oil #4 Prod.	Aluminum (elemental)	secondary	1.50e-09	7.56e-11
Japanese Electric Grid	2,3,7,8-TCDF	model/secondary	1.49e-09	7.53e-11
LPG Production	Benzo[b,j,k]fluoranthene	secondary	1.47e-09	7.44e-11
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	1.42e-09	7.16e-11
Fuel Oil #6 Prod.	Bromoform	secondary	1.41e-09	7.14e-11
Fuel Oil #6 Prod.	Dichloromethane	secondary	1.40e-09	7.05e-11
Japanese Electric Grid	o-xylene	model/secondary	1.28e-09	6.48e-11
Fuel Oil #4 Prod.	Chloroform	secondary	1.24e-09	6.25e-11
Japanese Electric Grid	Benzo[a]anthracene	model/secondary	1.22e-09	6.17e-11
US electric grid	Acenaphthene	model/secondary	1.21e-09	6.14e-11
LPG Production	Chrysene	secondary	1.20e-09	6.08e-11
US electric grid	Ethyl Chloride	model/secondary	1.15e-09	5.80e-11
Fuel Oil #4 Prod.	Propionaldehyde	secondary	1.14e-09	5.77e-11
Fuel Oil #6 Prod.	Chlorobenzene	secondary	1.13e-09	5.71e-11
Natural Gas Prod.	Dimethyl sulfate	secondary	1.11e-09	5.63e-11
Fuel Oil #2 Prod.	1,4-Dichlorobenzene	secondary	1.08e-09	5.44e-11
Natural Gas Prod.	Zinc (+2)	secondary	1.05e-09	5.30e-11
LPG Production	HALON-1301	secondary	1.02e-09	5.13e-11
Fuel Oil #2 Prod.	Isophorone	secondary	9.74e-10	4.92e-11
US electric grid	Cumene	model/secondary	9.71e-10	4.90e-11
Fuel Oil #6 Prod.	Aromatic hydrocarbons	secondary	9.47e-10	4.79e-11
Natural Gas Prod.	Chlorine	secondary	9.46e-10	4.78e-11

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Glass/frit	Chromium	primary	9.33e-10	4.72e-11
Japanese Electric Grid	Ethyl Chloride	model/secondary	9.16e-10	4.63e-11
Fuel Oil #6 Prod.	2,4-Dinitrotoluene	secondary	9.07e-10	4.58e-11
Fuel Oil #6 Prod.	Acetophenone	secondary	8.33e-10	4.21e-11
Fuel Oil #2 Prod.	Aromatic hydrocarbons	secondary	7.86e-10	3.97e-11
Fuel Oil #2 Prod.	Methyl ethyl ketone	secondary	7.79e-10	3.94e-11
Japanese Electric Grid	Benzo[b,j,k]fluoranthene	model/secondary	7.77e-10	3.93e-11
Fuel Oil #2 Prod.	Tetrachloroethylene	secondary	7.70e-10	3.89e-11
LPG Production	Benzo[b]fluoranthene	secondary	7.62e-10	3.85e-11
Natural Gas Prod.	Silicon	secondary	7.43e-10	3.75e-11
LPG Production	Mercury compounds	secondary	7.08e-10	3.58e-11
Fuel Oil #6 Prod.	Chromium (III)	secondary	6.96e-10	3.52e-11
Fuel Oil #2 Prod.	1,2-Dichloroethane	secondary	6.85e-10	3.46e-11
Japanese Electric Grid	Indeno(1,2,3-cd)pyrene	model/secondary	6.84e-10	3.45e-11
Fuel Oil #2 Prod.	Methyl methacrylate	secondary	6.66e-10	3.37e-11
LPG Production	Fluorene	secondary	6.60e-10	3.34e-11
Fuel Oil #4 Prod.	Acrolein	secondary	6.49e-10	3.28e-11
Glass/frit	Lead	primary	6.40e-10	3.23e-11
Fuel Oil #2 Prod.	Styrene	secondary	5.89e-10	2.97e-11
US electric grid	Biphenyl	model/secondary	5.79e-10	2.93e-11
LPG Production	Pyrene	secondary	5.71e-10	2.88e-11
LPG Production	Benzo[g,h,i]perylene	secondary	5.55e-10	2.80e-11
Fuel Oil #2 Prod.	Bromoform	secondary	5.50e-10	2.78e-11
Fuel Oil #2 Prod.	Dichloromethane	secondary	5.42e-10	2.74e-11
LPG Production	Fluoranthene	secondary	5.39e-10	2.72e-11
Fuel Oil #4 Prod.	Methyl chloride	secondary	5.39e-10	2.72e-11
Natural Gas Prod.	Isophorone	secondary	5.38e-10	2.72e-11
Japanese Electric Grid	Chrysene	model/secondary	5.38e-10	2.72e-11
Japanese Electric Grid	2-Methylnaphthalene	model/secondary	4.75e-10	2.40e-11
Glass/frit	Manganese	primary	4.67e-10	2.36e-11
Japanese Electric Grid	Biphenyl	model/secondary	4.62e-10	2.34e-11
Japanese Electric Grid	Anthracene	model/secondary	4.61e-10	2.33e-11
Fuel Oil #6 Prod.	Ethylbenzene	secondary	4.47e-10	2.26e-11
Fuel Oil #6 Prod.	Copper (+1 & +2)	secondary	4.43e-10	2.24e-11
Fuel Oil #2 Prod.	Chlorobenzene	secondary	4.40e-10	2.22e-11
Natural Gas Prod.	Methyl ethyl ketone	secondary	4.31e-10	2.18e-11
Japanese Electric Grid	Benzo[g,h,i]perylene	model/secondary	4.30e-10	2.17e-11
Fuel Oil #6 Prod.	o-xylene	secondary	4.29e-10	2.17e-11
Natural Gas Prod.	Tetrachloroethylene	secondary	4.26e-10	2.15e-11
Fuel Oil #4 Prod.	Di(2-ethylhexyl)phthalate	secondary	3.88e-10	1.96e-11
Natural Gas Prod.	1,2-Dichloroethane	secondary	3.79e-10	1.91e-11
Natural Gas Prod.	Methyl methacrylate	secondary	3.68e-10	1.86e-11
Fuel Oil #2 Prod.	Copper (+1 & +2)	secondary	3.68e-10	1.86e-11
US electric grid	Acenaphthylene	model/secondary	3.60e-10	1.82e-11
Fuel Oil #2 Prod.	2,4-Dinitrotoluene	secondary	3.52e-10	1.78e-11
US electric grid	Benzo[a]pyrene	model/secondary	3.41e-10	1.72e-11
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	3.40e-10	1.72e-11
Japanese Electric Grid	Acenaphthylene	model/secondary	3.29e-10	1.66e-11
Natural Gas Prod.	Styrene	secondary	3.25e-10	1.64e-11
Fuel Oil #2 Prod.	Acetophenone	secondary	3.24e-10	1.64e-11

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Barium cmpds	secondary	3.21e-10	1.62e-11
US electric grid	Anthracene	model/secondary	3.15e-10	1.59e-11
Fuel Oil #4 Prod.	Acetaldehyde	secondary	3.09e-10	1.56e-11
Natural Gas Prod.	Bromoform	secondary	3.04e-10	1.54e-11
Natural Gas Prod.	Dichloromethane	secondary	3.00e-10	1.52e-11
LPG Production	5-Methyl chrysene	secondary	2.94e-10	1.49e-11
Fuel Oil #4 Prod.	Mercury	secondary	2.89e-10	1.46e-11
Glass/frit	Cobalt	primary	2.87e-10	1.45e-11
Japanese Electric Grid	Benzo[a]pyrene	model/secondary	2.73e-10	1.38e-11
Fuel Oil #2 Prod.	Chromium (III)	secondary	2.70e-10	1.36e-11
Natural Gas Prod.	Chlorobenzene	secondary	2.43e-10	1.23e-11
LPG Production	Halogenated matter (organic)	secondary	2.33e-10	1.18e-11
US electric grid	Benzo[a]anthracene	model/secondary	2.26e-10	1.14e-11
Fuel Oil #6 Prod.	Methyl tert-butyl ether	secondary	2.25e-10	1.14e-11
Fuel Oil #4 Prod.	Dimethyl sulfate	secondary	2.15e-10	1.09e-11
Fuel Oil #2 Prod.	o-xylene	secondary	2.06e-10	1.04e-11
Japanese Electric Grid	Pyrene	model/secondary	2.00e-10	1.01e-11
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	1.95e-10	9.85e-12
Fuel Oil #4 Prod.	Toluene	secondary	1.90e-10	9.57e-12
Natural Gas Prod.	Acetophenone	secondary	1.79e-10	9.04e-12
Fuel Oil #2 Prod.	Ethylbenzene	secondary	1.74e-10	8.80e-12
Japanese Electric Grid	Fluorene	model/secondary	1.74e-10	8.80e-12
Natural Gas Prod.	3-Methylcholanthrene	secondary	1.73e-10	8.73e-12
Fuel Oil #6 Prod.	Phenanthrene	secondary	1.71e-10	8.65e-12
Japanese Electric Grid	Fluoranthene	model/secondary	1.66e-10	8.40e-12
US electric grid	Chrysene	model/secondary	1.64e-10	8.28e-12
Natural Gas Prod.	Chromium (III)	secondary	1.61e-10	8.14e-12
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	1.61e-10	8.12e-12
Fuel Oil #6 Prod.	Vinyl acetate	secondary	1.60e-10	8.09e-12
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	1.58e-10	8.00e-12
Fuel Oil #6 Prod.	Ethylene dibromide	secondary	1.48e-10	7.50e-12
US electric grid	Fluorene	model/secondary	1.28e-10	6.45e-12
Fuel Oil #6 Prod.	3-Methylcholanthrene	secondary	1.10e-10	5.54e-12
Natural Gas Prod.	2-Methylnaphthalene	secondary	1.08e-10	5.47e-12
Fuel Oil #6 Prod.	Zinc (+2)	secondary	1.07e-10	5.38e-12
Fuel Oil #4 Prod.	Isophorone	secondary	1.04e-10	5.25e-12
US electric grid	Fluoranthene	model/secondary	1.02e-10	5.15e-12
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	1.02e-10	5.15e-12
Natural Gas Prod.	Ethylbenzene	secondary	9.66e-11	4.88e-12
US electric grid	Dibenzo[a,h]anthracene	model/secondary	8.75e-11	4.42e-12
Fuel Oil #2 Prod.	Methyl tert-butyl ether	secondary	8.74e-11	4.42e-12
US electric grid	2-Methylnaphthalene	model/secondary	8.51e-11	4.30e-12
Natural Gas Prod.	Aluminum (elemental)	secondary	8.50e-11	4.29e-12
US electric grid	Pyrene	model/secondary	8.43e-11	4.26e-12
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	8.31e-11	4.20e-12
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	8.21e-11	4.15e-12
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	7.30e-11	3.69e-12
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	7.10e-11	3.59e-12
Natural Gas Prod.	Phenanthrene	secondary	7.05e-11	3.56e-12
Fuel Oil #2 Prod.	Phenanthrene	secondary	7.03e-11	3.55e-12
Fuel Oil #6 Prod.	2-Methylnaphthalene	secondary	6.87e-11	3.47e-12

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #2 Prod.	Zinc (+2)	secondary	6.78e-11	3.42e-12
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	6.39e-11	3.23e-12
US electric grid	5-Methyl chrysene	model/secondary	6.30e-11	3.18e-12
Fuel Oil #4 Prod.	Styrene	secondary	6.28e-11	3.17e-12
Fuel Oil #2 Prod.	Vinyl acetate	secondary	6.23e-11	3.15e-12
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	6.11e-11	3.08e-12
US electric grid	o-xylene	model/secondary	6.06e-11	3.06e-12
Fuel Oil #6 Prod.	Chlorine	secondary	5.92e-11	2.99e-12
Fuel Oil #4 Prod.	Bromoform	secondary	5.86e-11	2.96e-12
Fuel Oil #4 Prod.	Dichloromethane	secondary	5.78e-11	2.92e-12
Fuel Oil #2 Prod.	Ethylene dibromide	secondary	5.77e-11	2.92e-12
US electric grid	Benzo[g,h,i]perylene	model/secondary	5.75e-11	2.91e-12
Fuel Oil #2 Prod.	3-Methylcholanthrene	secondary	5.70e-11	2.88e-12
Japanese Electric Grid	5-Methyl chrysene	model/secondary	5.03e-11	2.54e-12
Natural Gas Prod.	Methyl tert-butyl ether	secondary	4.83e-11	2.44e-12
Fuel Oil #4 Prod.	Chlorobenzene	secondary	4.69e-11	2.37e-12
Fuel Oil #6 Prod.	Acenaphthene	secondary	4.67e-11	2.36e-12
Fuel Oil #6 Prod.	Ethyl Chloride	secondary	4.33e-11	2.19e-12
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	3.76e-11	1.90e-12
Fuel Oil #6 Prod.	Cumene	secondary	3.66e-11	1.85e-12
Fuel Oil #2 Prod.	2-Methylnaphthalene	secondary	3.57e-11	1.80e-12
Fuel Oil #4 Prod.	Acetophenone	secondary	3.45e-11	1.74e-12
Natural Gas Prod.	Vinyl acetate	secondary	3.44e-11	1.74e-12
Fuel Oil #6 Prod.	Benzo[a]pyrene	secondary	3.20e-11	1.62e-12
Natural Gas Prod.	Ethylene dibromide	secondary	3.19e-11	1.61e-12
Fuel Oil #2 Prod.	Chlorine	secondary	3.12e-11	1.58e-12
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	2.99e-11	1.51e-12
Fuel Oil #4 Prod.	Chromium (III)	secondary	2.88e-11	1.45e-12
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	2.37e-11	1.20e-12
Fuel Oil #6 Prod.	Biphenyl	secondary	2.18e-11	1.10e-12
Fuel Oil #2 Prod.	Acenaphthene	secondary	2.13e-11	1.08e-12
Fuel Oil #4 Prod.	o-xylene	secondary	2.01e-11	1.02e-12
Natural Gas Prod.	Benzo[a]pyrene	secondary	1.97e-11	9.97e-13
Fuel Oil #4 Prod.	Ethylbenzene	secondary	1.86e-11	9.37e-13
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	1.78e-11	8.98e-13
Natural Gas Prod.	Acenaphthene	secondary	1.77e-11	8.96e-13
Fuel Oil #2 Prod.	Ethyl Chloride	secondary	1.68e-11	8.50e-13
Fuel Oil #6 Prod.	Acenaphthylene	secondary	1.61e-11	8.15e-13
Fuel Oil #6 Prod.	Anthracene	secondary	1.52e-11	7.69e-13
Fuel Oil #2 Prod.	Cumene	secondary	1.42e-11	7.19e-13
Natural Gas Prod.	Cadmium cmpds	secondary	1.40e-11	7.09e-13
Fuel Oil #2 Prod.	Benzo[a]pyrene	secondary	1.33e-11	6.70e-13
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	1.31e-11	6.63e-13
Fuel Oil #6 Prod.	Dibenzo[a,h]anthracene	secondary	1.19e-11	6.03e-13
Fuel Oil #6 Prod.	Benzo[a]anthracene	secondary	1.19e-11	6.02e-13
Fuel Oil #6 Prod.	Benzo[b,j,k]fluoranthene	secondary	1.19e-11	6.00e-13
Fuel Oil #6 Prod.	Indeno(1,2,3-cd)pyrene	secondary	9.33e-12	4.71e-13
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	9.32e-12	4.71e-13
Natural Gas Prod.	Ethyl Chloride	secondary	9.30e-12	4.70e-13
Natural Gas Prod.	Benzo[a]anthracene	secondary	8.56e-12	4.32e-13

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #2 Prod.	Biphenyl	secondary	8.49e-12	4.29e-13
Fuel Oil #6 Prod.	Chrysene	secondary	8.28e-12	4.19e-13
Natural Gas Prod.	Anthracene	secondary	8.13e-12	4.11e-13
Fuel Oil #6 Prod.	Lead cmpds	secondary	7.89e-12	3.99e-13
Natural Gas Prod.	Cumene	secondary	7.87e-12	3.98e-13
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	7.53e-12	3.80e-13
Fuel Oil #4 Prod.	Phenanthrene	secondary	7.32e-12	3.70e-13
Natural Gas Prod.	Acenaphthylene	secondary	7.00e-12	3.54e-13
Fuel Oil #6 Prod.	Nickel cmpds	secondary	6.67e-12	3.37e-13
Fuel Oil #4 Prod.	Vinyl acetate	secondary	6.64e-12	3.35e-13
Fuel Oil #2 Prod.	Acenaphthylene	secondary	6.63e-12	3.35e-13
Fuel Oil #2 Prod.	Dibenzo[a,h]anthracene	secondary	6.56e-12	3.31e-13
Fuel Oil #2 Prod.	Lead cmpds	secondary	6.55e-12	3.31e-13
Fuel Oil #2 Prod.	Anthracene	secondary	6.49e-12	3.28e-13
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	6.37e-12	3.22e-13
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	6.16e-12	3.11e-13
Fuel Oil #4 Prod.	Zinc (+2)	secondary	5.97e-12	3.02e-13
Fuel Oil #2 Prod.	Benzo[a]anthracene	secondary	5.73e-12	2.90e-13
Natural Gas Prod.	Aromatic hydrocarbons	secondary	5.66e-12	2.86e-13
Fuel Oil #2 Prod.	Nickel cmpds	secondary	5.53e-12	2.80e-13
Natural Gas Prod.	Chrysene	secondary	5.43e-12	2.74e-13
Fuel Oil #4 Prod.	3-Methylcholanthrene	secondary	5.39e-12	2.73e-13
Fuel Oil #6 Prod.	Fluorene	secondary	5.11e-12	2.58e-13
Natural Gas Prod.	Biphenyl	secondary	4.70e-12	2.37e-13
Fuel Oil #2 Prod.	Benzo[b,j,k]fluoranthene	secondary	4.62e-12	2.33e-13
Fuel Oil #2 Prod.	Indeno(1,2,3-cd)pyrene	secondary	4.30e-12	2.17e-13
Fuel Oil #6 Prod.	Benzo[b]fluoranthene	secondary	4.19e-12	2.11e-13
Fuel Oil #6 Prod.	Fluoranthene	secondary	4.11e-12	2.08e-13
Fuel Oil #6 Prod.	Pyrene	secondary	4.04e-12	2.04e-13
Fuel Oil #2 Prod.	Chrysene	secondary	3.68e-12	1.86e-13
Fuel Oil #6 Prod.	HALON-1301	secondary	3.43e-12	1.74e-13
Fuel Oil #6 Prod.	Benzo[g,h,i]perylene	secondary	3.43e-12	1.73e-13
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	3.38e-12	1.71e-13
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	3.19e-12	1.61e-13
Fuel Oil #4 Prod.	Chlorine	secondary	2.94e-12	1.48e-13
Fuel Oil #2 Prod.	HALON-1301	secondary	2.85e-12	1.44e-13
Natural Gas Prod.	Copper (+1 & +2)	secondary	2.65e-12	1.34e-13
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	2.55e-12	1.29e-13
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	2.53e-12	1.28e-13
Natural Gas Prod.	Pyrene	secondary	2.45e-12	1.24e-13
Fuel Oil #6 Prod.	Mercury compounds	secondary	2.39e-12	1.21e-13
Fuel Oil #6 Prod.	5-Methyl chrysene	secondary	2.38e-12	1.20e-13
Fuel Oil #2 Prod.	Benzo[b]fluoranthene	secondary	2.25e-12	1.14e-13
Fuel Oil #4 Prod.	Acenaphthene	secondary	2.12e-12	1.07e-13
Fuel Oil #2 Prod.	Fluorene	secondary	2.06e-12	1.04e-13
Fuel Oil #2 Prod.	Mercury compounds	secondary	1.99e-12	1.00e-13
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	1.79e-12	9.06e-14
Fuel Oil #2 Prod.	Pyrene	secondary	1.75e-12	8.85e-14
Fuel Oil #2 Prod.	Fluoranthene	secondary	1.67e-12	8.46e-14
Fuel Oil #2 Prod.	Benzo[g,h,i]perylene	secondary	1.67e-12	8.42e-14

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Fluorene	secondary	1.64e-12	8.28e-14
Fuel Oil #4 Prod.	Cumene	secondary	1.52e-12	7.67e-14
Natural Gas Prod.	Fluoranthene	secondary	1.46e-12	7.40e-14
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	1.37e-12	6.95e-14
Fuel Oil #2 Prod.	5-Methyl chrysene	secondary	9.24e-13	4.67e-14
Fuel Oil #4 Prod.	Biphenyl	secondary	9.06e-13	4.58e-14
Fuel Oil #6 Prod.	Halogenated matter (organic)	secondary	7.89e-13	3.99e-14
Fuel Oil #4 Prod.	Acenaphthylene	secondary	6.90e-13	3.49e-14
Fuel Oil #4 Prod.	Anthracene	secondary	6.65e-13	3.36e-14
Fuel Oil #2 Prod.	Halogenated matter (organic)	secondary	6.55e-13	3.31e-14
Fuel Oil #4 Prod.	Dibenzo[a,h]anthracene	secondary	6.08e-13	3.07e-14
LPG Production	Halogenated hydrocarbons (unspecified)	secondary	5.84e-13	2.95e-14
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	5.59e-13	2.82e-14
Fuel Oil #4 Prod.	Lead cmpds	secondary	5.32e-13	2.69e-14
Natural Gas Prod.	5-Methyl chrysene	secondary	5.11e-13	2.58e-14
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	4.92e-13	2.49e-14
Fuel Oil #4 Prod.	Nickel cmpds	secondary	4.50e-13	2.27e-14
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	4.26e-13	2.15e-14
Fuel Oil #4 Prod.	Chrysene	secondary	3.70e-13	1.87e-14
Fuel Oil #4 Prod.	HALON-1301	secondary	2.32e-13	1.17e-14
Fuel Oil #4 Prod.	Fluorene	secondary	2.16e-13	1.09e-14
Fuel Oil #4 Prod.	Benzo[b]fluoranthene	secondary	2.10e-13	1.06e-14
Fuel Oil #4 Prod.	Pyrene	secondary	1.78e-13	9.00e-15
Fuel Oil #4 Prod.	Fluoranthene	secondary	1.75e-13	8.83e-15
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	1.62e-13	8.18e-15
Fuel Oil #4 Prod.	Mercury compounds	secondary	1.61e-13	8.16e-15
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	9.85e-14	4.98e-15
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	5.32e-14	2.69e-15
Natural Gas Prod.	Lead cmpds	secondary	4.72e-14	2.38e-15
Natural Gas Prod.	Nickel cmpds	secondary	3.99e-14	2.01e-15
Natural Gas Prod.	HALON-1301	secondary	2.05e-14	1.04e-15
Natural Gas Prod.	Mercury compounds	secondary	1.43e-14	7.23e-16
Natural Gas Prod.	Halogenated matter (organic)	secondary	4.72e-15	2.38e-16
Fuel Oil #6 Prod.	Halogenated hydrocarbons (unspecified)	secondary	1.97e-15	9.98e-17
Fuel Oil #2 Prod.	Halogenated hydrocarbons (unspecified)	secondary	1.64e-15	8.27e-17
Fuel Oil #4 Prod.	Halogenated hydrocarbons (unspecified)	secondary	1.33e-16	6.72e-18
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	1.18e-17	5.95e-19
Total Manufacturing			**9.77e+01**	**4.94e+00**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Sulfur dioxide	model/secondary	1.65e+03	8.32e+01
US electric grid	Nitrogen oxides	model/secondary	2.35e+00	1.19e-01
US electric grid	Methane	model/secondary	1.29e+00	6.52e-02
US electric grid	Carbon monoxide	model/secondary	1.09e+00	5.51e-02
US electric grid	Arsenic	model/secondary	5.58e-01	2.82e-02
US electric grid	Hydrochloric acid	model/secondary	4.93e-01	2.49e-02
US electric grid	PM-10	model/secondary	1.16e-01	5.84e-03
US electric grid	Selenium	model/secondary	9.28e-02	4.69e-03
US electric grid	Vanadium	model/secondary	6.98e-02	3.53e-03
US electric grid	Hydrofluoric acid	model/secondary	2.69e-02	1.36e-03
US electric grid	Formaldehyde	model/secondary	9.70e-03	4.90e-04

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
US electric grid	Benzene	model/secondary	6.98e-03	3.53e-04
US electric grid	Nitrous oxide	model/secondary	6.80e-03	3.43e-04
US electric grid	Phosphorus (yellow or white)	model/secondary	3.93e-03	1.99e-04
US electric grid	Zinc (elemental)	model/secondary	1.81e-03	9.16e-05
US electric grid	Antimony	model/secondary	1.49e-03	7.52e-05
US electric grid	Chromium (VI)	model/secondary	5.37e-04	2.71e-05
US electric grid	Molybdenum	model/secondary	4.97e-04	2.51e-05
US electric grid	Methyl hydrazine	model/secondary	4.61e-04	2.33e-05
US electric grid	2-Chloroacetophenone	model/secondary	4.32e-04	2.18e-05
US electric grid	Bromomethane	model/secondary	4.27e-04	2.16e-05
US electric grid	Nickel	model/secondary	2.32e-04	1.17e-05
US electric grid	Cyanide (-1)	model/secondary	2.24e-04	1.13e-05
US electric grid	2,3,7,8-TCDD	model/secondary	1.70e-04	8.58e-06
US electric grid	Naphthalene	model/secondary	1.37e-04	6.92e-06
US electric grid	Barium	model/secondary	1.16e-04	5.88e-06
US electric grid	Carbon disulfide	model/secondary	9.18e-05	4.64e-06
US electric grid	Benzyl chloride	model/secondary	7.02e-05	3.55e-06
US electric grid	Cadmium	model/secondary	5.48e-05	2.77e-06
US electric grid	Chloroform	model/secondary	4.95e-05	2.50e-06
US electric grid	Propionaldehyde	model/secondary	4.58e-05	2.31e-06
US electric grid	Manganese	model/secondary	4.56e-05	2.30e-06
US electric grid	Fluoride	model/secondary	3.91e-05	1.97e-06
US electric grid	Beryllium	model/secondary	2.92e-05	1.47e-06
US electric grid	Acrolein	model/secondary	2.60e-05	1.31e-06
US electric grid	Lead	model/secondary	2.55e-05	1.29e-06
US electric grid	Cobalt	model/secondary	2.43e-05	1.23e-06
US electric grid	Copper	model/secondary	2.24e-05	1.13e-06
US electric grid	Methyl chloride	model/secondary	2.16e-05	1.09e-06
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	1.55e-05	7.85e-07
US electric grid	Acetaldehyde	model/secondary	1.24e-05	6.25e-07
US electric grid	Hexane	model/secondary	1.20e-05	6.07e-07
US electric grid	Dimethyl sulfate	model/secondary	8.61e-06	4.35e-07
US electric grid	Mercury	model/secondary	7.51e-06	3.80e-07
US electric grid	Toluene	model/secondary	4.25e-06	2.15e-07
US electric grid	Isophorone	model/secondary	4.16e-06	2.10e-07
US electric grid	Methyl ethyl ketone	model/secondary	3.33e-06	1.68e-07
US electric grid	Tetrachloroethylene	model/secondary	3.29e-06	1.66e-07
US electric grid	1,2-Dichloroethane	model/secondary	2.93e-06	1.48e-07
US electric grid	Methyl methacrylate	model/secondary	2.85e-06	1.44e-07
US electric grid	Styrene	model/secondary	2.51e-06	1.27e-07
US electric grid	Bromoform	model/secondary	2.35e-06	1.19e-07
US electric grid	Dichloromethane	model/secondary	2.32e-06	1.17e-07
US electric grid	Chlorobenzene	model/secondary	1.88e-06	9.49e-08
US electric grid	2,4-Dinitrotoluene	model/secondary	1.51e-06	7.61e-08
US electric grid	Acetophenone	model/secondary	1.38e-06	6.99e-08
US electric grid	Ethylbenzene	model/secondary	7.41e-07	3.74e-08
US electric grid	Methyl tert-butyl ether	model/secondary	3.74e-07	1.89e-08
US electric grid	Phenol	model/secondary	2.85e-07	1.44e-08
US electric grid	Vinyl acetate	model/secondary	2.66e-07	1.34e-08
US electric grid	Phenanthrene	model/secondary	2.51e-07	1.27e-08

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
US electric grid	Ethylene dibromide	model/secondary	2.47e-07	1.25e-08
US electric grid	Xylene (mixed isomers)	model/secondary	2.21e-07	1.11e-08
US electric grid	Chromium (III)	model/secondary	1.97e-07	9.96e-09
US electric grid	2,3,7,8-TCDF	model/secondary	1.17e-07	5.89e-09
US electric grid	1,1,1-Trichloroethane	model/secondary	1.08e-07	5.48e-09
US electric grid	Acenaphthene	model/secondary	7.61e-08	3.84e-09
US electric grid	Ethyl Chloride	model/secondary	7.19e-08	3.63e-09
US electric grid	Cumene	model/secondary	6.08e-08	3.07e-09
US electric grid	Biphenyl	model/secondary	3.63e-08	1.83e-09
US electric grid	Acenaphthylene	model/secondary	2.26e-08	1.14e-09
US electric grid	Benzo[a]pyrene	model/secondary	2.14e-08	1.08e-09
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	2.13e-08	1.08e-09
US electric grid	Anthracene	model/secondary	1.97e-08	9.96e-10
US electric grid	Benzo[a]anthracene	model/secondary	1.42e-08	7.15e-10
US electric grid	Chrysene	model/secondary	1.03e-08	5.19e-10
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	1.01e-08	5.08e-10
US electric grid	Fluorene	model/secondary	7.99e-09	4.04e-10
US electric grid	Fluoranthene	model/secondary	6.39e-09	3.23e-10
US electric grid	Dibenzo[a,h]anthracene	model/secondary	5.48e-09	2.77e-10
US electric grid	2-Methylnaphthalene	model/secondary	5.33e-09	2.69e-10
US electric grid	Pyrene	model/secondary	5.28e-09	2.67e-10
US electric grid	5-Methyl chrysene	model/secondary	3.95e-09	1.99e-10
US electric grid	o-xylene	model/secondary	3.79e-09	1.92e-10
US electric grid	Benzo[g,h,i]perylene	model/secondary	3.60e-09	1.82e-10
Total Use, Maintenance and Repair			**1.65e+03**	**8.35e+01**
End-of-life Life-cycle Stage				
CRT Incineration	Sulfur dioxide	secondary	1.98e-01	1.00e-02
CRT landfilling	Sulfur dioxide	primary	1.85e-01	9.34e-03
US electric grid	Sulfur dioxide	model/secondary	1.65e-01	8.32e-03
CRT landfilling	Carbon monoxide	primary	9.95e-03	5.03e-04
CRT landfilling	Nitrogen dioxide	primary	3.71e-03	1.87e-04
CRT landfilling	PM	primary	4.17e-04	2.11e-05
US electric grid	Nitrogen oxides	model/secondary	2.36e-04	1.19e-05
US electric grid	Methane	model/secondary	1.29e-04	6.52e-06
US electric grid	Carbon monoxide	model/secondary	1.09e-04	5.52e-06
CRT landfilling	Methane	primary	1.09e-04	5.50e-06
CRT landfilling	Arsenic cmpds	primary	1.02e-04	5.17e-06
CRT Incineration	Arsenic cmpds	secondary	9.83e-05	4.97e-06
US electric grid	Arsenic	model/secondary	5.58e-05	2.82e-06
LPG Production	Carbon monoxide	secondary	4.98e-05	2.52e-06
US electric grid	Hydrochloric acid	model/secondary	4.93e-05	2.49e-06
CRT landfilling	Benzene	primary	4.05e-05	2.04e-06
CRT Incineration	Lead	secondary	2.86e-05	1.44e-06
LPG Production	Methane	secondary	1.45e-05	7.32e-07
LPG Production	Sulfur oxides	secondary	1.38e-05	6.99e-07
CRT Incineration	Barium cmpds	secondary	1.27e-05	6.43e-07
US electric grid	PM-10	model/secondary	1.16e-05	5.84e-07
CRT Incineration	Silver compounds	secondary	1.12e-05	5.67e-07
CRT landfilling	Silver compounds	primary	1.05e-05	5.29e-07
CRT landfilling	Barium cmpds	primary	1.01e-05	5.12e-07

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Nitrogen oxides	secondary	9.89e-06	5.00e-07
US electric grid	Selenium	model/secondary	9.28e-06	4.69e-07
LPG Production	Vanadium	secondary	9.04e-06	4.57e-07
LPG Production	Benzene	secondary	7.41e-06	3.74e-07
US electric grid	Vanadium	model/secondary	6.99e-06	3.53e-07
CRT landfilling	Hydrochloric acid	primary	4.69e-06	2.37e-07
CRT landfilling	Ammonia	primary	3.81e-06	1.92e-07
US electric grid	Hydrofluoric acid	model/secondary	2.69e-06	1.36e-07
LPG Production	PM	secondary	2.23e-06	1.12e-07
LPG Production	Arsenic	secondary	1.78e-06	9.01e-08
LPG Production	Formaldehyde	secondary	1.16e-06	5.85e-08
CRT landfilling	Cadmium cmpds	primary	9.72e-07	4.91e-08
US electric grid	Formaldehyde	model/secondary	9.70e-07	4.90e-08
CRT Incineration	Cadmium cmpds	secondary	9.41e-07	4.76e-08
US electric grid	Benzene	model/secondary	6.98e-07	3.53e-08
US electric grid	Nitrous oxide	model/secondary	6.80e-07	3.44e-08
CRT landfilling	Hydrogen sulfide	primary	4.61e-07	2.33e-08
CRT landfilling	Chromium (VI)	primary	4.44e-07	2.24e-08
US electric grid	Phosphorus (yellow or white)	model/secondary	3.93e-07	1.99e-08
LPG Production	Hydrochloric acid	secondary	3.18e-07	1.60e-08
LPG Production	Nitrous oxide	secondary	2.80e-07	1.41e-08
US electric grid	Zinc (elemental)	model/secondary	1.81e-07	9.16e-09
US electric grid	Antimony	model/secondary	1.49e-07	7.52e-09
LPG Production	Phosphorus (yellow or white)	secondary	8.47e-08	4.28e-09
LPG Production	Fluorides (F-)	secondary	6.51e-08	3.29e-09
LPG Production	Selenium	secondary	6.40e-08	3.23e-09
US electric grid	Chromium (VI)	model/secondary	5.37e-08	2.72e-09
LPG Production	Hydrogen sulfide	secondary	5.29e-08	2.67e-09
LPG Production	Ammonia	secondary	5.11e-08	2.58e-09
US electric grid	Molybdenum	model/secondary	4.97e-08	2.51e-09
US electric grid	Methyl hydrazine	model/secondary	4.61e-08	2.33e-09
US electric grid	2-Chloroacetophenone	model/secondary	4.32e-08	2.18e-09
US electric grid	Bromomethane	model/secondary	4.27e-08	2.16e-09
CRT landfilling	Selenium	primary	3.21e-08	1.62e-09
US electric grid	Nickel	model/secondary	2.32e-08	1.17e-09
US electric grid	Cyanide (-1)	model/secondary	2.24e-08	1.13e-09
CRT Incineration	Carbon tetrachloride	secondary	1.81e-08	9.16e-10
LPG Production	Hydrofluoric acid	secondary	1.73e-08	8.75e-10
US electric grid	2,3,7,8-TCDD	model/secondary	1.70e-08	8.59e-10
CRT landfilling	Carbon tetrachloride	primary	1.69e-08	8.54e-10
LPG Production	Molybdenum	secondary	1.42e-08	7.19e-10
US electric grid	Naphthalene	model/secondary	1.37e-08	6.92e-10
LPG Production	Chromium (VI)	secondary	1.36e-08	6.88e-10
LPG Production	Ethane	secondary	1.34e-08	6.77e-10
CRT landfilling	Chloroform	primary	1.32e-08	6.67e-10
US electric grid	Barium	model/secondary	1.17e-08	5.89e-10
CRT landfilling	Mercury compounds	primary	1.15e-08	5.84e-10
CRT Incineration	Mercury compounds	secondary	1.13e-08	5.72e-10
LPG Production	Zinc (elemental)	secondary	1.04e-08	5.23e-10
US electric grid	Carbon disulfide	model/secondary	9.18e-09	4.64e-10

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
CRT landfilling	Toluene	primary	8.22e-09	4.15e-10
LPG Production	Hexane	secondary	7.78e-09	3.93e-10
US electric grid	Benzyl chloride	model/secondary	7.03e-09	3.55e-10
LPG Production	Phenol	secondary	6.17e-09	3.12e-10
LPG Production	Pentane	secondary	5.62e-09	2.84e-10
US electric grid	Cadmium	model/secondary	5.48e-09	2.77e-10
US electric grid	Chloroform	model/secondary	4.96e-09	2.50e-10
US electric grid	Propionaldehyde	model/secondary	4.58e-09	2.31e-10
US electric grid	Manganese	model/secondary	4.56e-09	2.30e-10
US electric grid	Fluoride	model/secondary	3.91e-09	1.97e-10
LPG Production	PM-10	secondary	3.88e-09	1.96e-10
LPG Production	Nickel	secondary	3.56e-09	1.80e-10
US electric grid	Beryllium	model/secondary	2.92e-09	1.47e-10
US electric grid	Acrolein	model/secondary	2.60e-09	1.31e-10
US electric grid	Lead	model/secondary	2.55e-09	1.29e-10
LPG Production	Aluminum (+3)	secondary	2.44e-09	1.24e-10
US electric grid	Cobalt	model/secondary	2.43e-09	1.23e-10
US electric grid	Copper	model/secondary	2.24e-09	1.13e-10
US electric grid	Methyl chloride	model/secondary	2.16e-09	1.09e-10
LPG Production	Antimony	secondary	1.85e-09	9.35e-11
CRT landfilling	Xylene (mixed isomers)	primary	1.69e-09	8.56e-11
CRT Incineration	Lead cmpds	secondary	1.62e-09	8.19e-11
CRT landfilling	Lead cmpds	primary	1.58e-09	7.98e-11
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	1.55e-09	7.86e-11
US electric grid	Acetaldehyde	model/secondary	1.24e-09	6.26e-11
CRT landfilling	Tetrachloroethylene	primary	1.20e-09	6.08e-11
US electric grid	Hexane	model/secondary	1.20e-09	6.07e-11
CRT landfilling	1,2-Dichloroethane	primary	1.15e-09	5.81e-11
LPG Production	Nitrate	secondary	1.05e-09	5.28e-11
US electric grid	Dimethyl sulfate	model/secondary	8.61e-10	4.35e-11
CRT Incineration	Trichloroethylene	secondary	7.65e-10	3.86e-11
US electric grid	Mercury	model/secondary	7.52e-10	3.80e-11
CRT landfilling	Trichloroethylene	primary	7.13e-10	3.60e-11
CRT landfilling	Ethylbenzene	primary	4.44e-10	2.24e-11
US electric grid	Toluene	model/secondary	4.25e-10	2.15e-11
US electric grid	Isophorone	model/secondary	4.16e-10	2.10e-11
US electric grid	Methyl ethyl ketone	model/secondary	3.33e-10	1.68e-11
US electric grid	Tetrachloroethylene	model/secondary	3.29e-10	1.66e-11
LPG Production	Copper	secondary	3.01e-10	1.52e-11
LPG Production	Methyl hydrazine	secondary	2.97e-10	1.50e-11
US electric grid	1,2-Dichloroethane	model/secondary	2.93e-10	1.48e-11
LPG Production	Silicon	secondary	2.92e-10	1.48e-11
US electric grid	Methyl methacrylate	model/secondary	2.85e-10	1.44e-11
LPG Production	2-Chloroacetophenone	secondary	2.78e-10	1.41e-11
LPG Production	Dimethylbenzanthracene	secondary	2.75e-10	1.39e-11
LPG Production	Bromomethane	secondary	2.75e-10	1.39e-11
US electric grid	Styrene	model/secondary	2.52e-10	1.27e-11
US electric grid	Bromoform	model/secondary	2.35e-10	1.19e-11
US electric grid	Dichloromethane	model/secondary	2.32e-10	1.17e-11
LPG Production	Naphthalene	secondary	2.26e-10	1.14e-11

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Lead	secondary	2.13e-10	1.08e-11
CRT landfilling	Dichloromethane	primary	2.01e-10	1.01e-11
LPG Production	Manganese	secondary	1.93e-10	9.73e-12
US electric grid	Chlorobenzene	model/secondary	1.88e-10	9.50e-12
LPG Production	Beryllium	secondary	1.85e-10	9.36e-12
CRT Incineration	Vinyl chloride	secondary	1.61e-10	8.14e-12
LPG Production	Barium	secondary	1.61e-10	8.13e-12
US electric grid	2,4-Dinitrotoluene	model/secondary	1.51e-10	7.61e-12
CRT landfilling	Vinyl chloride	primary	1.50e-10	7.59e-12
LPG Production	Cyanide (-1)	secondary	1.44e-10	7.30e-12
US electric grid	Acetophenone	model/secondary	1.38e-10	6.99e-12
LPG Production	Barium cmpds	secondary	1.37e-10	6.92e-12
LPG Production	Cadmium	secondary	7.95e-11	4.02e-12
US electric grid	Ethylbenzene	model/secondary	7.41e-11	3.74e-12
LPG Production	Carbon disulfide	secondary	5.91e-11	2.99e-12
CRT Incineration	o-xylene	secondary	5.21e-11	2.63e-12
CRT landfilling	Chromium (III)	primary	4.83e-11	2.44e-12
LPG Production	Benzyl chloride	secondary	4.52e-11	2.29e-12
LPG Production	Cobalt	secondary	4.34e-11	2.19e-12
US electric grid	Methyl tert-butyl ether	model/secondary	3.74e-11	1.89e-12
LPG Production	Aluminum (elemental)	secondary	3.34e-11	1.69e-12
LPG Production	Chloroform	secondary	3.19e-11	1.61e-12
LPG Production	Propionaldehyde	secondary	2.95e-11	1.49e-12
US electric grid	Phenol	model/secondary	2.85e-11	1.44e-12
US electric grid	Vinyl acetate	model/secondary	2.66e-11	1.34e-12
US electric grid	Phenanthrene	model/secondary	2.51e-11	1.27e-12
US electric grid	Ethylene dibromide	model/secondary	2.47e-11	1.25e-12
US electric grid	Xylene (mixed isomers)	model/secondary	2.21e-11	1.12e-12
US electric grid	Chromium (III)	model/secondary	1.97e-11	9.96e-13
LPG Production	Acrolein	secondary	1.67e-11	8.46e-13
LPG Production	Methyl chloride	secondary	1.39e-11	7.02e-13
US electric grid	2,3,7,8-TCDF	model/secondary	1.17e-11	5.90e-13
US electric grid	1,1,1-Trichloroethane	model/secondary	1.08e-11	5.48e-13
LPG Production	Di(2-ethylhexyl)phthalate	secondary	1.00e-11	5.06e-13
LPG Production	Acetaldehyde	secondary	7.97e-12	4.03e-13
US electric grid	Acenaphthene	model/secondary	7.61e-12	3.85e-13
LPG Production	Mercury	secondary	7.50e-12	3.79e-13
US electric grid	Ethyl Chloride	model/secondary	7.19e-12	3.63e-13
US electric grid	Cumene	model/secondary	6.08e-12	3.07e-13
LPG Production	Cadmium cmpds	secondary	6.00e-12	3.03e-13
LPG Production	Dimethyl sulfate	secondary	5.54e-12	2.80e-13
LPG Production	Toluene	secondary	5.38e-12	2.72e-13
US electric grid	Biphenyl	model/secondary	3.63e-12	1.83e-13
LPG Production	1,4-Dichlorobenzene	secondary	3.13e-12	1.58e-13
LPG Production	Isophorone	secondary	2.68e-12	1.35e-13
LPG Production	Aromatic hydrocarbons	secondary	2.42e-12	1.22e-13
US electric grid	Acenaphthylene	model/secondary	2.26e-12	1.14e-13
LPG Production	Methyl ethyl ketone	secondary	2.14e-12	1.08e-13
US electric grid	Benzo[a]pyrene	model/secondary	2.14e-12	1.08e-13
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	2.13e-12	1.08e-13

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Tetrachloroethylene	secondary	2.12e-12	1.07e-13
US electric grid	Anthracene	model/secondary	1.97e-12	9.96e-14
LPG Production	1,2-Dichloroethane	secondary	1.88e-12	9.52e-14
LPG Production	Methyl methacrylate	secondary	1.83e-12	9.26e-14
LPG Production	Styrene	secondary	1.62e-12	8.18e-14
LPG Production	Bromoform	secondary	1.51e-12	7.64e-14
LPG Production	Dichloromethane	secondary	1.49e-12	7.54e-14
LPG Production	Chromium (III)	secondary	1.48e-12	7.49e-14
US electric grid	Benzo[a]anthracene	model/secondary	1.42e-12	7.16e-14
LPG Production	Chlorobenzene	secondary	1.21e-12	6.11e-14
LPG Production	Copper (+1 & +2)	secondary	1.13e-12	5.71e-14
US electric grid	Chrysene	model/secondary	1.03e-12	5.19e-14
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	1.01e-12	5.09e-14
LPG Production	2,4-Dinitrotoluene	secondary	9.70e-13	4.90e-14
LPG Production	Acetophenone	secondary	8.91e-13	4.50e-14
US electric grid	Fluorene	model/secondary	8.00e-13	4.04e-14
US electric grid	Fluoranthene	model/secondary	6.39e-13	3.23e-14
LPG Production	o-xylene	secondary	5.92e-13	2.99e-14
US electric grid	Dibenzo[a,h]anthracene	model/secondary	5.48e-13	2.77e-14
US electric grid	2-Methylnaphthalene	model/secondary	5.34e-13	2.70e-14
US electric grid	Pyrene	model/secondary	5.29e-13	2.67e-14
LPG Production	Ethylbenzene	secondary	4.80e-13	2.42e-14
US electric grid	5-Methyl chrysene	model/secondary	3.95e-13	1.99e-14
US electric grid	o-xylene	model/secondary	3.80e-13	1.92e-14
US electric grid	Benzo[g,h,i]perylene	model/secondary	3.61e-13	1.82e-14
LPG Production	Methyl tert-butyl ether	secondary	2.41e-13	1.22e-14
LPG Production	Zinc (+2)	secondary	2.03e-13	1.02e-14
LPG Production	Phenanthrene	secondary	1.96e-13	9.88e-15
LPG Production	Vinyl acetate	secondary	1.71e-13	8.66e-15
LPG Production	3-Methylcholanthrene	secondary	1.66e-13	8.37e-15
LPG Production	Ethylene dibromide	secondary	1.59e-13	8.03e-15
LPG Production	2-Methylnaphthalene	secondary	1.04e-13	5.24e-15
LPG Production	Chlorine	secondary	9.19e-14	4.64e-15
LPG Production	1,1,1-Trichloroethane	secondary	6.53e-14	3.30e-15
LPG Production	Acenaphthene	secondary	6.07e-14	3.06e-15
LPG Production	Ethyl Chloride	secondary	4.63e-14	2.34e-15
LPG Production	Cumene	secondary	3.92e-14	1.98e-15
LPG Production	Benzo[a]pyrene	secondary	3.70e-14	1.87e-15
LPG Production	Biphenyl	secondary	2.34e-14	1.18e-15
LPG Production	Lead cmpds	secondary	2.01e-14	1.02e-15
LPG Production	Dibenzo[a,h]anthracene	secondary	1.92e-14	9.71e-16
LPG Production	Acenaphthylene	secondary	1.85e-14	9.33e-16
LPG Production	Anthracene	secondary	1.82e-14	9.20e-16
LPG Production	Nickel cmpds	secondary	1.70e-14	8.60e-16
LPG Production	Benzo[a]anthracene	secondary	1.65e-14	8.31e-16
LPG Production	Benzo[b,j,k]fluoranthene	secondary	1.27e-14	6.42e-16
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	1.22e-14	6.18e-16
LPG Production	Chrysene	secondary	1.04e-14	5.25e-16
LPG Production	HALON-1301	secondary	8.76e-15	4.43e-16
LPG Production	Benzo[b]fluoranthene	secondary	6.58e-15	3.32e-16

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Mercury compounds	secondary	6.11e-15	3.09e-16
LPG Production	Fluorene	secondary	5.70e-15	2.88e-16
LPG Production	Pyrene	secondary	4.93e-15	2.49e-16
LPG Production	Benzo[g,h,i]perylene	secondary	4.79e-15	2.42e-16
LPG Production	Fluoranthene	secondary	4.65e-15	2.35e-16
LPG Production	5-Methyl chrysene	secondary	2.54e-15	1.28e-16
LPG Production	Halogenated matter (organic)	secondary	2.01e-15	1.02e-16
LPG Production	Halogenated hydrocarbons (unspecified)	secondary	5.04e-18	2.55e-19
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	-5.91e-18	-2.98e-19
CRT Incineration	Halogenated hydrocarbons (unspecified)	secondary	-8.69e-17	-4.39e-18
Fuel Oil #4 Prod.	Halogenated hydrocarbons (unspecified)	secondary	-1.43e-15	-7.22e-17
Natural Gas Prod.	Halogenated matter (organic)	secondary	-2.37e-15	-1.20e-16
Natural Gas Prod.	Mercury compounds	secondary	-7.18e-15	-3.63e-16
Natural Gas Prod.	HALON-1301	secondary	-1.03e-14	-5.20e-16
Natural Gas Prod.	Nickel cmpds	secondary	-2.00e-14	-1.01e-15
Natural Gas Prod.	Lead cmpds	secondary	-2.37e-14	-1.20e-15
CRT Incineration	Halogenated matter (organic)	secondary	-3.67e-14	-1.85e-15
CRT Incineration	HALON-1301	secondary	-1.60e-13	-8.07e-15
Natural Gas Prod.	5-Methyl chrysene	secondary	-2.56e-13	-1.29e-14
CRT Incineration	Nickel cmpds	secondary	-3.10e-13	-1.57e-14
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	-5.72e-13	-2.89e-14
Natural Gas Prod.	Fluoranthene	secondary	-7.34e-13	-3.71e-14
Natural Gas Prod.	Fluorene	secondary	-8.22e-13	-4.15e-14
CRT Incineration	Benzo[b]fluoranthene	secondary	-1.02e-12	-5.13e-14
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	-1.06e-12	-5.35e-14
Natural Gas Prod.	Pyrene	secondary	-1.23e-12	-6.20e-14
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	-1.28e-12	-6.47e-14
Natural Gas Prod.	Copper (+1 & +2)	secondary	-1.33e-12	-6.71e-14
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	-1.60e-12	-8.09e-14
Fuel Oil #4 Prod.	Mercury compounds	secondary	-1.74e-12	-8.77e-14
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	-1.74e-12	-8.79e-14
Fuel Oil #4 Prod.	Fluoranthene	secondary	-1.88e-12	-9.50e-14
Fuel Oil #4 Prod.	Pyrene	secondary	-1.91e-12	-9.67e-14
Fuel Oil #4 Prod.	Benzo[b]fluoranthene	secondary	-2.26e-12	-1.14e-13
Fuel Oil #4 Prod.	Fluorene	secondary	-2.32e-12	-1.17e-13
Natural Gas Prod.	Biphenyl	secondary	-2.35e-12	-1.19e-13
Fuel Oil #4 Prod.	HALON-1301	secondary	-2.49e-12	-1.26e-13
Natural Gas Prod.	Chrysene	secondary	-2.72e-12	-1.38e-13
CRT Incineration	Dibenzo[a,h]anthracene	secondary	-2.82e-12	-1.42e-13
Natural Gas Prod.	Aromatic hydrocarbons	secondary	-2.84e-12	-1.43e-13
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	-3.19e-12	-1.61e-13
Natural Gas Prod.	Acenaphthylene	secondary	-3.51e-12	-1.77e-13
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	-3.78e-12	-1.91e-13
Natural Gas Prod.	Cumene	secondary	-3.95e-12	-1.99e-13
Fuel Oil #4 Prod.	Chrysene	secondary	-3.98e-12	-2.01e-13
Natural Gas Prod.	Anthracene	secondary	-4.08e-12	-2.06e-13
Natural Gas Prod.	Benzo[a]anthracene	secondary	-4.29e-12	-2.17e-13
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	-4.58e-12	-2.32e-13
Natural Gas Prod.	Ethyl Chloride	secondary	-4.66e-12	-2.36e-13
Fuel Oil #4 Prod.	Nickel cmpds	secondary	-4.83e-12	-2.44e-13

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	-5.29e-12	-2.67e-13
Fuel Oil #4 Prod.	Lead cmpds	secondary	-5.72e-12	-2.89e-13
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	-6.01e-12	-3.03e-13
Fuel Oil #4 Prod.	Dibenzo[a,h]anthracene	secondary	-6.53e-12	-3.30e-13
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-6.58e-12	-3.33e-13
Natural Gas Prod.	Cadmium cmpds	secondary	-7.04e-12	-3.56e-13
Fuel Oil #4 Prod.	Anthracene	secondary	-7.15e-12	-3.61e-13
Fuel Oil #4 Prod.	Acenaphthylene	secondary	-7.42e-12	-3.75e-13
Natural Gas Prod.	Acenaphthene	secondary	-8.90e-12	-4.50e-13
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	-8.91e-12	-4.50e-13
Fuel Oil #4 Prod.	Biphenyl	secondary	-9.73e-12	-4.92e-13
Natural Gas Prod.	Benzo[a]pyrene	secondary	-9.90e-12	-5.00e-13
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	-1.48e-11	-7.47e-13
Natural Gas Prod.	Ethylene dibromide	secondary	-1.60e-11	-8.09e-13
Fuel Oil #4 Prod.	Cumene	secondary	-1.63e-11	-8.24e-13
Natural Gas Prod.	Vinyl acetate	secondary	-1.73e-11	-8.72e-13
CRT Incineration	2-Methylnaphthalene	secondary	-1.74e-11	-8.80e-13
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	-1.93e-11	-9.74e-13
CRT Incineration	Copper (+1 & +2)	secondary	-2.06e-11	-1.04e-12
Fuel Oil #4 Prod.	Acenaphthene	secondary	-2.28e-11	-1.15e-12
Natural Gas Prod.	Methyl tert-butyl ether	secondary	-2.42e-11	-1.22e-12
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-2.72e-11	-1.37e-12
CRT Incineration	3-Methylcholanthrene	secondary	-2.78e-11	-1.41e-12
Fuel Oil #4 Prod.	Chlorine	secondary	-3.16e-11	-1.59e-12
Natural Gas Prod.	Phenanthrene	secondary	-3.53e-11	-1.79e-12
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	-3.63e-11	-1.83e-12
CRT Incineration	Chlorine	secondary	-3.87e-11	-1.96e-12
CRT Incineration	Benzo[g,h,i]perylene	secondary	-4.06e-11	-2.05e-12
Natural Gas Prod.	Aluminum (elemental)	secondary	-4.26e-11	-2.15e-12
CRT Incineration	Aromatic hydrocarbons	secondary	-4.41e-11	-2.23e-12
CRT Incineration	Zinc (+2)	secondary	-4.48e-11	-2.26e-12
Natural Gas Prod.	Ethylbenzene	secondary	-4.85e-11	-2.45e-12
CRT Incineration	Dichlorobenzene (mixed isomers)	secondary	-4.90e-11	-2.48e-12
Natural Gas Prod.	2-Methylnaphthalene	secondary	-5.42e-11	-2.74e-12
Fuel Oil #4 Prod.	3-Methylcholanthrene	secondary	-5.80e-11	-2.93e-12
Fuel Oil #4 Prod.	Zinc (+2)	secondary	-6.42e-11	-3.24e-12
CRT Incineration	5-Methyl chrysene	secondary	-6.54e-11	-3.31e-12
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	-6.62e-11	-3.34e-12
Fuel Oil #4 Prod.	Vinyl acetate	secondary	-7.14e-11	-3.61e-12
CRT Incineration	Pyrene	secondary	-7.81e-11	-3.95e-12
Fuel Oil #4 Prod.	Phenanthrene	secondary	-7.87e-11	-3.97e-12
Natural Gas Prod.	Chromium (III)	secondary	-8.08e-11	-4.08e-12
Natural Gas Prod.	3-Methylcholanthrene	secondary	-8.67e-11	-4.38e-12
Natural Gas Prod.	Acetophenone	secondary	-8.98e-11	-4.53e-12
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	-9.77e-11	-4.94e-12
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	-1.00e-10	-5.06e-12
CRT Incineration	Fluoranthene	secondary	-1.01e-10	-5.08e-12
Natural Gas Prod.	Chlorobenzene	secondary	-1.22e-10	-6.16e-12
CRT Incineration	Fluorene	secondary	-1.29e-10	-6.51e-12
CRT Incineration	Indeno(1,2,3-cd)pyrene	secondary	-1.40e-10	-7.05e-12

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
CRT Incineration	Chrysene	secondary	-1.50e-10	-7.59e-12
Natural Gas Prod.	Dichloromethane	secondary	-1.50e-10	-7.60e-12
Natural Gas Prod.	Bromoform	secondary	-1.52e-10	-7.70e-12
Natural Gas Prod.	Barium cmpds	secondary	-1.61e-10	-8.13e-12
Natural Gas Prod.	Styrene	secondary	-1.63e-10	-8.24e-12
CRT Incineration	Benzo[a]anthracene	secondary	-1.83e-10	-9.23e-12
Natural Gas Prod.	Methyl methacrylate	secondary	-1.85e-10	-9.33e-12
Natural Gas Prod.	1,2-Dichloroethane	secondary	-1.90e-10	-9.60e-12
Fuel Oil #4 Prod.	Ethylbenzene	secondary	-1.99e-10	-1.01e-11
Natural Gas Prod.	Tetrachloroethylene	secondary	-2.14e-10	-1.08e-11
Natural Gas Prod.	Methyl ethyl ketone	secondary	-2.16e-10	-1.09e-11
Fuel Oil #4 Prod.	o-xylene	secondary	-2.16e-10	-1.09e-11
Natural Gas Prod.	Isophorone	secondary	-2.70e-10	-1.36e-11
Fuel Oil #4 Prod.	Chromium (III)	secondary	-3.09e-10	-1.56e-11
CRT Incineration	Anthracene	secondary	-3.17e-10	-1.60e-11
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	-3.21e-10	-1.62e-11
CRT Incineration	Benzo[b,j,k]fluoranthene	secondary	-3.27e-10	-1.65e-11
CRT Incineration	Benzo[a]pyrene	secondary	-3.57e-10	-1.80e-11
Fuel Oil #4 Prod.	Acetophenone	secondary	-3.71e-10	-1.87e-11
CRT Incineration	Acenaphthylene	secondary	-3.72e-10	-1.88e-11
Natural Gas Prod.	Silicon	secondary	-3.72e-10	-1.88e-11
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	-4.04e-10	-2.04e-11
Natural Gas Prod.	Chlorine	secondary	-4.75e-10	-2.40e-11
Fuel Oil #4 Prod.	Chlorobenzene	secondary	-5.04e-10	-2.55e-11
Natural Gas Prod.	Zinc (+2)	secondary	-5.26e-10	-2.66e-11
Natural Gas Prod.	Dimethyl sulfate	secondary	-5.59e-10	-2.82e-11
CRT Incineration	Biphenyl	secondary	-6.02e-10	-3.04e-11
Fuel Oil #4 Prod.	Dichloromethane	secondary	-6.22e-10	-3.14e-11
Fuel Oil #4 Prod.	Bromoform	secondary	-6.30e-10	-3.18e-11
Fuel Oil #4 Prod.	Styrene	secondary	-6.75e-10	-3.41e-11
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	-6.87e-10	-3.47e-11
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	-7.64e-10	-3.86e-11
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	-7.85e-10	-3.97e-11
Natural Gas Prod.	Acetaldehyde	secondary	-8.03e-10	-4.06e-11
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	-8.83e-10	-4.46e-11
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	-8.93e-10	-4.51e-11
Natural Gas Prod.	Mercury	secondary	-9.44e-10	-4.77e-11
CRT Incineration	Cumene	secondary	-1.01e-09	-5.09e-11
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	-1.01e-09	-5.10e-11
CRT Incineration	Acenaphthene	secondary	-1.02e-09	-5.14e-11
CRT Incineration	Aluminum (elemental)	secondary	-1.08e-09	-5.47e-11
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	-1.09e-09	-5.53e-11
Fuel Oil #4 Prod.	Isophorone	secondary	-1.12e-09	-5.64e-11
CRT Incineration	Ethyl Chloride	secondary	-1.19e-09	-6.02e-11
Natural Gas Prod.	Methyl chloride	secondary	-1.40e-09	-7.07e-11
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	-1.64e-09	-8.27e-11
CRT Incineration	1,1,1-Trichloroethane	secondary	-1.68e-09	-8.50e-11
Natural Gas Prod.	Acrolein	secondary	-1.69e-09	-8.53e-11
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	-1.70e-09	-8.60e-11
Fuel Oil #4 Prod.	Toluene	secondary	-2.04e-09	-1.03e-10

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
CRT Incineration	Xylene (mixed isomers)	secondary	-2.13e-09	-1.08e-10
Natural Gas Prod.	o-xylene	secondary	-2.31e-09	-1.17e-10
Fuel Oil #4 Prod.	Dimethyl sulfate	secondary	-2.31e-09	-1.17e-10
Natural Gas Prod.	Cobalt	secondary	-2.65e-09	-1.34e-10
Natural Gas Prod.	Aluminum (+3)	secondary	-2.87e-09	-1.45e-10
Natural Gas Prod.	Propionaldehyde	secondary	-2.97e-09	-1.50e-10
Fuel Oil #4 Prod.	Mercury	secondary	-3.11e-09	-1.57e-10
Natural Gas Prod.	Chloroform	secondary	-3.21e-09	-1.62e-10
Fuel Oil #4 Prod.	Acetaldehyde	secondary	-3.32e-09	-1.68e-10
CRT Incineration	Phenanthrene	secondary	-4.02e-09	-2.03e-10
CRT Incineration	Ethylene dibromide	secondary	-4.09e-09	-2.07e-10
Fuel Oil #4 Prod.	Di(2-ethylhexyl)phthalate	secondary	-4.17e-09	-2.11e-10
Natural Gas Prod.	Toluene	secondary	-4.33e-09	-2.19e-10
CRT Incineration	Vinyl acetate	secondary	-4.41e-09	-2.23e-10
Natural Gas Prod.	Benzyl chloride	secondary	-4.56e-09	-2.30e-10
Natural Gas Prod.	PM-10	secondary	-4.95e-09	-2.50e-10
Fuel Oil #4 Prod.	Methyl chloride	secondary	-5.79e-09	-2.92e-10
Natural Gas Prod.	Carbon disulfide	secondary	-5.95e-09	-3.01e-10
CRT Incineration	Methyl tert-butyl ether	secondary	-6.19e-09	-3.13e-10
Fuel Oil #4 Prod.	Acrolein	secondary	-6.98e-09	-3.53e-10
Natural Gas Prod.	Phenol	secondary	-7.32e-09	-3.70e-10
Natural Gas Prod.	Cadmium	secondary	-8.00e-09	-4.04e-10
CRT Incineration	Silicon	secondary	-9.47e-09	-4.78e-10
CRT Incineration	Ethylbenzene	secondary	-1.18e-08	-5.96e-10
Fuel Oil #4 Prod.	Propionaldehyde	secondary	-1.23e-08	-6.21e-10
Fuel Oil #4 Prod.	Chloroform	secondary	-1.33e-08	-6.72e-10
Natural Gas Prod.	Cyanide (-1)	secondary	-1.45e-08	-7.35e-10
Natural Gas Prod.	Nitrate	secondary	-1.51e-08	-7.62e-10
Fuel Oil #4 Prod.	Aluminum (elemental)	secondary	-1.61e-08	-8.13e-10
CRT Incineration	Chromium (III)	secondary	-1.69e-08	-8.55e-10
Fuel Oil #4 Prod.	Cobalt	secondary	-1.85e-08	-9.36e-10
Fuel Oil #4 Prod.	Benzyl chloride	secondary	-1.88e-08	-9.52e-10
Natural Gas Prod.	Manganese	secondary	-1.98e-08	-1.00e-09
CRT Incineration	Chloroacetophenone	secondary	-2.08e-08	-1.05e-09
Natural Gas Prod.	Beryllium	secondary	-2.14e-08	-1.08e-09
Natural Gas Prod.	Lead	secondary	-2.17e-08	-1.10e-09
CRT Incineration	Acetophenone	secondary	-2.29e-08	-1.16e-09
Fuel Oil #4 Prod.	Carbon disulfide	secondary	-2.46e-08	-1.24e-09
CRT Incineration	2,4-Dinitrotoluene	secondary	-2.50e-08	-1.26e-09
Natural Gas Prod.	Copper	secondary	-2.65e-08	-1.34e-09
Natural Gas Prod.	Bromomethane	secondary	-2.77e-08	-1.40e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	-2.80e-08	-1.42e-09
Natural Gas Prod.	Barium	secondary	-2.96e-08	-1.49e-09
Natural Gas Prod.	Methyl hydrazine	secondary	-2.99e-08	-1.51e-09
CRT Incineration	Chlorobenzene	secondary	-3.11e-08	-1.57e-09
Fuel Oil #4 Prod.	Cadmium	secondary	-3.26e-08	-1.65e-09
CRT Incineration	Dichloromethane	secondary	-3.82e-08	-1.93e-09
Fuel Oil #4 Prod.	Barium cmpds	secondary	-3.89e-08	-1.97e-09
CRT Incineration	Bromoform	secondary	-3.89e-08	-1.97e-09
CRT Incineration	Styrene	secondary	-4.17e-08	-2.11e-09

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
CRT Incineration	Aluminum (+3)	secondary	-4.46e-08	-2.25e-09
CRT Incineration	Methyl methacrylate	secondary	-4.72e-08	-2.38e-09
CRT Incineration	1,2-Dichloroethane	secondary	-4.73e-08	-2.39e-09
CRT Incineration	Dimethylbenzanthracene	secondary	-4.82e-08	-2.44e-09
CRT Incineration	Tetrachloroethylene	secondary	-5.33e-08	-2.69e-09
Fuel Oil #4 Prod.	Barium	secondary	-5.46e-08	-2.76e-09
CRT Incineration	Methyl ethyl ketone	secondary	-5.52e-08	-2.79e-09
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	-6.02e-08	-3.04e-09
Natural Gas Prod.	Naphthalene	secondary	-6.61e-08	-3.34e-09
CRT Incineration	Toluene	secondary	-6.65e-08	-3.36e-09
Natural Gas Prod.	Hydrogen sulfide	secondary	-6.75e-08	-3.41e-09
CRT Incineration	Isophorone	secondary	-6.90e-08	-3.49e-09
Fuel Oil #4 Prod.	Beryllium	secondary	-7.66e-08	-3.87e-09
Fuel Oil #4 Prod.	Manganese	secondary	-8.00e-08	-4.04e-09
Fuel Oil #4 Prod.	Naphthalene	secondary	-8.11e-08	-4.10e-09
Natural Gas Prod.	Nickel	secondary	-8.75e-08	-4.42e-09
Fuel Oil #4 Prod.	Lead	secondary	-8.90e-08	-4.50e-09
Fuel Oil #4 Prod.	Dimethylbenzanthracene	secondary	-9.64e-08	-4.87e-09
CRT Incineration	Mercury	secondary	-1.12e-07	-5.64e-09
Fuel Oil #4 Prod.	Bromomethane	secondary	-1.15e-07	-5.79e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	-1.16e-07	-5.85e-09
CRT Incineration	Phenol	secondary	-1.17e-07	-5.92e-09
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	-1.24e-07	-6.25e-09
CRT Incineration	PM-10	secondary	-1.26e-07	-6.36e-09
Fuel Oil #4 Prod.	Copper	secondary	-1.34e-07	-6.77e-09
Fuel Oil #4 Prod.	Silicon	secondary	-1.41e-07	-7.10e-09
CRT Incineration	Dimethyl sulfate	secondary	-1.43e-07	-7.21e-09
Natural Gas Prod.	Dimethylbenzanthracene	secondary	-1.44e-07	-7.28e-09
CRT Incineration	Acetaldehyde	secondary	-2.05e-07	-1.04e-08
Natural Gas Prod.	Antimony	secondary	-2.24e-07	-1.13e-08
CRT Incineration	Di(2-ethylhexyl)phthalate	secondary	-2.58e-07	-1.30e-08
Fuel Oil #4 Prod.	Nitrate	secondary	-3.15e-07	-1.59e-08
CRT Incineration	Methyl chloride	secondary	-3.58e-07	-1.81e-08
CRT Incineration	Cobalt	secondary	-3.83e-07	-1.94e-08
CRT Incineration	Copper	secondary	-4.12e-07	-2.08e-08
CRT Incineration	Acrolein	secondary	-4.31e-07	-2.18e-08
Fuel Oil #4 Prod.	Antimony	secondary	-6.39e-07	-3.23e-08
CRT Incineration	Cadmium	secondary	-6.89e-07	-3.48e-08
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	-6.94e-07	-3.51e-08
Natural Gas Prod.	Chromium (VI)	secondary	-7.42e-07	-3.75e-08
CRT Incineration	Propionaldehyde	secondary	-7.59e-07	-3.84e-08
CRT Incineration	Chloroform	secondary	-8.07e-07	-4.08e-08
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	-8.87e-07	-4.48e-08
CRT Incineration	Pentane	secondary	-9.44e-07	-4.77e-08
Natural Gas Prod.	Molybdenum	secondary	-1.16e-06	-5.86e-08
CRT Incineration	Benzyl chloride	secondary	-1.16e-06	-5.88e-08
CRT Incineration	Hydrogen sulfide	secondary	-1.22e-06	-6.17e-08
CRT Incineration	Barium	secondary	-1.31e-06	-6.64e-08
CRT Incineration	Hexane	secondary	-1.51e-06	-7.61e-08
CRT Incineration	Carbon disulfide	secondary	-1.52e-06	-7.69e-08

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Nickel	secondary	-1.64e-06	-8.31e-08
Natural Gas Prod.	Hydrofluoric acid	secondary	-1.75e-06	-8.83e-08
Fuel Oil #4 Prod.	Phenol	secondary	-1.75e-06	-8.86e-08
Fuel Oil #4 Prod.	PM-10	secondary	-1.87e-06	-9.45e-08
Fuel Oil #4 Prod.	Pentane	secondary	-1.97e-06	-9.93e-08
CRT Incineration	Naphthalene	secondary	-2.05e-06	-1.04e-07
CRT Incineration	Ethane	secondary	-2.25e-06	-1.14e-07
Fuel Oil #4 Prod.	Hexane	secondary	-2.72e-06	-1.38e-07
Fuel Oil #4 Prod.	Chromium (VI)	secondary	-2.84e-06	-1.44e-07
Natural Gas Prod.	Pentane	secondary	-2.94e-06	-1.48e-07
Fuel Oil #4 Prod.	Zinc (elemental)	secondary	-3.56e-06	-1.80e-07
CRT Incineration	Nitrate	secondary	-3.60e-06	-1.82e-07
CRT Incineration	Cyanide (-1)	secondary	-3.72e-06	-1.88e-07
Natural Gas Prod.	Hexane	secondary	-4.07e-06	-2.06e-07
Natural Gas Prod.	Zinc (elemental)	secondary	-4.26e-06	-2.15e-07
CRT Incineration	Beryllium	secondary	-4.59e-06	-2.32e-07
Fuel Oil #4 Prod.	Ethane	secondary	-4.69e-06	-2.37e-07
CRT Incineration	Manganese	secondary	-4.89e-06	-2.47e-07
Natural Gas Prod.	Selenium	secondary	-6.09e-06	-3.07e-07
Fuel Oil #4 Prod.	Molybdenum	secondary	-6.49e-06	-3.28e-07
Natural Gas Prod.	Fluorides (F-)	secondary	-6.82e-06	-3.44e-07
Natural Gas Prod.	Ethane	secondary	-7.01e-06	-3.54e-07
CRT Incineration	Bromomethane	secondary	-7.08e-06	-3.58e-07
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	-7.22e-06	-3.65e-07
CRT Incineration	Methyl hydrazine	secondary	-7.64e-06	-3.86e-07
CRT Incineration	Molybdenum	secondary	-9.96e-06	-5.03e-07
Natural Gas Prod.	Nitrous oxide	secondary	-1.16e-05	-5.85e-07
CRT Incineration	Nickel	secondary	-1.38e-05	-6.97e-07
Natural Gas Prod.	Formaldehyde	secondary	-1.39e-05	-7.02e-07
Fuel Oil #4 Prod.	Ammonia	secondary	-1.74e-05	-8.79e-07
CRT Incineration	Antimony	secondary	-2.16e-05	-1.09e-06
CRT Incineration	Zinc (elemental)	secondary	-2.54e-05	-1.28e-06
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	-2.55e-05	-1.29e-06
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	-2.66e-05	-1.34e-06
Fuel Oil #4 Prod.	Selenium	secondary	-2.69e-05	-1.36e-06
Natural Gas Prod.	Hydrochloric acid	secondary	-3.20e-05	-1.62e-06
Natural Gas Prod.	Vanadium	secondary	-3.49e-05	-1.76e-06
Fuel Oil #4 Prod.	Phosphorus (yellow or white)	secondary	-3.98e-05	-2.01e-06
CRT Incineration	Phosphorus (yellow or white)	secondary	-5.50e-05	-2.78e-06
CRT Incineration	Ammonia	secondary	-7.13e-05	-3.60e-06
Fuel Oil #4 Prod.	Nitrous oxide	secondary	-1.24e-04	-6.24e-06
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	-1.32e-04	-6.68e-06
CRT Incineration	Chromium (VI)	secondary	-1.56e-04	-7.86e-06
Natural Gas Prod.	Arsenic	secondary	-1.58e-04	-7.97e-06
Natural Gas Prod.	Ammonia	secondary	-2.13e-04	-1.08e-05
Natural Gas Prod.	Sulfur oxides	secondary	-2.76e-04	-1.40e-05
Natural Gas Prod.	PM	secondary	-4.15e-04	-2.10e-05
CRT Incineration	Hydrofluoric acid	secondary	-4.46e-04	-2.25e-05
CRT Incineration	Formaldehyde	secondary	-4.47e-04	-2.26e-05

Table M-33. CRT LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Formaldehyde	secondary	-5.52e-04	-2.79e-05
Fuel Oil #4 Prod.	Arsenic	secondary	-7.57e-04	-3.82e-05
Fuel Oil #4 Prod.	PM	secondary	-8.70e-04	-4.40e-05
CRT Incineration	Vanadium	secondary	-1.17e-03	-5.92e-05
CRT Incineration	Selenium	secondary	-1.53e-03	-7.74e-05
CRT Incineration	Fluorides (F-)	secondary	-1.57e-03	-7.93e-05
CRT Incineration	Nitrous oxide	secondary	-2.08e-03	-1.05e-04
Fuel Oil #4 Prod.	Benzene	secondary	-2.59e-03	-1.31e-04
CRT Incineration	Benzene	secondary	-3.18e-03	-1.61e-04
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	-3.86e-03	-1.95e-04
Fuel Oil #4 Prod.	Vanadium	secondary	-4.33e-03	-2.19e-04
CRT Incineration	Hydrochloric acid	secondary	-4.66e-03	-2.35e-04
Fuel Oil #4 Prod.	Sulfur oxides	secondary	-5.27e-03	-2.66e-04
Fuel Oil #4 Prod.	Methane	secondary	-5.60e-03	-2.83e-04
Natural Gas Prod.	Nitrogen oxides	secondary	-9.35e-03	-4.72e-04
CRT Incineration	Carbon monoxide	secondary	-1.56e-02	-7.88e-04
Fuel Oil #4 Prod.	Carbon monoxide	secondary	-1.63e-02	-8.23e-04
CRT Incineration	Nitrogen oxides	secondary	-2.51e-02	-1.27e-03
CRT Incineration	Methane	secondary	-3.03e-02	-1.53e-03
Natural Gas Prod.	Carbon monoxide	secondary	-3.45e-02	-1.74e-03
CRT Incineration	PM	secondary	-3.67e-02	-1.85e-03
Natural Gas Prod.	Benzene	secondary	-3.80e-02	-1.92e-03
CRT Incineration	Arsenic	secondary	-3.84e-02	-1.94e-03
Natural Gas Prod.	Methane	secondary	-5.03e-02	-2.54e-03
CRT Incineration	Sulfur oxides	secondary	-5.39e-02	-2.73e-03
Total End-of-life			**1.74e-01**	**8.78e-03**
Total All Life-cycle Stages			**1.98e+03**	**1.00e+02**

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Sulfur dioxide	secondary	1.24e+01	1.38e+00
PMMA Sheet Prod.	Sulfur dioxide	secondary	8.61e+00	9.55e-01
Natural Gas Prod.	Methane	secondary	7.01e+00	7.77e-01
Natural Gas Prod.	Benzene	secondary	5.29e+00	5.87e-01
Aluminum Prod.	Sulfur dioxide	secondary	5.13e+00	5.70e-01
Natural Gas Prod.	Carbon monoxide	secondary	4.80e+00	5.32e-01
Polycarbonate Production	Sulfur dioxide	secondary	4.43e+00	4.91e-01
Natural Gas Prod.	Nitrogen oxides	secondary	1.30e+00	1.44e-01
Aluminum Prod.	Titanium tetrachloride	secondary	2.68e-01	2.97e-02
Steel Prod., cold-rolled, semi-finished	Carbon monoxide	secondary	1.47e-01	1.63e-02
Steel Prod., cold-rolled, semi-finished	PM	secondary	1.03e-01	1.14e-02
Aluminum Prod.	Manganese cmpds	secondary	6.03e-02	6.69e-03
Natural Gas Prod.	PM	secondary	5.78e-02	6.42e-03
Aluminum Prod.	Vanadium	secondary	4.00e-02	4.44e-03
Natural Gas Prod.	Sulfur oxides	secondary	3.85e-02	4.27e-03
Natural Gas Prod.	Ammonia	secondary	2.97e-02	3.30e-03
PET Resin Production	Carbon monoxide	secondary	2.82e-02	3.12e-03
PMMA Sheet Prod.	Carbon monoxide	secondary	2.53e-02	2.81e-03
Steel Prod., cold-rolled, semi-finished	Vanadium	secondary	2.53e-02	2.80e-03
Polycarbonate Production	Carbon monoxide	secondary	2.50e-02	2.78e-03
PMMA Sheet Prod.	Methane	secondary	2.30e-02	2.55e-03
Polycarbonate Production	Methane	secondary	2.27e-02	2.52e-03
Natural Gas Prod.	Arsenic	secondary	2.20e-02	2.44e-03
Polycarbonate Production	Nitrogen dioxide	secondary	2.17e-02	2.40e-03
PMMA Sheet Prod.	Nitrogen dioxide	secondary	2.15e-02	2.38e-03
Aluminum Prod.	Arsenic cmpds	secondary	1.77e-02	1.96e-03
Steel Prod., cold-rolled, semi-finished	Nitrogen dioxide	secondary	1.37e-02	1.52e-03
Steel Prod., cold-rolled, semi-finished	Methane	secondary	1.07e-02	1.19e-03
Steel Prod., cold-rolled, semi-finished	Fluorides (F-)	secondary	9.41e-03	1.04e-03
PET Resin Production	Sulfur oxides	secondary	7.99e-03	8.86e-04
Styrene-butadiene Copolymer Prod.	Carbon monoxide	secondary	7.56e-03	8.39e-04
Steel Prod., cold-rolled, semi-finished	Manganese cmpds	secondary	7.30e-03	8.10e-04
Polycarbonate Production	PM	secondary	7.22e-03	8.01e-04
Aluminum Prod.	Carbon monoxide	secondary	6.93e-03	7.69e-04
Aluminum Prod.	PM	secondary	6.63e-03	7.35e-04
PMMA Sheet Prod.	PM	secondary	6.44e-03	7.15e-04
Styrene-butadiene Copolymer Prod.	Nitrogen oxides	secondary	6.11e-03	6.78e-04
Styrene-butadiene Copolymer Prod.	Methane	secondary	6.00e-03	6.66e-04
Aluminum Prod.	Methane	secondary	5.99e-03	6.65e-04
Aluminum Prod.	Nitrogen dioxide	secondary	5.31e-03	5.89e-04
Styrene-butadiene Copolymer Prod.	Sulfur oxides	secondary	4.99e-03	5.54e-04
Natural Gas Prod.	Vanadium	secondary	4.86e-03	5.39e-04
Natural Gas Prod.	Hydrochloric acid	secondary	4.46e-03	4.95e-04
Aluminum Prod.	Barium cmpds	secondary	3.89e-03	4.31e-04
PET Resin Production	Nitrogen oxides	secondary	3.45e-03	3.83e-04
Aluminum Prod.	Selenium	secondary	2.34e-03	2.60e-04
Steel Prod., cold-rolled, semi-finished	Arsenic	secondary	2.22e-03	2.46e-04
PET Resin Production	Methane	secondary	2.00e-03	2.21e-04

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Phosphorus (yellow or white)	secondary	1.99e-03	2.21e-04
Natural Gas Prod.	Formaldehyde	secondary	1.94e-03	2.15e-04
PMMA Sheet Prod.	Ammonia	secondary	1.64e-03	1.82e-04
Natural Gas Prod.	Nitrous oxide	secondary	1.61e-03	1.79e-04
PET Resin Production	PM	secondary	1.40e-03	1.55e-04
Aluminum Prod.	Aluminum (+3)	secondary	1.18e-03	1.31e-04
Steel Prod., cold-rolled, semi-finished	Hydrochloric acid	secondary	1.00e-03	1.11e-04
Natural Gas Prod.	Ethane	secondary	9.76e-04	1.08e-04
Natural Gas Prod.	Fluorides (F-)	secondary	9.49e-04	1.05e-04
Styrene-butadiene Copolymer Prod.	PM	secondary	8.68e-04	9.63e-05
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	8.62e-04	9.56e-05
Steel Prod., cold-rolled, semi-finished	Barium cmpds	secondary	8.49e-04	9.41e-05
Natural Gas Prod.	Selenium	secondary	8.48e-04	9.40e-05
Steel Prod., cold-rolled, semi-finished	Nitrous oxide	secondary	7.62e-04	8.45e-05
Steel Prod., cold-rolled, semi-finished	Arsenic cmpds	secondary	7.53e-04	8.35e-05
Aluminum Prod.	Hydrochloric acid	secondary	6.64e-04	7.37e-05
PMMA Sheet Prod.	Nitrates/nitrites	secondary	6.47e-04	7.18e-05
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	6.19e-04	6.87e-05
Natural Gas Prod.	Zinc (elemental)	secondary	5.94e-04	6.59e-05
Natural Gas Prod.	Hexane	secondary	5.67e-04	6.29e-05
Steel Prod., cold-rolled, semi-finished	Silicon	secondary	4.96e-04	5.50e-05
Aluminum Prod.	Cadmium cmpds	secondary	4.36e-04	4.84e-05
Natural Gas Prod.	Pentane	secondary	4.09e-04	4.54e-05
Steel Prod., cold-rolled, semi-finished	Titanium tetrachloride	secondary	4.08e-04	4.53e-05
PMMA Sheet Prod.	Hydrogen cyanide	secondary	3.73e-04	4.13e-05
PMMA Sheet Prod.	Hydrochloric acid	secondary	2.99e-04	3.31e-05
Polycarbonate Production	Hydrochloric acid	secondary	2.60e-04	2.88e-05
Natural Gas Prod.	Hydrofluoric acid	secondary	2.43e-04	2.70e-05
Steel Prod., cold-rolled, semi-finished	Ethane	secondary	2.41e-04	2.67e-05
Aluminum Prod.	Benzene	secondary	2.12e-04	2.35e-05
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	2.03e-04	2.26e-05
Aluminum Prod.	Hydrofluoric acid	secondary	1.79e-04	1.99e-05
Polycarbonate Production	Sulfuric acid	secondary	1.77e-04	1.97e-05
Aluminum Prod.	Barium sulfate	secondary	1.69e-04	1.87e-05
Steel Prod., cold-rolled, semi-finished	Titanium	secondary	1.62e-04	1.80e-05
Natural Gas Prod.	Molybdenum	secondary	1.62e-04	1.79e-05
Steel Prod., cold-rolled, semi-finished	Selenium	secondary	1.47e-04	1.63e-05
PET Resin Production	Hydrochloric acid	secondary	1.45e-04	1.61e-05
Polycarbonate Production	Mercury compounds	secondary	1.36e-04	1.51e-05
PMMA Sheet Prod.	Sulfuric acid	secondary	1.32e-04	1.46e-05
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	1.24e-04	1.37e-05
Steel Prod., cold-rolled, semi-finished	Zinc (elemental)	secondary	1.06e-04	1.18e-05
Natural Gas Prod.	Chromium (VI)	secondary	1.03e-04	1.15e-05
Aluminum Prod.	Nitrous oxide	secondary	1.03e-04	1.14e-05
Steel Prod., cold-rolled, semi-finished	Tin (Sn++, Sn4+)	secondary	1.02e-04	1.13e-05
PMMA Sheet Prod.	Mercury compounds	secondary	1.01e-04	1.12e-05
Aluminum Prod.	Perfluoromethane	secondary	9.65e-05	1.07e-05
Steel Prod., cold-rolled, semi-finished	Molybdenum	secondary	9.21e-05	1.02e-05
Polycarbonate Production	Aromatic hydrocarbons	secondary	9.18e-05	1.02e-05
Aluminum Prod.	Titanium	secondary	8.57e-05	9.51e-06
Aluminum Prod.	Zinc (elemental)	secondary	8.55e-05	9.48e-06

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Aluminum Prod.	Silicon	secondary	8.14e-05	9.03e-06
Aluminum Prod.	Copper (+1 & +2)	secondary	6.70e-05	7.44e-06
Aluminum Prod.	Strontium (Sr II)	secondary	6.32e-05	7.01e-06
PET Resin Production	Sulfuric acid	secondary	6.24e-05	6.93e-06
Styrene-butadiene Copolymer Prod.	Sulfuric acid	secondary	6.22e-05	6.90e-06
Steel Prod., cold-rolled, semi-finished	Barium	secondary	6.03e-05	6.69e-06
Styrene-butadiene Copolymer Prod.	Aromatic hydrocarbons	secondary	5.93e-05	6.58e-06
Polycarbonate Production	Fluorides (F-)	secondary	5.14e-05	5.70e-06
Styrene-butadiene Copolymer Prod.	Mercury compounds	secondary	4.77e-05	5.29e-06
Steel Prod., cold-rolled, semi-finished	Antimony	secondary	4.67e-05	5.18e-06
Steel Prod., cold-rolled, semi-finished	Boron	secondary	4.20e-05	4.66e-06
Steel Prod., cold-rolled, semi-finished	Strontium (Sr II)	secondary	3.88e-05	4.31e-06
PMMA Sheet Prod.	Fluorine	secondary	3.82e-05	4.24e-06
Aluminum Prod.	Nitrate	secondary	3.40e-05	3.77e-06
Natural Gas Prod.	Antimony	secondary	3.11e-05	3.45e-06
Steel Prod., cold-rolled, semi-finished	Silver compounds	secondary	3.03e-05	3.36e-06
Styrene-butadiene Copolymer Prod.	Hydrochloric acid	secondary	2.98e-05	3.31e-06
Steel Prod., cold-rolled, semi-finished	Nitrates/nitrites	secondary	2.77e-05	3.08e-06
Steel Prod., cold-rolled, semi-finished	Chromium (VI)	secondary	2.53e-05	2.81e-06
Steel Prod., cold-rolled, semi-finished	Acetylene	secondary	2.28e-05	2.53e-06
Steel Prod., cold-rolled, semi-finished	Mercury compounds	secondary	2.22e-05	2.46e-06
Natural Gas Prod.	Dimethylbenzanthracene	secondary	2.01e-05	2.23e-06
Steel Prod., cold-rolled, semi-finished	Hydrofluoric acid	secondary	1.86e-05	2.06e-06
PET Resin Production	Fluorine	secondary	1.81e-05	2.01e-06
Styrene-butadiene Copolymer Prod.	Fluorides (F-)	secondary	1.80e-05	2.00e-06
Steel Prod., cold-rolled, semi-finished	Barium sulfate	secondary	1.68e-05	1.87e-06
Steel Prod., cold-rolled, semi-finished	Aluminum (+3)	secondary	1.54e-05	1.71e-06
Aluminum Prod.	Barium	secondary	1.46e-05	1.62e-06
Steel Prod., cold-rolled, semi-finished	Hydrogen sulfide	secondary	1.33e-05	1.48e-06
Steel Prod., cold-rolled, semi-finished	Cadmium cmpds	secondary	1.32e-05	1.47e-06
Aluminum Prod.	Zinc (+2)	secondary	1.30e-05	1.44e-06
Natural Gas Prod.	Nickel	secondary	1.22e-05	1.35e-06
Steel Prod., cold-rolled, semi-finished	Aluminum (elemental)	secondary	1.21e-05	1.34e-06
Aluminum Prod.	Aromatic hydrocarbons	secondary	1.05e-05	1.17e-06
Aluminum Prod.	Nickel cmpds	secondary	1.01e-05	1.12e-06
Natural Gas Prod.	Hydrogen sulfide	secondary	9.40e-06	1.04e-06
Aluminum Prod.	Nickel	secondary	9.40e-06	1.04e-06
Natural Gas Prod.	Naphthalene	secondary	9.21e-06	1.02e-06
Aluminum Prod.	Ammonia	secondary	9.11e-06	1.01e-06
Aluminum Prod.	Copper	secondary	8.87e-06	9.84e-07
Steel Prod., cold-rolled, semi-finished	Pentane	secondary	8.31e-06	9.22e-07
Steel Prod., cold-rolled, semi-finished	Aromatic hydrocarbons	secondary	7.02e-06	7.79e-07
PMMA Sheet Prod.	Hydrofluoric acid	secondary	6.90e-06	7.66e-07
Aluminum Prod.	Fluoride	secondary	6.78e-06	7.52e-07
Aluminum Prod.	Lead cmpds	secondary	6.49e-06	7.20e-07
Aluminum Prod.	Vanadium (V3+, V5+)	secondary	6.06e-06	6.73e-07
Steel Prod., cold-rolled, semi-finished	Copper	secondary	5.99e-06	6.64e-07
Polycarbonate Production	Copper (+1 & +2)	secondary	5.79e-06	6.42e-07
Steel Prod., cold-rolled, semi-finished	Nickel	secondary	5.67e-06	6.29e-07

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Aluminum Prod.	Nitrites	secondary	5.46e-06	6.05e-07
Aluminum Prod.	Perfluoroethane	secondary	5.36e-06	5.95e-07
Polycarbonate Production	Phenol	secondary	5.22e-06	5.79e-07
Aluminum Prod.	Chromium (VI)	secondary	5.18e-06	5.75e-07
Steel Prod., cold-rolled, semi-finished	Hexane	secondary	4.34e-06	4.82e-07
PMMA Sheet Prod.	Copper (+1 & +2)	secondary	4.31e-06	4.78e-07
Steel Prod., cold-rolled, semi-finished	Copper (+1 & +2)	secondary	4.21e-06	4.67e-07
Natural Gas Prod.	Methyl hydrazine	secondary	4.17e-06	4.62e-07
Polycarbonate Production	Hydrofluoric acid	secondary	4.13e-06	4.58e-07
Natural Gas Prod.	Barium	secondary	4.12e-06	4.57e-07
Aluminum Prod.	Aluminum (elemental)	secondary	3.92e-06	4.35e-07
Natural Gas Prod.	2-Chloroacetophenone	secondary	3.90e-06	4.33e-07
Natural Gas Prod.	Bromomethane	secondary	3.86e-06	4.28e-07
PMMA Sheet Prod.	Cyanide (-1)	secondary	3.83e-06	4.25e-07
Natural Gas Prod.	Copper	secondary	3.69e-06	4.09e-07
Aluminum Prod.	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	3.68e-06	4.08e-07
Polycarbonate Production	Ammonia	secondary	3.27e-06	3.63e-07
PMMA Sheet Prod.	Hydrogen sulfide	secondary	3.07e-06	3.40e-07
Natural Gas Prod.	Lead	secondary	3.03e-06	3.36e-07
Natural Gas Prod.	Beryllium	secondary	2.99e-06	3.31e-07
Aluminum Prod.	Hydrogen sulfide	secondary	2.80e-06	3.11e-07
Natural Gas Prod.	Manganese	secondary	2.76e-06	3.06e-07
Aluminum Prod.	Acetic acid	secondary	2.73e-06	3.03e-07
Styrene-butadiene Copolymer Prod.	Nitrate	secondary	2.53e-06	2.81e-07
Natural Gas Prod.	Nitrate	secondary	2.10e-06	2.33e-07
Polycarbonate Production	Halogenated hydrocarbons (unspecified)	secondary	2.06e-06	2.29e-07
Polycarbonate Production	Hydrogen sulfide	secondary	2.06e-06	2.29e-07
PET Resin Production	Copper (+1 & +2)	secondary	2.04e-06	2.26e-07
Styrene-butadiene Copolymer Prod.	Copper (+1 & +2)	secondary	2.03e-06	2.25e-07
Natural Gas Prod.	Cyanide (-1)	secondary	2.03e-06	2.25e-07
Steel Prod., cold-rolled, semi-finished	Bromine	secondary	1.99e-06	2.21e-07
PET Resin Production	Hydrofluoric acid	secondary	1.82e-06	2.01e-07
PMMA Sheet Prod.	Phenol	secondary	1.75e-06	1.94e-07
Steel Prod., cold-rolled, semi-finished	Acetic acid	secondary	1.74e-06	1.93e-07
Steel Prod., cold-rolled, semi-finished	Boric acid	secondary	1.62e-06	1.80e-07
PMMA Sheet Prod.	Aromatic hydrocarbons	secondary	1.53e-06	1.70e-07
Steel Prod., cold-rolled, semi-finished	Strontium	secondary	1.47e-06	1.63e-07
Aluminum Prod.	Cadmium	secondary	1.25e-06	1.39e-07
Natural Gas Prod.	Cadmium	secondary	1.11e-06	1.24e-07
Steel Prod., cold-rolled, semi-finished	Lead	secondary	1.08e-06	1.20e-07
Steel Prod., cold-rolled, semi-finished	Triethylene glycol	secondary	1.04e-06	1.15e-07
Polycarbonate Production	Chlorine	secondary	1.03e-06	1.14e-07
Natural Gas Prod.	Phenol	secondary	1.02e-06	1.13e-07
Aluminum Prod.	Triethylene glycol	secondary	1.00e-06	1.11e-07
Steel Prod., cold-rolled, semi-finished	Cadmium	secondary	9.71e-07	1.08e-07
Aluminum Prod.	Lead	secondary	8.94e-07	9.92e-08
Steel Prod., cold-rolled, semi-finished	Lead cmpds	secondary	8.65e-07	9.60e-08
Steel Prod., cold-rolled, semi-finished	Uranium	secondary	8.39e-07	9.31e-08
Natural Gas Prod.	Carbon disulfide	secondary	8.29e-07	9.20e-08
PMMA Sheet Prod.	Chlorine	secondary	7.67e-07	8.51e-08

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	7.44e-07	8.25e-08
Styrene-butadiene Copolymer Prod.	Aluminum (+3)	secondary	7.23e-07	8.02e-08
Natural Gas Prod.	PM-10	secondary	6.90e-07	7.65e-08
Aluminum Prod.	Toluene	secondary	6.75e-07	7.48e-08
PMMA Sheet Prod.	Nickel cmpds	secondary	6.48e-07	7.19e-08
Natural Gas Prod.	Benzyl chloride	secondary	6.35e-07	7.04e-08
Natural Gas Prod.	Toluene	secondary	6.03e-07	6.69e-08
Steel Prod., cold-rolled, semi-finished	Ethylene	secondary	6.02e-07	6.67e-08
Steel Prod., cold-rolled, semi-finished	Cyanide (-1)	secondary	5.92e-07	6.56e-08
Steel Prod., cold-rolled, semi-finished	Methanol	secondary	5.84e-07	6.48e-08
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	5.50e-07	6.10e-08
Steel Prod., cold-rolled, semi-finished	Naphthalene	secondary	5.46e-07	6.05e-08
Steel Prod., cold-rolled, semi-finished	Zinc (+2)	secondary	5.20e-07	5.77e-08
Polycarbonate Production	Aluminum (+3)	secondary	5.16e-07	5.72e-08
Polycarbonate Production	Ethanethiol	secondary	5.16e-07	5.72e-08
Polycarbonate Production	Lead	secondary	5.16e-07	5.72e-08
Polycarbonate Production	Nitrate	secondary	5.16e-07	5.72e-08
Polycarbonate Production	Nitrous oxide	secondary	5.16e-07	5.72e-08
Polycarbonate Production	Zinc (+2)	secondary	5.16e-07	5.72e-08
Aluminum Prod.	Xylene (mixed isomers)	secondary	5.13e-07	5.69e-08
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	4.75e-07	5.27e-08
Steel Prod., cold-rolled, semi-finished	Heptane	secondary	4.57e-07	5.07e-08
Natural Gas Prod.	Chloroform	secondary	4.48e-07	4.97e-08
Steel Prod., cold-rolled, semi-finished	Nickel cmpds	secondary	4.15e-07	4.60e-08
Natural Gas Prod.	Propionaldehyde	secondary	4.14e-07	4.59e-08
Natural Gas Prod.	Aluminum (+3)	secondary	4.00e-07	4.44e-08
Steel Prod., cold-rolled, semi-finished	Cobalt	secondary	3.97e-07	4.40e-08
PMMA Sheet Prod.	Aluminum (+3)	secondary	3.83e-07	4.25e-08
PMMA Sheet Prod.	Ethanethiol	secondary	3.83e-07	4.25e-08
PMMA Sheet Prod.	Lead	secondary	3.83e-07	4.25e-08
PMMA Sheet Prod.	Nitrous oxide	secondary	3.83e-07	4.25e-08
PMMA Sheet Prod.	Zinc (+2)	secondary	3.83e-07	4.25e-08
Natural Gas Prod.	Cobalt	secondary	3.69e-07	4.09e-08
PET Resin Production	Chlorine	secondary	3.63e-07	4.03e-08
Styrene-butadiene Copolymer Prod.	Chlorine	secondary	3.62e-07	4.01e-08
Styrene-butadiene Copolymer Prod.	Hydrofluoric acid	secondary	3.62e-07	4.01e-08
Steel Prod., cold-rolled, semi-finished	Beryllium	secondary	3.53e-07	3.92e-08
Natural Gas Prod.	o-xylene	secondary	3.21e-07	3.56e-08
Aluminum Prod.	Cobalt	secondary	3.06e-07	3.40e-08
Steel Prod., cold-rolled, semi-finished	Vanadium (V3+, V5+)	secondary	2.91e-07	3.23e-08
Aluminum Prod.	Strontium	secondary	2.83e-07	3.14e-08
Steel Prod., cold-rolled, semi-finished	Benzo[a]pyrene	secondary	2.74e-07	3.04e-08
Polycarbonate Production	Mercury	secondary	2.58e-07	2.86e-08
PET Resin Production	Ammonia	secondary	2.47e-07	2.74e-08
Styrene-butadiene Copolymer Prod.	Ammonia	secondary	2.46e-07	2.73e-08
Aluminum Prod.	Phenol	secondary	2.38e-07	2.64e-08
Natural Gas Prod.	Acrolein	secondary	2.35e-07	2.61e-08
Steel Prod., cold-rolled, semi-finished	Boron (B III)	secondary	2.30e-07	2.55e-08
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	2.28e-07	2.53e-08

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Styrene-butadiene Copolymer Prod.	Phenol	secondary	2.15e-07	2.39e-08
PET Resin Production	Phenol	secondary	1.98e-07	2.20e-08
Natural Gas Prod.	Methyl chloride	secondary	1.95e-07	2.16e-08
PMMA Sheet Prod.	Mercury	secondary	1.92e-07	2.13e-08
PET Resin Production	Mercury	secondary	1.82e-07	2.01e-08
PET Resin Production	Aluminum (+3)	secondary	1.82e-07	2.01e-08
PET Resin Production	Hydrogen sulfide	secondary	1.82e-07	2.01e-08
PET Resin Production	Lead	secondary	1.82e-07	2.01e-08
PET Resin Production	Nitrate	secondary	1.82e-07	2.01e-08
PET Resin Production	Nitrous oxide	secondary	1.82e-07	2.01e-08
PET Resin Production	Zinc (+2)	secondary	1.82e-07	2.01e-08
Styrene-butadiene Copolymer Prod.	Halogenated hydrocarbons (unspecified)	secondary	1.81e-07	2.01e-08
Styrene-butadiene Copolymer Prod.	Hydrogen sulfide	secondary	1.81e-07	2.01e-08
Styrene-butadiene Copolymer Prod.	Lead	secondary	1.81e-07	2.01e-08
Styrene-butadiene Copolymer Prod.	Nitrous oxide	secondary	1.81e-07	2.01e-08
Styrene-butadiene Copolymer Prod.	Zinc (+2)	secondary	1.81e-07	2.01e-08
Steel Prod., cold-rolled, semi-finished	Manganese	secondary	1.76e-07	1.96e-08
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	1.40e-07	1.56e-08
Aluminum Prod.	HALON-1301	secondary	1.34e-07	1.49e-08
Natural Gas Prod.	Mercury	secondary	1.32e-07	1.46e-08
Steel Prod., cold-rolled, semi-finished	Rubidium ion (Rb+)	secondary	1.19e-07	1.32e-08
Natural Gas Prod.	Acetaldehyde	secondary	1.12e-07	1.24e-08
Aluminum Prod.	1,2-Dichlorotetrafluoroethane	secondary	9.29e-08	1.03e-08
Styrene-butadiene Copolymer Prod.	Mercury	secondary	9.04e-08	1.00e-08
Steel Prod., cold-rolled, semi-finished	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	8.89e-08	9.86e-09
Steel Prod., cold-rolled, semi-finished	Morpholine	secondary	8.78e-08	9.74e-09
Steel Prod., cold-rolled, semi-finished	Propylene	secondary	8.67e-08	9.62e-09
Steel Prod., cold-rolled, semi-finished	Acetaldehyde	secondary	7.93e-08	8.80e-09
Natural Gas Prod.	Dimethyl sulfate	secondary	7.78e-08	8.63e-09
Aluminum Prod.	Mercury	secondary	7.51e-08	8.33e-09
Natural Gas Prod.	Zinc (+2)	secondary	7.32e-08	8.12e-09
Aluminum Prod.	Cyanide (-1)	secondary	7.05e-08	7.82e-09
Natural Gas Prod.	Chlorine	secondary	6.61e-08	7.33e-09
Steel Prod., cold-rolled, semi-finished	Fluorine	secondary	5.60e-08	6.21e-09
Steel Prod., cold-rolled, semi-finished	Lanthanum	secondary	5.27e-08	5.84e-09
Natural Gas Prod.	Silicon	secondary	5.19e-08	5.75e-09
Aluminum Prod.	Chromium (III)	secondary	4.88e-08	5.42e-09
Steel Prod., cold-rolled, semi-finished	Acetone	secondary	3.87e-08	4.30e-09
Natural Gas Prod.	Isophorone	secondary	3.76e-08	4.17e-09
Natural Gas Prod.	Methyl ethyl ketone	secondary	3.01e-08	3.34e-09
Natural Gas Prod.	Tetrachloroethylene	secondary	2.97e-08	3.30e-09
Steel Prod., cold-rolled, semi-finished	Thorium	secondary	2.83e-08	3.13e-09
Natural Gas Prod.	1,2-Dichloroethane	secondary	2.65e-08	2.93e-09
Natural Gas Prod.	Methyl methacrylate	secondary	2.57e-08	2.85e-09
Steel Prod., cold-rolled, semi-finished	Ethylbenzene	secondary	2.57e-08	2.85e-09
Steel Prod., cold-rolled, semi-finished	HALON-1301	secondary	2.47e-08	2.74e-09
Natural Gas Prod.	Styrene	secondary	2.27e-08	2.52e-09
Natural Gas Prod.	Barium cmpds	secondary	2.24e-08	2.49e-09
Natural Gas Prod.	Bromoform	secondary	2.12e-08	2.35e-09
Natural Gas Prod.	Dichloromethane	secondary	2.10e-08	2.32e-09

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Chlorobenzene	secondary	1.70e-08	1.88e-09
Steel Prod., cold-rolled, semi-finished	Tin	secondary	1.64e-08	1.82e-09
Steel Prod., cold-rolled, semi-finished	Mercury	secondary	1.60e-08	1.77e-09
Steel Prod., cold-rolled, semi-finished	Phosphorus pentoxide	secondary	1.58e-08	1.75e-09
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	1.36e-08	1.51e-09
Steel Prod., cold-rolled, semi-finished	Hydrazine	secondary	1.30e-08	1.44e-09
Steel Prod., cold-rolled, semi-finished	Scandium	secondary	1.28e-08	1.42e-09
Natural Gas Prod.	Acetophenone	secondary	1.25e-08	1.39e-09
Natural Gas Prod.	3-Methylcholanthrene	secondary	1.21e-08	1.34e-09
Natural Gas Prod.	Chromium (III)	secondary	1.13e-08	1.25e-09
Steel Prod., cold-rolled, semi-finished	Chlorine	secondary	1.12e-08	1.24e-09
Steel Prod., cold-rolled, semi-finished	Thallium	secondary	8.72e-09	9.67e-10
Natural Gas Prod.	2-Methylnaphthalene	secondary	7.56e-09	8.38e-10
Natural Gas Prod.	Ethylbenzene	secondary	6.75e-09	7.49e-10
Steel Prod., cold-rolled, semi-finished	Zirconium	secondary	6.73e-09	7.47e-10
Natural Gas Prod.	Aluminum (elemental)	secondary	5.93e-09	6.58e-10
Natural Gas Prod.	Phenanthrene	secondary	4.92e-09	5.46e-10
Natural Gas Prod.	Methyl tert-butyl ether	secondary	3.38e-09	3.75e-10
Steel Prod., cold-rolled, semi-finished	Nitrites	secondary	2.76e-09	3.06e-10
Steel Prod., cold-rolled, semi-finished	Chromium (III)	secondary	2.59e-09	2.88e-10
Natural Gas Prod.	Vinyl acetate	secondary	2.40e-09	2.67e-10
Natural Gas Prod.	Ethylene dibromide	secondary	2.23e-09	2.47e-10
Steel Prod., cold-rolled, semi-finished	Edetic acid (EDTA)	secondary	1.89e-09	2.10e-10
Steel Prod., cold-rolled, semi-finished	Hypochlorous acid	secondary	1.72e-09	1.91e-10
Steel Prod., cold-rolled, semi-finished	Cobalt (Co I, Co II, Co III)	secondary	1.54e-09	1.71e-10
Natural Gas Prod.	Benzo[a]pyrene	secondary	1.38e-09	1.53e-10
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	1.24e-09	1.38e-10
Natural Gas Prod.	Acenaphthene	secondary	1.24e-09	1.37e-10
Natural Gas Prod.	Cadmium cmpds	secondary	9.81e-10	1.09e-10
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	9.17e-10	1.02e-10
Steel Prod., cold-rolled, semi-finished	Dichloromethane	secondary	7.33e-10	8.13e-11
Natural Gas Prod.	Ethyl Chloride	secondary	6.50e-10	7.21e-11
Natural Gas Prod.	Benzo[a]anthracene	secondary	5.98e-10	6.63e-11
Natural Gas Prod.	Anthracene	secondary	5.68e-10	6.30e-11
Natural Gas Prod.	Cumene	secondary	5.50e-10	6.10e-11
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	5.26e-10	5.83e-11
Natural Gas Prod.	Acenaphthylene	secondary	4.89e-10	5.42e-11
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	4.45e-10	4.93e-11
Natural Gas Prod.	Aromatic hydrocarbons	secondary	3.95e-10	4.39e-11
Natural Gas Prod.	Chrysene	secondary	3.79e-10	4.21e-11
Natural Gas Prod.	Biphenyl	secondary	3.28e-10	3.64e-11
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	2.23e-10	2.47e-11
Steel Prod., cold-rolled, semi-finished	Isopropylpropionate	secondary	1.98e-10	2.20e-11
Natural Gas Prod.	Copper (+1 & +2)	secondary	1.85e-10	2.05e-11
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	1.78e-10	1.98e-11
Natural Gas Prod.	Pyrene	secondary	1.71e-10	1.90e-11
Natural Gas Prod.	Fluorene	secondary	1.14e-10	1.27e-11
Natural Gas Prod.	Fluoranthene	secondary	1.02e-10	1.13e-11
Steel Prod., cold-rolled, semi-finished	Lithium salts	secondary	9.71e-11	1.08e-11

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Perfluoromethane	secondary	4.40e-11	4.88e-12
Natural Gas Prod.	5-Methyl chrysene	secondary	3.57e-11	3.96e-12
Steel Prod., cold-rolled, semi-finished	Chloroform	secondary	2.69e-11	2.98e-12
Natural Gas Prod.	Lead cmpds	secondary	3.30e-12	3.66e-13
Natural Gas Prod.	Nickel cmpds	secondary	2.78e-12	3.09e-13
Natural Gas Prod.	HALON-1301	secondary	1.43e-12	1.59e-13
Natural Gas Prod.	Mercury compounds	secondary	1.00e-12	1.11e-13
Steel Prod., cold-rolled, semi-finished	Trichloroethylene	secondary	3.88e-13	4.30e-14
Natural Gas Prod.	Halogenated matter (organic)	secondary	3.29e-13	3.65e-14
Steel Prod., cold-rolled, semi-finished	Propionaldehyde	secondary	1.02e-13	1.13e-14
Steel Prod., cold-rolled, semi-finished	Benzaldehyde	secondary	3.01e-14	3.34e-15
Steel Prod., cold-rolled, semi-finished	Tetrachloroethylene	secondary	1.08e-14	1.20e-15
Steel Prod., cold-rolled, semi-finished	1,1,1-Trichloroethane	secondary	1.57e-15	1.75e-16
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	8.23e-16	9.13e-17
Steel Prod., cold-rolled, semi-finished	Hexachloroethane	secondary	6.03e-17	6.69e-18
Total Materials Processing			**5.01e+01**	**5.56e+00**
Manufacturing Life-cycle Stage				
Japanese Electric Grid	Sulfur dioxide	model/secondary	1.92e+02	2.12e+01
Monitor/module	Phosphine	primary	2.87e+01	3.18e+00
Monitor/module	Phosphorus (yellow or white)	primary	3.42e+00	3.79e-01
US electric grid	Sulfur dioxide	model/secondary	3.19e+00	3.54e-01
Monitor/module	Fluorides (F-)	primary	2.55e+00	2.83e-01
Monitor/module	Tetramethyl ammonium hydroxide	primary	1.29e+00	1.43e-01
Monitor/module	Nitrogen oxides	primary	1.10e+00	1.22e-01
Monitor/module	Nitrogen fluoride	primary	4.91e-01	5.44e-02
Monitor/module	Hydrochloric acid	primary	2.77e-01	3.08e-02
LPG Production	Carbon monoxide	secondary	2.77e-01	3.07e-02
Japanese Electric Grid	Nitrogen oxides	model/secondary	2.73e-01	3.03e-02
Monitor/module	Ammonia	primary	1.69e-01	1.88e-02
Natural Gas Prod.	Methane	secondary	1.58e-01	1.75e-02
Japanese Electric Grid	Carbon monoxide	model/secondary	1.27e-01	1.41e-02
Natural Gas Prod.	Benzene	secondary	1.19e-01	1.32e-02
Natural Gas Prod.	Carbon monoxide	secondary	1.08e-01	1.20e-02
Monitor/module	Hydrofluoric acid	primary	1.04e-01	1.16e-02
LPG Production	Methane	secondary	8.05e-02	8.93e-03
LPG Production	Sulfur oxides	secondary	7.69e-02	8.53e-03
Japanese Electric Grid	Vanadium	model/secondary	7.63e-02	8.46e-03
Backlight	Nitrogen oxides	primary	5.89e-02	6.53e-03
LPG Production	Nitrogen oxides	secondary	5.50e-02	6.10e-03
LPG Production	Vanadium	secondary	5.02e-02	5.57e-03
LPG Production	Benzene	secondary	4.12e-02	4.57e-03
Japanese Electric Grid	Arsenic	model/secondary	3.51e-02	3.89e-03
Natural Gas Prod.	Nitrogen oxides	secondary	2.94e-02	3.26e-03
LCD glass mfg.	Fluorides (F-)	primary	2.71e-02	3.01e-03
Monitor/module	Isopropyl alcohol	primary	2.23e-02	2.47e-03
Japanese Electric Grid	Hydrochloric acid	model/secondary	2.11e-02	2.34e-03
Panel components	Phosphorus (yellow or white)	primary	1.97e-02	2.19e-03
Monitor/module	N-bromoacetamide	primary	1.84e-02	2.04e-03
Monitor/module	Sulfur hexafluoride	primary	1.46e-02	1.62e-03
Japanese Electric Grid	PM-10	model/secondary	1.34e-02	1.49e-03

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	PM	secondary	1.24e-02	1.37e-03
LPG Production	Arsenic	secondary	9.91e-03	1.10e-03
LPG Production	Formaldehyde	secondary	6.43e-03	7.14e-04
US electric grid	Nitrogen oxides	model/secondary	4.56e-03	5.06e-04
Japanese Electric Grid	Fluorides (F-)	model/secondary	4.43e-03	4.91e-04
Japanese Electric Grid	Selenium	model/secondary	4.29e-03	4.76e-04
LCD glass mfg.	Nitrogen oxides	primary	4.09e-03	4.54e-04
Japanese Electric Grid	Formaldehyde	model/secondary	3.93e-03	4.36e-04
Monitor/module	Monosilane	primary	3.07e-03	3.41e-04
US electric grid	Methane	model/secondary	2.50e-03	2.77e-04
Fuel Oil #4 Prod.	Carbon monoxide	secondary	2.34e-03	2.59e-04
Monitor/module	Sulfur oxides	primary	2.23e-03	2.47e-04
US electric grid	Carbon monoxide	model/secondary	2.11e-03	2.34e-04
Japanese Electric Grid	Zinc (elemental)	model/secondary	2.06e-03	2.29e-04
PWB Mfg.	Formaldehyde	model/secondary	1.96e-03	2.18e-04
LPG Production	Hydrochloric acid	secondary	1.77e-03	1.96e-04
Monitor/module	Arsenic	primary	1.70e-03	1.88e-04
LPG Production	Nitrous oxide	secondary	1.56e-03	1.73e-04
Monitor/module	Acetic acid	primary	1.44e-03	1.60e-04
Natural Gas Prod.	PM	secondary	1.31e-03	1.45e-04
Monitor/module	Hexane	primary	1.18e-03	1.31e-04
Japanese Electric Grid	Hydrofluoric acid	model/secondary	1.15e-03	1.28e-04
Japanese Electric Grid	Antimony	model/secondary	1.09e-03	1.21e-04
US electric grid	Arsenic	model/secondary	1.08e-03	1.20e-04
Fuel Oil #6 Prod.	Carbon monoxide	secondary	9.64e-04	1.07e-04
US electric grid	Hydrochloric acid	model/secondary	9.54e-04	1.06e-04
Natural Gas Prod.	Sulfur oxides	secondary	8.69e-04	9.64e-05
Panel components	Nitrogen oxides	primary	8.22e-04	9.12e-05
Fuel Oil #4 Prod.	Methane	secondary	8.03e-04	8.91e-05
Fuel Oil #2 Prod.	Carbon monoxide	secondary	7.85e-04	8.71e-05
Fuel Oil #4 Prod.	Sulfur oxides	secondary	7.55e-04	8.37e-05
Japanese Electric Grid	Nitrous oxide	model/secondary	7.52e-04	8.34e-05
Natural Gas Prod.	Ammonia	secondary	6.71e-04	7.44e-05
Fuel Oil #4 Prod.	Vanadium	secondary	6.21e-04	6.89e-05
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	5.53e-04	6.14e-05
Japanese Electric Grid	Methane	model/secondary	5.47e-04	6.07e-05
Monitor/module	Nitric acid	primary	5.37e-04	5.96e-05
Natural Gas Prod.	Arsenic	secondary	4.96e-04	5.50e-05
LPG Production	Phosphorus (yellow or white)	secondary	4.71e-04	5.22e-05
Japanese Electric Grid	Molybdenum	model/secondary	4.43e-04	4.91e-05
Fuel Oil #6 Prod.	Methane	secondary	4.01e-04	4.45e-05
Fuel Oil #6 Prod.	Sulfur oxides	secondary	3.72e-04	4.13e-05
Fuel Oil #4 Prod.	Benzene	secondary	3.71e-04	4.12e-05
Fuel Oil #6 Prod.	Vanadium	secondary	3.67e-04	4.07e-05
LPG Production	Fluorides (F-)	secondary	3.62e-04	4.01e-05
LPG Production	Selenium	secondary	3.56e-04	3.94e-05
Monitor/module	Zinc (elemental)	primary	3.13e-04	3.48e-05
Japanese Electric Grid	Benzene	model/secondary	3.06e-04	3.40e-05
LPG Production	Hydrogen sulfide	secondary	2.94e-04	3.26e-05

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Ammonia	secondary	2.84e-04	3.15e-05
Panel components	HCFC-225ca	primary	2.80e-04	3.10e-05
Panel components	HCFC-225cb	primary	2.80e-04	3.10e-05
Fuel Oil #6 Prod.	Nitrogen oxides	secondary	2.79e-04	3.09e-05
Fuel Oil #2 Prod.	Methane	secondary	2.40e-04	2.66e-05
Monitor/module	Phosphoric acid	primary	2.33e-04	2.59e-05
Fuel Oil #2 Prod.	Sulfur oxides	secondary	2.27e-04	2.52e-05
US electric grid	PM-10	model/secondary	2.24e-04	2.48e-05
US electric grid	Selenium	model/secondary	1.80e-04	1.99e-05
Japanese Electric Grid	Nickel	model/secondary	1.67e-04	1.86e-05
Fuel Oil #6 Prod.	Benzene	secondary	1.67e-04	1.85e-05
Fuel Oil #2 Prod.	Nitrogen oxides	secondary	1.64e-04	1.82e-05
Fuel Oil #2 Prod.	Vanadium	secondary	1.61e-04	1.79e-05
US electric grid	Vanadium	model/secondary	1.35e-04	1.50e-05
Fuel Oil #4 Prod.	PM	secondary	1.25e-04	1.38e-05
Fuel Oil #2 Prod.	Benzene	secondary	1.19e-04	1.32e-05
Natural Gas Prod.	Vanadium	secondary	1.10e-04	1.22e-05
Fuel Oil #4 Prod.	Arsenic	secondary	1.09e-04	1.20e-05
Natural Gas Prod.	Hydrochloric acid	secondary	1.01e-04	1.12e-05
Japanese Electric Grid	Barium	model/secondary	9.88e-05	1.10e-05
Monitor/module	Diethylene glycol	primary	9.79e-05	1.09e-05
LPG Production	Hydrofluoric acid	secondary	9.63e-05	1.07e-05
Backlight	Diethyl ether	primary	9.49e-05	1.05e-05
Fuel Oil #4 Prod.	Formaldehyde	secondary	7.92e-05	8.78e-06
LPG Production	Molybdenum	secondary	7.91e-05	8.77e-06
LPG Production	Chromium (VI)	secondary	7.57e-05	8.39e-06
LPG Production	Ethane	secondary	7.44e-05	8.26e-06
Fuel Oil #6 Prod.	PM	secondary	6.29e-05	6.98e-06
Fuel Oil #6 Prod.	Arsenic	secondary	5.87e-05	6.51e-06
LPG Production	Zinc (elemental)	secondary	5.75e-05	6.38e-06
Japanese Electric Grid	Naphthalene	model/secondary	5.57e-05	6.18e-06
Panel components	PM	primary	5.48e-05	6.08e-06
US electric grid	Hydrofluoric acid	model/secondary	5.21e-05	5.78e-06
Fuel Oil #6 Prod.	Formaldehyde	secondary	4.66e-05	5.17e-06
Natural Gas Prod.	Formaldehyde	secondary	4.37e-05	4.85e-06
LPG Production	Hexane	secondary	4.33e-05	4.80e-06
Monitor/module	Antimony	primary	3.89e-05	4.32e-06
Fuel Oil #2 Prod.	PM	secondary	3.69e-05	4.10e-06
Natural Gas Prod.	Nitrous oxide	secondary	3.64e-05	4.04e-06
LPG Production	Phenol	secondary	3.43e-05	3.81e-06
Japanese Electric Grid	Chromium (VI)	model/secondary	3.36e-05	3.73e-06
Panel components	Hydrochloric acid	primary	3.35e-05	3.72e-06
Panel components	Heptane	primary	3.28e-05	3.63e-06
LPG Production	Pentane	secondary	3.12e-05	3.46e-06
Fuel Oil #2 Prod.	Arsenic	secondary	3.04e-05	3.38e-06
Japanese Electric Grid	Copper	model/secondary	2.40e-05	2.67e-06
Monitor/module	Acetone	primary	2.22e-05	2.46e-06
Natural Gas Prod.	Ethane	secondary	2.20e-05	2.44e-06
Monitor/module	PM	primary	2.20e-05	2.44e-06
LPG Production	PM-10	secondary	2.16e-05	2.40e-06
Natural Gas Prod.	Fluorides (F-)	secondary	2.14e-05	2.38e-06

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Monitor/module	Copper	primary	2.06e-05	2.29e-06
Fuel Oil #2 Prod.	Formaldehyde	secondary	2.06e-05	2.28e-06
LPG Production	Nickel	secondary	1.98e-05	2.19e-06
Japanese Electric Grid	Methyl hydrazine	model/secondary	1.98e-05	2.19e-06
Monitor/module	Polychlorinated biphenyls	primary	1.94e-05	2.15e-06
Natural Gas Prod.	Selenium	secondary	1.91e-05	2.12e-06
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	1.90e-05	2.10e-06
US electric grid	Formaldehyde	model/secondary	1.88e-05	2.08e-06
Japanese Electric Grid	2-Chloroacetophenone	model/secondary	1.85e-05	2.05e-06
Japanese Electric Grid	Bromomethane	model/secondary	1.83e-05	2.03e-06
Fuel Oil #4 Prod.	Nitrous oxide	secondary	1.77e-05	1.97e-06
Monitor/module	Chromium	primary	1.77e-05	1.96e-06
Monitor/module	Chromium (VI)	primary	1.71e-05	1.89e-06
LPG Production	Aluminum (+3)	secondary	1.36e-05	1.51e-06
US electric grid	Benzene	model/secondary	1.35e-05	1.50e-06
Natural Gas Prod.	Zinc (elemental)	secondary	1.34e-05	1.49e-06
US electric grid	Nitrous oxide	model/secondary	1.32e-05	1.46e-06
Natural Gas Prod.	Hexane	secondary	1.28e-05	1.42e-06
Monitor/module	Lead	primary	1.23e-05	1.37e-06
Monitor/module	Boron	primary	1.08e-05	1.20e-06
LPG Production	Antimony	secondary	1.03e-05	1.14e-06
LCD glass mfg.	PM	primary	1.01e-05	1.12e-06
Fuel Oil #6 Prod.	Hydrochloric acid	secondary	1.01e-05	1.12e-06
Fuel Oil #6 Prod.	Nitrous oxide	secondary	9.88e-06	1.10e-06
Japanese Electric Grid	Cyanide (-1)	model/secondary	9.61e-06	1.07e-06
Natural Gas Prod.	Pentane	secondary	9.24e-06	1.02e-06
Panel components	Toluene	primary	9.09e-06	1.01e-06
Japanese Electric Grid	Cobalt	model/secondary	7.96e-06	8.83e-07
US electric grid	Phosphorus (yellow or white)	model/secondary	7.61e-06	8.44e-07
Japanese Electric Grid	2,3,7,8-TCDD	model/secondary	7.49e-06	8.30e-07
LPG Production	Nitrate	secondary	5.81e-06	6.45e-07
Fuel Oil #4 Prod.	Phosphorus (yellow or white)	secondary	5.71e-06	6.33e-07
Natural Gas Prod.	Hydrofluoric acid	secondary	5.49e-06	6.09e-07
Japanese Electric Grid	Cadmium	model/secondary	5.39e-06	5.98e-07
Fuel Oil #2 Prod.	Hydrochloric acid	secondary	5.39e-06	5.98e-07
Fuel Oil #2 Prod.	Nitrous oxide	secondary	4.84e-06	5.37e-07
LCD glass mfg.	Sulfur oxides	primary	4.71e-06	5.22e-07
LCD glass mfg.	Lead	primary	4.02e-06	4.46e-07
Japanese Electric Grid	Carbon disulfide	model/secondary	3.93e-06	4.36e-07
Fuel Oil #4 Prod.	Selenium	secondary	3.85e-06	4.27e-07
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	3.81e-06	4.23e-07
Monitor/module	Cyanide (-1)	primary	3.66e-06	4.06e-07
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	3.65e-06	4.05e-07
Natural Gas Prod.	Molybdenum	secondary	3.65e-06	4.05e-07
US electric grid	Zinc (elemental)	model/secondary	3.51e-06	3.89e-07
Fuel Oil #6 Prod.	Phosphorus (yellow or white)	secondary	3.33e-06	3.69e-07
Japanese Electric Grid	Benzyl chloride	model/secondary	3.01e-06	3.34e-07
US electric grid	Antimony	model/secondary	2.88e-06	3.20e-07
LCD glass mfg.	Carbon monoxide	primary	2.79e-06	3.10e-07

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	2.79e-06	3.09e-07
Monitor/module	Hexamethyldisilizane	primary	2.75e-06	3.04e-07
Fuel Oil #4 Prod.	Ammonia	secondary	2.49e-06	2.77e-07
Natural Gas Prod.	Chromium (VI)	secondary	2.33e-06	2.59e-07
Monitor/module	Cyclohexane	primary	2.22e-06	2.46e-07
Fuel Oil #6 Prod.	Hydrogen sulfide	secondary	2.16e-06	2.40e-07
Japanese Electric Grid	Chloroform	model/secondary	2.12e-06	2.36e-07
Fuel Oil #6 Prod.	Selenium	secondary	2.07e-06	2.29e-07
Fuel Oil #6 Prod.	Fluorides (F-)	secondary	2.00e-06	2.21e-07
Japanese Electric Grid	Propionaldehyde	model/secondary	1.96e-06	2.18e-07
LPG Production	Copper	secondary	1.67e-06	1.86e-07
Japanese Electric Grid	Beryllium	model/secondary	1.66e-06	1.84e-07
LPG Production	Methyl hydrazine	secondary	1.65e-06	1.83e-07
LPG Production	Silicon	secondary	1.62e-06	1.80e-07
LPG Production	2-Chloroacetophenone	secondary	1.55e-06	1.72e-07
LPG Production	Dimethylbenzanthracene	secondary	1.53e-06	1.70e-07
LPG Production	Bromomethane	secondary	1.53e-06	1.70e-07
Fuel Oil #2 Prod.	Phosphorus (yellow or white)	secondary	1.50e-06	1.66e-07
Monitor/module	Cadmium	primary	1.30e-06	1.44e-07
LPG Production	Naphthalene	secondary	1.25e-06	1.39e-07
LPG Production	Lead	secondary	1.19e-06	1.32e-07
Japanese Electric Grid	Acrolein	model/secondary	1.11e-06	1.24e-07
Fuel Oil #2 Prod.	Fluorides (F-)	secondary	1.10e-06	1.22e-07
Fuel Oil #2 Prod.	Selenium	secondary	1.09e-06	1.21e-07
Fuel Oil #6 Prod.	Ammonia	secondary	1.08e-06	1.20e-07
LPG Production	Manganese	secondary	1.07e-06	1.19e-07
US electric grid	Chromium (VI)	model/secondary	1.04e-06	1.15e-07
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	1.03e-06	1.15e-07
LPG Production	Beryllium	secondary	1.03e-06	1.14e-07
US electric grid	Molybdenum	model/secondary	9.62e-07	1.07e-07
Fuel Oil #2 Prod.	Hydrogen sulfide	secondary	9.44e-07	1.05e-07
Fuel Oil #4 Prod.	Molybdenum	secondary	9.30e-07	1.03e-07
Japanese Electric Grid	Methyl chloride	model/secondary	9.25e-07	1.03e-07
Monitor/module	Tin	primary	9.16e-07	1.02e-07
LPG Production	Barium	secondary	8.94e-07	9.92e-08
US electric grid	Methyl hydrazine	model/secondary	8.93e-07	9.90e-08
US electric grid	2-Chloroacetophenone	model/secondary	8.36e-07	9.28e-08
US electric grid	Bromomethane	model/secondary	8.27e-07	9.17e-08
Fuel Oil #2 Prod.	Ammonia	secondary	8.14e-07	9.03e-08
Japanese Electric Grid	Toluene	model/secondary	8.04e-07	8.92e-08
LPG Production	Cyanide (-1)	secondary	8.03e-07	8.90e-08
Monitor/module	Nickel	primary	7.74e-07	8.59e-08
LPG Production	Barium cmpds	secondary	7.62e-07	8.45e-08
Natural Gas Prod.	Antimony	secondary	7.03e-07	7.79e-08
Fuel Oil #4 Prod.	Ethane	secondary	6.72e-07	7.45e-08
Japanese Electric Grid	Di(2-ethylhexyl)phthalate	model/secondary	6.66e-07	7.39e-08
Fuel Oil #6 Prod.	Hydrofluoric acid	secondary	5.52e-07	6.12e-08
Fuel Oil #6 Prod.	Molybdenum	secondary	5.31e-07	5.89e-08
Japanese Electric Grid	Acetaldehyde	model/secondary	5.31e-07	5.88e-08
Japanese Electric Grid	Hexane	model/secondary	5.15e-07	5.71e-08
Fuel Oil #4 Prod.	Zinc (elemental)	secondary	5.10e-07	5.66e-08

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Dimethylbenzanthracene	secondary	4.53e-07	5.03e-08
US electric grid	Nickel	model/secondary	4.48e-07	4.97e-08
LPG Production	Cadmium	secondary	4.42e-07	4.90e-08
US electric grid	Cyanide (-1)	model/secondary	4.34e-07	4.82e-08
Fuel Oil #4 Prod.	Chromium (VI)	secondary	4.07e-07	4.52e-08
Japanese Electric Grid	Mercury	model/secondary	3.97e-07	4.41e-08
Fuel Oil #4 Prod.	Hexane	secondary	3.91e-07	4.33e-08
Japanese Electric Grid	Dimethyl sulfate	model/secondary	3.69e-07	4.09e-08
LCD glass mfg.	Nitrate	primary	3.66e-07	4.06e-08
US electric grid	2,3,7,8-TCDD	model/secondary	3.29e-07	3.65e-08
LPG Production	Carbon disulfide	secondary	3.28e-07	3.64e-08
Fuel Oil #6 Prod.	Ethane	secondary	3.02e-07	3.35e-08
Fuel Oil #2 Prod.	Hydrofluoric acid	secondary	2.94e-07	3.26e-08
Fuel Oil #4 Prod.	Pentane	secondary	2.82e-07	3.13e-08
Natural Gas Prod.	Nickel	secondary	2.75e-07	3.05e-08
Fuel Oil #4 Prod.	PM-10	secondary	2.68e-07	2.97e-08
US electric grid	Naphthalene	model/secondary	2.65e-07	2.94e-08
LPG Production	Benzyl chloride	secondary	2.51e-07	2.79e-08
Fuel Oil #4 Prod.	Phenol	secondary	2.51e-07	2.79e-08
Fuel Oil #2 Prod.	Molybdenum	secondary	2.49e-07	2.76e-08
LPG Production	Cobalt	secondary	2.41e-07	2.67e-08
Fuel Oil #4 Prod.	Nickel	secondary	2.36e-07	2.61e-08
Monitor/module	Manganese	primary	2.29e-07	2.54e-08
US electric grid	Barium	model/secondary	2.25e-07	2.50e-08
Fuel Oil #6 Prod.	Zinc (elemental)	secondary	2.25e-07	2.49e-08
Fuel Oil #6 Prod.	Chromium (VI)	secondary	2.18e-07	2.41e-08
Fuel Oil #2 Prod.	Ethane	secondary	2.15e-07	2.39e-08
Natural Gas Prod.	Hydrogen sulfide	secondary	2.12e-07	2.35e-08
Natural Gas Prod.	Naphthalene	secondary	2.08e-07	2.31e-08
LPG Production	Aluminum (elemental)	secondary	1.86e-07	2.06e-08
Japanese Electric Grid	Isophorone	model/secondary	1.78e-07	1.98e-08
US electric grid	Carbon disulfide	model/secondary	1.78e-07	1.97e-08
LPG Production	Chloroform	secondary	1.77e-07	1.97e-08
Fuel Oil #6 Prod.	Hexane	secondary	1.76e-07	1.95e-08
Fuel Oil #2 Prod.	Zinc (elemental)	secondary	1.65e-07	1.84e-08
LPG Production	Propionaldehyde	secondary	1.64e-07	1.82e-08
Fuel Oil #6 Prod.	PM-10	secondary	1.59e-07	1.76e-08
Japanese Electric Grid	Methyl ethyl ketone	model/secondary	1.43e-07	1.58e-08
Japanese Electric Grid	Tetrachloroethylene	model/secondary	1.41e-07	1.56e-08
US electric grid	Benzyl chloride	model/secondary	1.36e-07	1.51e-08
Fuel Oil #6 Prod.	Nickel	secondary	1.36e-07	1.51e-08
Fuel Oil #6 Prod.	Pentane	secondary	1.27e-07	1.40e-08
Japanese Electric Grid	1,2-Dichloroethane	model/secondary	1.25e-07	1.39e-08
Fuel Oil #2 Prod.	Hexane	secondary	1.25e-07	1.39e-08
Japanese Electric Grid	Methyl methacrylate	model/secondary	1.22e-07	1.35e-08
Fuel Oil #2 Prod.	Chromium (VI)	secondary	1.16e-07	1.28e-08
Japanese Electric Grid	Styrene	model/secondary	1.08e-07	1.20e-08
US electric grid	Cadmium	model/secondary	1.06e-07	1.18e-08
Japanese Electric Grid	Bromoform	model/secondary	1.01e-07	1.12e-08

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	9.95e-08	1.10e-08
Japanese Electric Grid	Dichloromethane	model/secondary	9.94e-08	1.10e-08
Monitor/module	Mercury	primary	9.69e-08	1.08e-08
US electric grid	Chloroform	model/secondary	9.59e-08	1.06e-08
Natural Gas Prod.	Methyl hydrazine	secondary	9.41e-08	1.04e-08
Fuel Oil #2 Prod.	Phenol	secondary	9.37e-08	1.04e-08
LPG Production	Acrolein	secondary	9.31e-08	1.03e-08
Natural Gas Prod.	Barium	secondary	9.30e-08	1.03e-08
Fuel Oil #4 Prod.	Antimony	secondary	9.15e-08	1.02e-08
Fuel Oil #2 Prod.	Pentane	secondary	9.02e-08	1.00e-08
US electric grid	Propionaldehyde	model/secondary	8.86e-08	9.83e-09
US electric grid	Manganese	model/secondary	8.83e-08	9.79e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	8.81e-08	9.77e-09
Natural Gas Prod.	Bromomethane	secondary	8.71e-08	9.66e-09
Natural Gas Prod.	Copper	secondary	8.32e-08	9.23e-09
Fuel Oil #6 Prod.	Phenol	secondary	8.24e-08	9.14e-09
Japanese Electric Grid	Chlorobenzene	model/secondary	8.05e-08	8.93e-09
LPG Production	Methyl chloride	secondary	7.72e-08	8.57e-09
US electric grid	Fluoride	model/secondary	7.56e-08	8.39e-09
Panel components	Methyl ethyl ketone	primary	6.97e-08	7.73e-09
Fuel Oil #2 Prod.	PM-10	secondary	6.93e-08	7.69e-09
Natural Gas Prod.	Lead	secondary	6.83e-08	7.58e-09
Natural Gas Prod.	Beryllium	secondary	6.74e-08	7.47e-09
Japanese Electric Grid	Cumene hydroperoxide	model/secondary	6.55e-08	7.27e-09
Japanese Electric Grid	2,4-Dinitrotoluene	model/secondary	6.44e-08	7.14e-09
Fuel Oil #2 Prod.	Nickel	secondary	6.25e-08	6.94e-09
Natural Gas Prod.	Manganese	secondary	6.23e-08	6.91e-09
Japanese Electric Grid	Acetophenone	model/secondary	5.93e-08	6.58e-09
US electric grid	Beryllium	model/secondary	5.64e-08	6.26e-09
LPG Production	Di(2-ethylhexyl)phthalate	secondary	5.56e-08	6.17e-09
US electric grid	Acrolein	model/secondary	5.04e-08	5.59e-09
US electric grid	Lead	model/secondary	4.94e-08	5.48e-09
Natural Gas Prod.	Nitrate	secondary	4.74e-08	5.26e-09
US electric grid	Cobalt	model/secondary	4.71e-08	5.22e-09
Natural Gas Prod.	Cyanide (-1)	secondary	4.57e-08	5.07e-09
Monitor/module	Phenol	primary	4.54e-08	5.04e-09
Fuel Oil #4 Prod.	Nitrate	secondary	4.52e-08	5.02e-09
LPG Production	Acetaldehyde	secondary	4.43e-08	4.91e-09
US electric grid	Copper	model/secondary	4.33e-08	4.80e-09
US electric grid	Methyl chloride	model/secondary	4.18e-08	4.63e-09
LPG Production	Mercury	secondary	4.17e-08	4.62e-09
Fuel Oil #6 Prod.	Antimony	secondary	4.05e-08	4.49e-09
Fuel Oil #2 Prod.	Aluminum (+3)	secondary	3.71e-08	4.11e-09
Japanese Electric Grid	Ethylbenzene	model/secondary	3.49e-08	3.88e-09
LPG Production	Cadmium cmpds	secondary	3.33e-08	3.70e-09
Fuel Oil #6 Prod.	Aluminum (+3)	secondary	3.26e-08	3.62e-09
LPG Production	Dimethyl sulfate	secondary	3.08e-08	3.42e-09
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	3.01e-08	3.34e-09
LPG Production	Toluene	secondary	2.99e-08	3.32e-09
Fuel Oil #2 Prod.	Antimony	secondary	2.96e-08	3.28e-09
Natural Gas Prod.	Cadmium	secondary	2.52e-08	2.79e-09

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
US electric grid	Acetaldehyde	model/secondary	2.40e-08	2.66e-09
US electric grid	Hexane	model/secondary	2.33e-08	2.58e-09
Natural Gas Prod.	Phenol	secondary	2.30e-08	2.55e-09
LCD glass mfg.	Chromium	primary	2.04e-08	2.26e-09
Fuel Oil #4 Prod.	Silicon	secondary	2.02e-08	2.24e-09
Monitor/module	Tetrachloroethylene	primary	1.95e-08	2.17e-09
Japanese Electric Grid	Acenaphthene	model/secondary	1.95e-08	2.16e-09
Fuel Oil #4 Prod.	Copper	secondary	1.92e-08	2.13e-09
Natural Gas Prod.	Carbon disulfide	secondary	1.87e-08	2.08e-09
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	1.77e-08	1.97e-09
Japanese Electric Grid	Phenanthrene	model/secondary	1.75e-08	1.94e-09
LPG Production	1,4-Dichlorobenzene	secondary	1.74e-08	1.93e-09
US electric grid	Dimethyl sulfate	model/secondary	1.67e-08	1.85e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	1.66e-08	1.84e-09
Fuel Oil #6 Prod.	Nitrate	secondary	1.65e-08	1.83e-09
Fuel Oil #4 Prod.	Bromomethane	secondary	1.64e-08	1.82e-09
Fuel Oil #2 Prod.	Nitrate	secondary	1.61e-08	1.79e-09
Japanese Electric Grid	Methyl tert-butyl ether	model/secondary	1.60e-08	1.77e-09
Natural Gas Prod.	PM-10	secondary	1.56e-08	1.73e-09
Japanese Electric Grid	Chromium (III)	model/secondary	1.51e-08	1.67e-09
LPG Production	Isophorone	secondary	1.49e-08	1.65e-09
US electric grid	Mercury	model/secondary	1.45e-08	1.61e-09
Natural Gas Prod.	Benzyl chloride	secondary	1.43e-08	1.59e-09
Fuel Oil #4 Prod.	Dimethylbenzanthracene	secondary	1.38e-08	1.53e-09
Natural Gas Prod.	Toluene	secondary	1.36e-08	1.51e-09
LPG Production	Aromatic hydrocarbons	secondary	1.34e-08	1.49e-09
LCD glass mfg.	Nickel	primary	1.28e-08	1.42e-09
Fuel Oil #4 Prod.	Lead	secondary	1.28e-08	1.41e-09
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	1.23e-08	1.36e-09
Japanese Electric Grid	Phenol	model/secondary	1.22e-08	1.35e-09
Fuel Oil #6 Prod.	Silicon	secondary	1.19e-08	1.32e-09
LPG Production	Methyl ethyl ketone	secondary	1.19e-08	1.32e-09
LPG Production	Tetrachloroethylene	secondary	1.18e-08	1.31e-09
Fuel Oil #4 Prod.	Naphthalene	secondary	1.16e-08	1.29e-09
Monitor/module	Trichloroethylene	primary	1.16e-08	1.29e-09
Fuel Oil #4 Prod.	Manganese	secondary	1.15e-08	1.27e-09
Japanese Electric Grid	Vinyl acetate	model/secondary	1.14e-08	1.26e-09
Fuel Oil #4 Prod.	Beryllium	secondary	1.10e-08	1.22e-09
Fuel Oil #6 Prod.	Copper	secondary	1.08e-08	1.20e-09
Japanese Electric Grid	Ethylene dibromide	model/secondary	1.06e-08	1.17e-09
LPG Production	1,2-Dichloroethane	secondary	1.05e-08	1.16e-09
LPG Production	Methyl methacrylate	secondary	1.02e-08	1.13e-09
Natural Gas Prod.	Chloroform	secondary	1.01e-08	1.12e-09
Japanese Electric Grid	Xylene (mixed isomers)	model/secondary	9.46e-09	1.05e-09
Fuel Oil #6 Prod.	Methyl hydrazine	secondary	9.45e-09	1.05e-09
Natural Gas Prod.	Propionaldehyde	secondary	9.34e-09	1.04e-09
Natural Gas Prod.	Aluminum (+3)	secondary	9.03e-09	1.00e-09
LPG Production	Styrene	secondary	9.00e-09	9.99e-10
Fuel Oil #6 Prod.	2-Chloroacetophenone	secondary	8.85e-09	9.82e-10

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #6 Prod.	Bromomethane	secondary	8.75e-09	9.71e-10
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	8.62e-09	9.56e-10
LPG Production	Bromoform	secondary	8.41e-09	9.33e-10
Natural Gas Prod.	Cobalt	secondary	8.33e-09	9.24e-10
LPG Production	Dichloromethane	secondary	8.30e-09	9.20e-10
LPG Production	Chromium (III)	secondary	8.24e-09	9.14e-10
US electric grid	Toluene	model/secondary	8.23e-09	9.12e-10
US electric grid	Isophorone	model/secondary	8.06e-09	8.94e-10
Fuel Oil #4 Prod.	Barium	secondary	7.83e-09	8.69e-10
Natural Gas Prod.	o-xylene	secondary	7.25e-09	8.04e-10
Fuel Oil #6 Prod.	Lead	secondary	6.80e-09	7.55e-10
LPG Production	Chlorobenzene	secondary	6.72e-09	7.46e-10
US electric grid	Methyl ethyl ketone	model/secondary	6.45e-09	7.15e-10
US electric grid	Tetrachloroethylene	model/secondary	6.37e-09	7.07e-10
LPG Production	Copper (+1 & +2)	secondary	6.29e-09	6.97e-10
Japanese Electric Grid	Dibenzo[a,h]anthracene	model/secondary	6.24e-09	6.92e-10
Fuel Oil #6 Prod.	Dimethylbenzanthracene	secondary	6.21e-09	6.89e-10
Fuel Oil #6 Prod.	Manganese	secondary	6.09e-09	6.76e-10
Fuel Oil #6 Prod.	Beryllium	secondary	5.82e-09	6.46e-10
US electric grid	1,2-Dichloroethane	model/secondary	5.67e-09	6.29e-10
Fuel Oil #4 Prod.	Barium cmpds	secondary	5.58e-09	6.19e-10
US electric grid	Methyl methacrylate	model/secondary	5.51e-09	6.11e-10
LPG Production	2,4-Dinitrotoluene	secondary	5.39e-09	5.98e-10
Fuel Oil #6 Prod.	Naphthalene	secondary	5.39e-09	5.98e-10
Natural Gas Prod.	Acrolein	secondary	5.31e-09	5.89e-10
Fuel Oil #2 Prod.	Copper	secondary	5.22e-09	5.79e-10
Fuel Oil #2 Prod.	Silicon	secondary	5.21e-09	5.78e-10
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	5.15e-09	5.71e-10
Fuel Oil #2 Prod.	Methyl hydrazine	secondary	5.04e-09	5.59e-10
Japanese Electric Grid	2,3,7,8-TCDF	model/secondary	5.01e-09	5.56e-10
LPG Production	Acetophenone	secondary	4.95e-09	5.49e-10
US electric grid	Styrene	model/secondary	4.87e-09	5.40e-10
Fuel Oil #2 Prod.	2-Chloroacetophenone	secondary	4.72e-09	5.23e-10
Fuel Oil #4 Prod.	Cadmium	secondary	4.68e-09	5.19e-10
Fuel Oil #2 Prod.	Bromomethane	secondary	4.66e-09	5.17e-10
Fuel Oil #6 Prod.	Cyanide (-1)	secondary	4.60e-09	5.10e-10
US electric grid	Bromoform	model/secondary	4.55e-09	5.04e-10
US electric grid	Dichloromethane	model/secondary	4.49e-09	4.98e-10
Fuel Oil #2 Prod.	Dimethylbenzanthracene	secondary	4.43e-09	4.91e-10
Natural Gas Prod.	Methyl chloride	secondary	4.40e-09	4.88e-10
Japanese Electric Grid	o-xylene	model/secondary	4.31e-09	4.79e-10
Japanese Electric Grid	Benzo[a]anthracene	model/secondary	4.11e-09	4.56e-10
Fuel Oil #2 Prod.	Naphthalene	secondary	3.65e-09	4.05e-10
US electric grid	Chlorobenzene	model/secondary	3.64e-09	4.03e-10
Fuel Oil #2 Prod.	Lead	secondary	3.62e-09	4.02e-10
Fuel Oil #4 Prod.	Carbon disulfide	secondary	3.53e-09	3.91e-10
Fuel Oil #6 Prod.	Barium	secondary	3.39e-09	3.76e-10
LPG Production	o-xylene	secondary	3.29e-09	3.65e-10
Fuel Oil #2 Prod.	Manganese	secondary	3.26e-09	3.62e-10
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	3.17e-09	3.52e-10
Fuel Oil #2 Prod.	Beryllium	secondary	3.13e-09	3.48e-10

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Japanese Electric Grid	Ethyl Chloride	model/secondary	3.08e-09	3.42e-10
Natural Gas Prod.	Mercury	secondary	2.97e-09	3.29e-10
US electric grid	2,4-Dinitrotoluene	model/secondary	2.92e-09	3.23e-10
Fuel Oil #4 Prod.	Benzyl chloride	secondary	2.70e-09	3.00e-10
US electric grid	Acetophenone	model/secondary	2.68e-09	2.97e-10
LPG Production	Ethylbenzene	secondary	2.67e-09	2.96e-10
Fuel Oil #4 Prod.	Cobalt	secondary	2.66e-09	2.95e-10
Japanese Electric Grid	Benzo[b,j,k]fluoranthene	model/secondary	2.61e-09	2.90e-10
Fuel Oil #2 Prod.	Barium	secondary	2.56e-09	2.84e-10
Natural Gas Prod.	Acetaldehyde	secondary	2.52e-09	2.80e-10
Fuel Oil #6 Prod.	Cadmium	secondary	2.46e-09	2.73e-10
Fuel Oil #2 Prod.	Cyanide (-1)	secondary	2.45e-09	2.72e-10
Fuel Oil #4 Prod.	Aluminum (elemental)	secondary	2.31e-09	2.56e-10
Japanese Electric Grid	Indeno(1,2,3-cd)pyrene	model/secondary	2.30e-09	2.55e-10
Fuel Oil #2 Prod.	Barium cmpds	secondary	2.08e-09	2.31e-10
Fuel Oil #4 Prod.	Chloroform	secondary	1.91e-09	2.11e-10
Fuel Oil #6 Prod.	Carbon disulfide	secondary	1.88e-09	2.09e-10
Fuel Oil #6 Prod.	Barium cmpds	secondary	1.83e-09	2.03e-10
Japanese Electric Grid	Chrysene	model/secondary	1.81e-09	2.01e-10
Fuel Oil #4 Prod.	Propionaldehyde	secondary	1.76e-09	1.95e-10
Natural Gas Prod.	Dimethyl sulfate	secondary	1.76e-09	1.95e-10
Natural Gas Prod.	Zinc (+2)	secondary	1.65e-09	1.83e-10
Japanese Electric Grid	2-Methylnaphthalene	model/secondary	1.60e-09	1.77e-10
Japanese Electric Grid	Biphenyl	model/secondary	1.56e-09	1.72e-10
Japanese Electric Grid	Anthracene	model/secondary	1.55e-09	1.72e-10
Natural Gas Prod.	Chlorine	secondary	1.49e-09	1.65e-10
Fuel Oil #6 Prod.	Cobalt	secondary	1.45e-09	1.60e-10
Japanese Electric Grid	Benzo[g,h,i]perylene	model/secondary	1.45e-09	1.60e-10
Fuel Oil #6 Prod.	Benzyl chloride	secondary	1.44e-09	1.60e-10
US electric grid	Ethylbenzene	model/secondary	1.43e-09	1.59e-10
Fuel Oil #6 Prod.	Aluminum (elemental)	secondary	1.37e-09	1.51e-10
Fuel Oil #2 Prod.	Cadmium	secondary	1.34e-09	1.49e-10
LPG Production	Methyl tert-butyl ether	secondary	1.34e-09	1.48e-10
Monitor/module	1,1,1-Trichloroethane	primary	1.30e-09	1.44e-10
Natural Gas Prod.	Silicon	secondary	1.17e-09	1.30e-10
LPG Production	Zinc (+2)	secondary	1.13e-09	1.25e-10
Japanese Electric Grid	Acenaphthylene	model/secondary	1.11e-09	1.23e-10
LPG Production	Phenanthrene	secondary	1.09e-09	1.21e-10
Fuel Oil #6 Prod.	Chloroform	secondary	1.02e-09	1.13e-10
Fuel Oil #2 Prod.	Carbon disulfide	secondary	1.00e-09	1.11e-10
Fuel Oil #4 Prod.	Acrolein	secondary	1.00e-09	1.11e-10
LPG Production	Vinyl acetate	secondary	9.52e-10	1.06e-10
Fuel Oil #6 Prod.	Propionaldehyde	secondary	9.38e-10	1.04e-10
LPG Production	3-Methylcholanthrene	secondary	9.21e-10	1.02e-10
Japanese Electric Grid	Benzo[a]pyrene	model/secondary	9.17e-10	1.02e-10
LPG Production	Ethylene dibromide	secondary	8.83e-10	9.79e-11
Natural Gas Prod.	Isophorone	secondary	8.49e-10	9.42e-11
Fuel Oil #4 Prod.	Methyl chloride	secondary	8.30e-10	9.20e-11
Fuel Oil #2 Prod.	Benzyl chloride	secondary	7.67e-10	8.51e-11

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #2 Prod.	Cobalt	secondary	7.42e-10	8.23e-11
US electric grid	Methyl tert-butyl ether	model/secondary	7.23e-10	8.02e-11
Natural Gas Prod.	Methyl ethyl ketone	secondary	6.79e-10	7.54e-11
Japanese Electric Grid	Pyrene	model/secondary	6.73e-10	7.46e-11
Natural Gas Prod.	Tetrachloroethylene	secondary	6.71e-10	7.45e-11
Fuel Oil #4 Prod.	Di(2-ethylhexyl)phthalate	secondary	5.98e-10	6.63e-11
Natural Gas Prod.	1,2-Dichloroethane	secondary	5.97e-10	6.62e-11
Fuel Oil #2 Prod.	Aluminum (elemental)	secondary	5.96e-10	6.61e-11
Japanese Electric Grid	Fluorene	model/secondary	5.86e-10	6.50e-11
Natural Gas Prod.	Methyl methacrylate	secondary	5.81e-10	6.44e-11
LPG Production	2-Methylnaphthalene	secondary	5.76e-10	6.39e-11
Japanese Electric Grid	Fluoranthene	model/secondary	5.59e-10	6.21e-11
US electric grid	Phenol	model/secondary	5.51e-10	6.11e-11
Fuel Oil #2 Prod.	Chloroform	secondary	5.41e-10	6.00e-11
Fuel Oil #6 Prod.	Acrolein	secondary	5.33e-10	5.91e-11
US electric grid	Vinyl acetate	model/secondary	5.15e-10	5.71e-11
Natural Gas Prod.	Styrene	secondary	5.13e-10	5.69e-11
LPG Production	Chlorine	secondary	5.11e-10	5.66e-11
Natural Gas Prod.	Barium cmpds	secondary	5.06e-10	5.61e-11
Fuel Oil #2 Prod.	Propionaldehyde	secondary	5.00e-10	5.55e-11
US electric grid	Phenanthrene	model/secondary	4.85e-10	5.38e-11
Natural Gas Prod.	Bromoform	secondary	4.79e-10	5.31e-11
US electric grid	Ethylene dibromide	model/secondary	4.78e-10	5.30e-11
Fuel Oil #4 Prod.	Acetaldehyde	secondary	4.76e-10	5.28e-11
Natural Gas Prod.	Dichloromethane	secondary	4.73e-10	5.24e-11
Fuel Oil #4 Prod.	Mercury	secondary	4.46e-10	4.94e-11
Fuel Oil #6 Prod.	Methyl chloride	secondary	4.42e-10	4.91e-11
US electric grid	Xylene (mixed isomers)	model/secondary	4.27e-10	4.74e-11
Natural Gas Prod.	Chlorobenzene	secondary	3.83e-10	4.25e-11
US electric grid	Chromium (III)	model/secondary	3.82e-10	4.23e-11
LPG Production	1,1,1-Trichloroethane	secondary	3.63e-10	4.03e-11
LPG Production	Acenaphthene	secondary	3.37e-10	3.74e-11
Fuel Oil #4 Prod.	Dimethyl sulfate	secondary	3.31e-10	3.67e-11
Fuel Oil #6 Prod.	Di(2-ethylhexyl)phthalate	secondary	3.19e-10	3.53e-11
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	3.07e-10	3.41e-11
Fuel Oil #4 Prod.	Toluene	secondary	2.92e-10	3.24e-11
Fuel Oil #2 Prod.	Acrolein	secondary	2.84e-10	3.15e-11
Natural Gas Prod.	Acetophenone	secondary	2.82e-10	3.13e-11
Natural Gas Prod.	3-Methylcholanthrene	secondary	2.72e-10	3.02e-11
LPG Production	Ethyl Chloride	secondary	2.57e-10	2.85e-11
Natural Gas Prod.	Chromium (III)	secondary	2.54e-10	2.82e-11
Fuel Oil #6 Prod.	Acetaldehyde	secondary	2.54e-10	2.81e-11
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	2.44e-10	2.71e-11
Fuel Oil #6 Prod.	Mercury	secondary	2.36e-10	2.62e-11
Fuel Oil #2 Prod.	Methyl chloride	secondary	2.36e-10	2.61e-11
US electric grid	2,3,7,8-TCDF	model/secondary	2.26e-10	2.50e-11
LPG Production	Cumene	secondary	2.18e-10	2.41e-11
US electric grid	1,1,1-Trichloroethane	model/secondary	2.10e-10	2.33e-11
LPG Production	Benzo[a]pyrene	secondary	2.06e-10	2.28e-11
Fuel Oil #6 Prod.	Dimethyl sulfate	secondary	1.76e-10	1.96e-11
Natural Gas Prod.	2-Methylnaphthalene	secondary	1.71e-10	1.89e-11

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #2 Prod.	Di(2-ethylhexyl)phthalate	secondary	1.70e-10	1.88e-11
Japanese Electric Grid	5-Methyl chrysene	model/secondary	1.69e-10	1.88e-11
Fuel Oil #4 Prod.	Isophorone	secondary	1.60e-10	1.78e-11
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	1.57e-10	1.74e-11
Natural Gas Prod.	Ethylbenzene	secondary	1.52e-10	1.69e-11
US electric grid	Acenaphthene	model/secondary	1.47e-10	1.63e-11
Fuel Oil #6 Prod.	Toluene	secondary	1.43e-10	1.58e-11
US electric grid	Ethyl Chloride	model/secondary	1.39e-10	1.54e-11
Fuel Oil #2 Prod.	Acetaldehyde	secondary	1.35e-10	1.50e-11
Natural Gas Prod.	Aluminum (elemental)	secondary	1.34e-10	1.49e-11
LPG Production	Biphenyl	secondary	1.30e-10	1.44e-11
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	1.28e-10	1.42e-11
Fuel Oil #2 Prod.	Mercury	secondary	1.27e-10	1.41e-11
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	1.27e-10	1.40e-11
US electric grid	Cumene	model/secondary	1.18e-10	1.31e-11
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	1.13e-10	1.25e-11
LPG Production	Lead cmpds	secondary	1.12e-10	1.24e-11
Natural Gas Prod.	Phenanthrene	secondary	1.11e-10	1.23e-11
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	1.09e-10	1.21e-11
LPG Production	Dibenzo[a,h]anthracene	secondary	1.07e-10	1.18e-11
LPG Production	Acenaphthylene	secondary	1.03e-10	1.14e-11
LPG Production	Anthracene	secondary	1.01e-10	1.12e-11
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	9.84e-11	1.09e-11
Fuel Oil #4 Prod.	Styrene	secondary	9.67e-11	1.07e-11
LPG Production	Nickel cmpds	secondary	9.46e-11	1.05e-11
Fuel Oil #2 Prod.	Dimethyl sulfate	secondary	9.40e-11	1.04e-11
LPG Production	Benzo[a]anthracene	secondary	9.15e-11	1.01e-11
Fuel Oil #2 Prod.	Cadmium cmpds	secondary	9.10e-11	1.01e-11
Fuel Oil #4 Prod.	Bromoform	secondary	9.03e-11	1.00e-11
Fuel Oil #4 Prod.	Dichloromethane	secondary	8.91e-11	9.89e-12
Fuel Oil #2 Prod.	Toluene	secondary	8.85e-11	9.82e-12
Fuel Oil #6 Prod.	Isophorone	secondary	8.53e-11	9.46e-12
Fuel Oil #6 Prod.	Cadmium cmpds	secondary	8.00e-11	8.87e-12
Natural Gas Prod.	Methyl tert-butyl ether	secondary	7.62e-11	8.45e-12
Fuel Oil #4 Prod.	Chlorobenzene	secondary	7.22e-11	8.01e-12
LPG Production	Benzo[b,j,k]fluoranthene	secondary	7.06e-11	7.83e-12
Fuel Oil #6 Prod.	1,4-Dichlorobenzene	secondary	7.05e-11	7.82e-12
US electric grid	Biphenyl	model/secondary	7.03e-11	7.79e-12
Fuel Oil #6 Prod.	Methyl ethyl ketone	secondary	6.82e-11	7.57e-12
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	6.80e-11	7.55e-12
Fuel Oil #6 Prod.	Tetrachloroethylene	secondary	6.75e-11	7.48e-12
Fuel Oil #6 Prod.	1,2-Dichloroethane	secondary	6.00e-11	6.65e-12
Fuel Oil #6 Prod.	Methyl methacrylate	secondary	5.83e-11	6.47e-12
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	5.79e-11	6.42e-12
LPG Production	Chrysene	secondary	5.78e-11	6.41e-12
Natural Gas Prod.	Vinyl acetate	secondary	5.43e-11	6.02e-12
Fuel Oil #4 Prod.	Acetophenone	secondary	5.32e-11	5.90e-12
Fuel Oil #6 Prod.	Styrene	secondary	5.15e-11	5.72e-12
Natural Gas Prod.	Ethylene dibromide	secondary	5.03e-11	5.58e-12

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #2 Prod.	1,4-Dichlorobenzene	secondary	5.02e-11	5.57e-12
LPG Production	HALON-1301	secondary	4.87e-11	5.40e-12
Fuel Oil #6 Prod.	Bromoform	secondary	4.81e-11	5.34e-12
Fuel Oil #6 Prod.	Dichloromethane	secondary	4.75e-11	5.27e-12
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	4.60e-11	5.11e-12
Fuel Oil #2 Prod.	Isophorone	secondary	4.55e-11	5.04e-12
Fuel Oil #4 Prod.	Chromium (III)	secondary	4.44e-11	4.92e-12
US electric grid	Acenaphthylene	model/secondary	4.37e-11	4.84e-12
US electric grid	Benzo[a]pyrene	model/secondary	4.14e-11	4.59e-12
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	4.12e-11	4.57e-12
Fuel Oil #6 Prod.	Chlorobenzene	secondary	3.85e-11	4.27e-12
US electric grid	Anthracene	model/secondary	3.82e-11	4.23e-12
Fuel Oil #2 Prod.	Aromatic hydrocarbons	secondary	3.67e-11	4.07e-12
LPG Production	Benzo[b]fluoranthene	secondary	3.66e-11	4.05e-12
Fuel Oil #2 Prod.	Methyl ethyl ketone	secondary	3.64e-11	4.03e-12
Fuel Oil #2 Prod.	Tetrachloroethylene	secondary	3.59e-11	3.99e-12
LPG Production	Mercury compounds	secondary	3.40e-11	3.77e-12
Fuel Oil #6 Prod.	Aromatic hydrocarbons	secondary	3.23e-11	3.58e-12
Fuel Oil #2 Prod.	1,2-Dichloroethane	secondary	3.20e-11	3.55e-12
LPG Production	Fluorene	secondary	3.17e-11	3.51e-12
Natural Gas Prod.	Benzo[a]pyrene	secondary	3.11e-11	3.45e-12
Fuel Oil #2 Prod.	Methyl methacrylate	secondary	3.11e-11	3.45e-12
Fuel Oil #4 Prod.	o-xylene	secondary	3.10e-11	3.44e-12
Fuel Oil #6 Prod.	2,4-Dinitrotoluene	secondary	3.09e-11	3.42e-12
Fuel Oil #4 Prod.	Ethylbenzene	secondary	2.86e-11	3.17e-12
Fuel Oil #6 Prod.	Acetophenone	secondary	2.83e-11	3.14e-12
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	2.80e-11	3.11e-12
Natural Gas Prod.	Acenaphthene	secondary	2.80e-11	3.10e-12
Fuel Oil #2 Prod.	Styrene	secondary	2.75e-11	3.05e-12
US electric grid	Benzo[a]anthracene	model/secondary	2.74e-11	3.04e-12
LPG Production	Pyrene	secondary	2.74e-11	3.04e-12
LPG Production	Benzo[g,h,i]perylene	secondary	2.66e-11	2.95e-12
LPG Production	Fluoranthene	secondary	2.59e-11	2.87e-12
Fuel Oil #2 Prod.	Bromoform	secondary	2.57e-11	2.85e-12
Fuel Oil #2 Prod.	Dichloromethane	secondary	2.53e-11	2.81e-12
Fuel Oil #6 Prod.	Chromium (III)	secondary	2.37e-11	2.63e-12
Natural Gas Prod.	Cadmium cmpds	secondary	2.21e-11	2.46e-12
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	2.07e-11	2.30e-12
Fuel Oil #2 Prod.	Chlorobenzene	secondary	2.05e-11	2.28e-12
US electric grid	Chrysene	model/secondary	1.99e-11	2.21e-12
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	1.95e-11	2.16e-12
Fuel Oil #2 Prod.	Copper (+1 & +2)	secondary	1.72e-11	1.90e-12
Fuel Oil #2 Prod.	2,4-Dinitrotoluene	secondary	1.65e-11	1.82e-12
US electric grid	Fluorene	model/secondary	1.55e-11	1.72e-12
Fuel Oil #6 Prod.	Ethylbenzene	secondary	1.52e-11	1.69e-12
Fuel Oil #2 Prod.	Acetophenone	secondary	1.51e-11	1.68e-12
Fuel Oil #6 Prod.	Copper (+1 & +2)	secondary	1.51e-11	1.67e-12
Natural Gas Prod.	Ethyl Chloride	secondary	1.47e-11	1.63e-12
Fuel Oil #6 Prod.	o-xylene	secondary	1.46e-11	1.62e-12
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	1.44e-11	1.59e-12
LPG Production	5-Methyl chrysene	secondary	1.41e-11	1.57e-12

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Benzo[a]anthracene	secondary	1.35e-11	1.50e-12
Natural Gas Prod.	Anthracene	secondary	1.28e-11	1.42e-12
Fuel Oil #2 Prod.	Chromium (III)	secondary	1.26e-11	1.40e-12
Natural Gas Prod.	Cumene	secondary	1.24e-11	1.38e-12
US electric grid	Fluoranthene	model/secondary	1.24e-11	1.37e-12
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	1.19e-11	1.32e-12
Fuel Oil #4 Prod.	Phenanthrene	secondary	1.13e-11	1.25e-12
LPG Production	Halogenated matter (organic)	secondary	1.12e-11	1.24e-12
Natural Gas Prod.	Acenaphthylene	secondary	1.10e-11	1.22e-12
US electric grid	Dibenzo[a,h]anthracene	model/secondary	1.06e-11	1.18e-12
US electric grid	2-Methylnaphthalene	model/secondary	1.03e-11	1.15e-12
Fuel Oil #4 Prod.	Vinyl acetate	secondary	1.02e-11	1.13e-12
US electric grid	Pyrene	model/secondary	1.02e-11	1.13e-12
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	1.00e-11	1.11e-12
Fuel Oil #2 Prod.	o-xylene	secondary	9.63e-12	1.07e-12
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	9.49e-12	1.05e-12
Fuel Oil #4 Prod.	Zinc (+2)	secondary	9.20e-12	1.02e-12
Natural Gas Prod.	Aromatic hydrocarbons	secondary	8.92e-12	9.90e-13
Natural Gas Prod.	Chrysene	secondary	8.56e-12	9.49e-13
Fuel Oil #4 Prod.	3-Methylcholanthrene	secondary	8.31e-12	9.22e-13
Fuel Oil #2 Prod.	Ethylbenzene	secondary	8.13e-12	9.02e-13
Fuel Oil #6 Prod.	Methyl tert-butyl ether	secondary	7.66e-12	8.49e-13
US electric grid	5-Methyl chrysene	model/secondary	7.64e-12	8.47e-13
Natural Gas Prod.	Biphenyl	secondary	7.40e-12	8.21e-13
US electric grid	o-xylene	model/secondary	7.35e-12	8.15e-13
US electric grid	Benzo[g,h,i]perylene	model/secondary	6.98e-12	7.74e-13
Fuel Oil #6 Prod.	Phenanthrene	secondary	5.83e-12	6.47e-13
Fuel Oil #6 Prod.	Vinyl acetate	secondary	5.45e-12	6.05e-13
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	5.20e-12	5.77e-13
Fuel Oil #6 Prod.	Ethylene dibromide	secondary	5.06e-12	5.61e-13
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	5.03e-12	5.58e-13
Fuel Oil #4 Prod.	Chlorine	secondary	4.52e-12	5.02e-13
Natural Gas Prod.	Copper (+1 & +2)	secondary	4.17e-12	4.63e-13
Fuel Oil #2 Prod.	Methyl tert-butyl ether	secondary	4.08e-12	4.53e-13
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	4.03e-12	4.46e-13
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	3.90e-12	4.33e-13
Natural Gas Prod.	Pyrene	secondary	3.86e-12	4.28e-13
Fuel Oil #6 Prod.	3-Methylcholanthrene	secondary	3.73e-12	4.14e-13
Fuel Oil #6 Prod.	Zinc (+2)	secondary	3.63e-12	4.02e-13
Fuel Oil #2 Prod.	Phenanthrene	secondary	3.28e-12	3.64e-13
Fuel Oil #4 Prod.	Acenaphthene	secondary	3.27e-12	3.63e-13
Fuel Oil #2 Prod.	Zinc (+2)	secondary	3.16e-12	3.51e-13
Fuel Oil #2 Prod.	Vinyl acetate	secondary	2.91e-12	3.22e-13
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	2.76e-12	3.07e-13
Fuel Oil #2 Prod.	Ethylene dibromide	secondary	2.69e-12	2.99e-13
Fuel Oil #2 Prod.	3-Methylcholanthrene	secondary	2.66e-12	2.95e-13
Natural Gas Prod.	Fluorene	secondary	2.58e-12	2.87e-13
Fuel Oil #4 Prod.	Cumene	secondary	2.34e-12	2.59e-13
Fuel Oil #6 Prod.	2-Methylnaphthalene	secondary	2.34e-12	2.59e-13

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Fluoranthene	secondary	2.31e-12	2.56e-13
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	2.12e-12	2.35e-13
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	2.08e-12	2.31e-13
Fuel Oil #6 Prod.	Chlorine	secondary	2.01e-12	2.23e-13
Fuel Oil #2 Prod.	2-Methylnaphthalene	secondary	1.67e-12	1.85e-13
Fuel Oil #6 Prod.	Acenaphthene	secondary	1.59e-12	1.76e-13
Fuel Oil #6 Prod.	Ethyl Chloride	secondary	1.47e-12	1.63e-13
Fuel Oil #2 Prod.	Chlorine	secondary	1.46e-12	1.62e-13
Fuel Oil #4 Prod.	Biphenyl	secondary	1.40e-12	1.55e-13
Fuel Oil #6 Prod.	Cumene	secondary	1.25e-12	1.38e-13
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	1.11e-12	1.23e-13
Fuel Oil #6 Prod.	Benzo[a]pyrene	secondary	1.09e-12	1.21e-13
Fuel Oil #4 Prod.	Acenaphthylene	secondary	1.06e-12	1.18e-13
Fuel Oil #4 Prod.	Anthracene	secondary	1.02e-12	1.14e-13
Fuel Oil #2 Prod.	Acenaphthene	secondary	9.96e-13	1.10e-13
Fuel Oil #4 Prod.	Dibenzo[a,h]anthracene	secondary	9.37e-13	1.04e-13
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	8.61e-13	9.55e-14
Fuel Oil #4 Prod.	Lead cmpds	secondary	8.20e-13	9.10e-14
Natural Gas Prod.	5-Methyl chrysene	secondary	8.05e-13	8.93e-14
Fuel Oil #2 Prod.	Ethyl Chloride	secondary	7.85e-13	8.71e-14
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	7.59e-13	8.42e-14
Fuel Oil #6 Prod.	Biphenyl	secondary	7.44e-13	8.25e-14
Fuel Oil #4 Prod.	Nickel cmpds	secondary	6.93e-13	7.69e-14
Fuel Oil #2 Prod.	Cumene	secondary	6.64e-13	7.37e-14
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	6.57e-13	7.29e-14
Fuel Oil #2 Prod.	Benzo[a]pyrene	secondary	6.19e-13	6.86e-14
Fuel Oil #4 Prod.	Chrysene	secondary	5.71e-13	6.33e-14
Fuel Oil #6 Prod.	Acenaphthylene	secondary	5.49e-13	6.09e-14
Fuel Oil #6 Prod.	Anthracene	secondary	5.18e-13	5.75e-14
Fuel Oil #6 Prod.	Dibenzo[a,h]anthracene	secondary	4.07e-13	4.51e-14
Fuel Oil #6 Prod.	Benzo[a]anthracene	secondary	4.05e-13	4.50e-14
Fuel Oil #6 Prod.	Benzo[b,j,k]fluoranthene	secondary	4.04e-13	4.49e-14
Fuel Oil #2 Prod.	Biphenyl	secondary	3.96e-13	4.40e-14
Fuel Oil #4 Prod.	HALON-1301	secondary	3.57e-13	3.96e-14
Fuel Oil #4 Prod.	Fluorene	secondary	3.33e-13	3.69e-14
Fuel Oil #4 Prod.	Benzo[b]fluoranthene	secondary	3.24e-13	3.59e-14
Fuel Oil #6 Prod.	Indeno(1,2,3-cd)pyrene	secondary	3.18e-13	3.52e-14
Fuel Oil #2 Prod.	Acenaphthylene	secondary	3.10e-13	3.43e-14
Fuel Oil #2 Prod.	Dibenzo[a,h]anthracene	secondary	3.06e-13	3.39e-14
Fuel Oil #2 Prod.	Lead cmpds	secondary	3.06e-13	3.39e-14
Fuel Oil #2 Prod.	Anthracene	secondary	3.03e-13	3.36e-14
Fuel Oil #6 Prod.	Chrysene	secondary	2.82e-13	3.13e-14
Fuel Oil #4 Prod.	Pyrene	secondary	2.74e-13	3.04e-14
Fuel Oil #4 Prod.	Fluoranthene	secondary	2.69e-13	2.99e-14
Fuel Oil #6 Prod.	Lead cmpds	secondary	2.69e-13	2.98e-14
Fuel Oil #2 Prod.	Benzo[a]anthracene	secondary	2.68e-13	2.97e-14
Fuel Oil #2 Prod.	Nickel cmpds	secondary	2.58e-13	2.86e-14
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	2.49e-13	2.77e-14
Fuel Oil #4 Prod.	Mercury compounds	secondary	2.49e-13	2.76e-14
Fuel Oil #6 Prod.	Nickel cmpds	secondary	2.27e-13	2.52e-14
Fuel Oil #2 Prod.	Benzo[b,j,k]fluoranthene	secondary	2.16e-13	2.39e-14

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #2 Prod.	Indeno(1,2,3-cd)pyrene	secondary	2.01e-13	2.23e-14
Fuel Oil #6 Prod.	Fluorene	secondary	1.74e-13	1.93e-14
Fuel Oil #2 Prod.	Chrysene	secondary	1.72e-13	1.90e-14
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	1.52e-13	1.68e-14
Fuel Oil #6 Prod.	Benzo[b]fluoranthene	secondary	1.43e-13	1.58e-14
Fuel Oil #6 Prod.	Fluoranthene	secondary	1.40e-13	1.55e-14
Fuel Oil #6 Prod.	Pyrene	secondary	1.37e-13	1.52e-14
Fuel Oil #2 Prod.	HALON-1301	secondary	1.33e-13	1.47e-14
Fuel Oil #6 Prod.	HALON-1301	secondary	1.17e-13	1.30e-14
Fuel Oil #6 Prod.	Benzo[g,h,i]perylene	secondary	1.17e-13	1.29e-14
Fuel Oil #2 Prod.	Benzo[b]fluoranthene	secondary	1.05e-13	1.17e-14
Fuel Oil #2 Prod.	Fluorene	secondary	9.59e-14	1.06e-14
Fuel Oil #2 Prod.	Mercury compounds	secondary	9.27e-14	1.03e-14
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	8.20e-14	9.10e-15
Fuel Oil #2 Prod.	Pyrene	secondary	8.17e-14	9.06e-15
Fuel Oil #6 Prod.	Mercury compounds	secondary	8.15e-14	9.04e-15
Fuel Oil #6 Prod.	5-Methyl chrysene	secondary	8.09e-14	8.97e-15
Fuel Oil #2 Prod.	Fluoranthene	secondary	7.81e-14	8.66e-15
Fuel Oil #2 Prod.	Benzo[g,h,i]perylene	secondary	7.78e-14	8.63e-15
Natural Gas Prod.	Lead cmpds	secondary	7.44e-14	8.25e-15
Natural Gas Prod.	Nickel cmpds	secondary	6.29e-14	6.97e-15
Fuel Oil #2 Prod.	5-Methyl chrysene	secondary	4.31e-14	4.78e-15
Natural Gas Prod.	HALON-1301	secondary	3.24e-14	3.59e-15
Fuel Oil #2 Prod.	Halogenated matter (organic)	secondary	3.06e-14	3.39e-15
LPG Production	Halogenated hydrocarbons (unspecified)	secondary	2.80e-14	3.11e-15
Fuel Oil #6 Prod.	Halogenated matter (organic)	secondary	2.69e-14	2.98e-15
Natural Gas Prod.	Mercury compounds	secondary	2.26e-14	2.50e-15
Natural Gas Prod.	Halogenated matter (organic)	secondary	7.44e-15	8.25e-16
Fuel Oil #4 Prod.	Halogenated hydrocarbons (unspecified)	secondary	2.05e-16	2.27e-17
Fuel Oil #2 Prod.	Halogenated hydrocarbons (unspecified)	secondary	7.64e-17	8.48e-18
Fuel Oil #6 Prod.	Halogenated hydrocarbons (unspecified)	secondary	6.72e-17	7.46e-18
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	1.86e-17	2.06e-18
Total Manufacturing			**2.35e+02**	**2.60e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Sulfur dioxide	model/secondary	6.15e+02	6.82e+01
US electric grid	Nitrogen oxides	model/secondary	8.79e-01	9.75e-02
US electric grid	Methane	model/secondary	4.81e-01	5.34e-02
US electric grid	Carbon monoxide	model/secondary	4.07e-01	4.52e-02
US electric grid	Arsenic	model/secondary	2.08e-01	2.31e-02
US electric grid	Hydrochloric acid	model/secondary	1.84e-01	2.04e-02
US electric grid	PM-10	model/secondary	4.31e-02	4.78e-03
US electric grid	Selenium	model/secondary	3.46e-02	3.84e-03
US electric grid	Vanadium	model/secondary	2.61e-02	2.89e-03
US electric grid	Hydrofluoric acid	model/secondary	1.00e-02	1.11e-03
US electric grid	Formaldehyde	model/secondary	3.62e-03	4.01e-04
US electric grid	Benzene	model/secondary	2.60e-03	2.89e-04
US electric grid	Nitrous oxide	model/secondary	2.54e-03	2.81e-04
US electric grid	Phosphorus (yellow or white)	model/secondary	1.47e-03	1.63e-04
US electric grid	Zinc (elemental)	model/secondary	6.77e-04	7.51e-05

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
US electric grid	Antimony	model/secondary	5.55e-04	6.16e-05
US electric grid	Chromium (VI)	model/secondary	2.00e-04	2.22e-05
US electric grid	Molybdenum	model/secondary	1.85e-04	2.06e-05
US electric grid	Methyl hydrazine	model/secondary	1.72e-04	1.91e-05
US electric grid	2-Chloroacetophenone	model/secondary	1.61e-04	1.79e-05
US electric grid	Bromomethane	model/secondary	1.59e-04	1.77e-05
US electric grid	Nickel	model/secondary	8.64e-05	9.59e-06
US electric grid	Cyanide (-1)	model/secondary	8.37e-05	9.28e-06
US electric grid	2,3,7,8-TCDD	model/secondary	6.34e-05	7.03e-06
US electric grid	Naphthalene	model/secondary	5.11e-05	5.67e-06
US electric grid	Barium	model/secondary	4.35e-05	4.82e-06
US electric grid	Carbon disulfide	model/secondary	3.42e-05	3.80e-06
US electric grid	Benzyl chloride	model/secondary	2.62e-05	2.91e-06
US electric grid	Cadmium	model/secondary	2.04e-05	2.27e-06
US electric grid	Chloroform	model/secondary	1.85e-05	2.05e-06
US electric grid	Propionaldehyde	model/secondary	1.71e-05	1.90e-06
US electric grid	Manganese	model/secondary	1.70e-05	1.89e-06
US electric grid	Fluoride	model/secondary	1.46e-05	1.62e-06
US electric grid	Beryllium	model/secondary	1.09e-05	1.21e-06
US electric grid	Acrolein	model/secondary	9.71e-06	1.08e-06
US electric grid	Lead	model/secondary	9.52e-06	1.06e-06
US electric grid	Cobalt	model/secondary	9.07e-06	1.01e-06
US electric grid	Copper	model/secondary	8.34e-06	9.25e-07
US electric grid	Methyl chloride	model/secondary	8.05e-06	8.93e-07
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	5.80e-06	6.43e-07
US electric grid	Acetaldehyde	model/secondary	4.62e-06	5.12e-07
US electric grid	Hexane	model/secondary	4.49e-06	4.98e-07
US electric grid	Dimethyl sulfate	model/secondary	3.21e-06	3.56e-07
US electric grid	Mercury	model/secondary	2.80e-06	3.11e-07
US electric grid	Toluene	model/secondary	1.59e-06	1.76e-07
US electric grid	Isophorone	model/secondary	1.55e-06	1.72e-07
US electric grid	Methyl ethyl ketone	model/secondary	1.24e-06	1.38e-07
US electric grid	Tetrachloroethylene	model/secondary	1.23e-06	1.36e-07
US electric grid	1,2-Dichloroethane	model/secondary	1.09e-06	1.21e-07
US electric grid	Methyl methacrylate	model/secondary	1.06e-06	1.18e-07
US electric grid	Styrene	model/secondary	9.39e-07	1.04e-07
US electric grid	Bromoform	model/secondary	8.76e-07	9.72e-08
US electric grid	Dichloromethane	model/secondary	8.65e-07	9.59e-08
US electric grid	Chlorobenzene	model/secondary	7.01e-07	7.78e-08
US electric grid	2,4-Dinitrotoluene	model/secondary	5.62e-07	6.23e-08
US electric grid	Acetophenone	model/secondary	5.16e-07	5.73e-08
US electric grid	Ethylbenzene	model/secondary	2.76e-07	3.07e-08
US electric grid	Methyl tert-butyl ether	model/secondary	1.39e-07	1.55e-08
US electric grid	Phenol	model/secondary	1.06e-07	1.18e-08
US electric grid	Vinyl acetate	model/secondary	9.93e-08	1.10e-08
US electric grid	Phenanthrene	model/secondary	9.35e-08	1.04e-08
US electric grid	Ethylene dibromide	model/secondary	9.21e-08	1.02e-08
US electric grid	Xylene (mixed isomers)	model/secondary	8.23e-08	9.13e-09
US electric grid	Chromium (III)	model/secondary	7.36e-08	8.16e-09
US electric grid	2,3,7,8-TCDF	model/secondary	4.35e-08	4.83e-09
US electric grid	1,1,1-Trichloroethane	model/secondary	4.05e-08	4.49e-09

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
US electric grid	Acenaphthene	model/secondary	2.84e-08	3.15e-09
US electric grid	Ethyl Chloride	model/secondary	2.68e-08	2.98e-09
US electric grid	Cumene	model/secondary	2.27e-08	2.52e-09
US electric grid	Biphenyl	model/secondary	1.35e-08	1.50e-09
US electric grid	Acenaphthylene	model/secondary	8.42e-09	9.34e-10
US electric grid	Benzo[a]pyrene	model/secondary	7.97e-09	8.85e-10
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	7.94e-09	8.81e-10
US electric grid	Anthracene	model/secondary	7.35e-09	8.16e-10
US electric grid	Benzo[a]anthracene	model/secondary	5.29e-09	5.86e-10
US electric grid	Chrysene	model/secondary	3.83e-09	4.25e-10
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	3.76e-09	4.17e-10
US electric grid	Fluorene	model/secondary	2.98e-09	3.31e-10
US electric grid	Fluoranthene	model/secondary	2.38e-09	2.64e-10
US electric grid	Dibenzo[a,h]anthracene	model/secondary	2.05e-09	2.27e-10
US electric grid	2-Methylnaphthalene	model/secondary	1.99e-09	2.21e-10
US electric grid	Pyrene	model/secondary	1.97e-09	2.19e-10
US electric grid	5-Methyl chrysene	model/secondary	1.47e-09	1.63e-10
US electric grid	o-xylene	model/secondary	1.42e-09	1.57e-10
US electric grid	Benzo[g,h,i]perylene	model/secondary	1.35e-09	1.49e-10
Total Use, Maintenance and Repair			**6.17e+02**	**6.84e+01**
End-of-life Life-cycle Stage				
US electric grid	Sulfur dioxide	model/secondary	1.17e-01	1.29e-02
LCD landfilling	Sulfur dioxide	primary	4.45e-02	4.94e-03
LCD incineration	Sulfur dioxide	secondary	3.45e-02	3.83e-03
LCD landfilling	Carbon monoxide	primary	2.40e-03	2.66e-04
LCD landfilling	Nitrogen dioxide	primary	8.92e-04	9.90e-05
US electric grid	Nitrogen oxides	model/secondary	1.67e-04	1.85e-05
LCD landfilling	PM	primary	1.00e-04	1.11e-05
US electric grid	Methane	model/secondary	9.13e-05	1.01e-05
US electric grid	Carbon monoxide	model/secondary	7.73e-05	8.57e-06
LCD incineration	Arsenic cmpds	secondary	4.30e-05	4.77e-06
US electric grid	Arsenic	model/secondary	3.95e-05	4.38e-06
LCD landfilling	Arsenic cmpds	primary	3.65e-05	4.05e-06
US electric grid	Hydrochloric acid	model/secondary	3.49e-05	3.87e-06
LCD landfilling	Methane	primary	2.62e-05	2.91e-06
LPG Production	Carbon monoxide	secondary	2.27e-05	2.52e-06
LCD landfilling	Benzene	primary	9.74e-06	1.08e-06
LCD incineration	Lead	secondary	9.60e-06	1.06e-06
US electric grid	PM-10	model/secondary	8.18e-06	9.08e-07
LPG Production	Methane	secondary	6.61e-06	7.33e-07
US electric grid	Selenium	model/secondary	6.57e-06	7.29e-07
LPG Production	Sulfur oxides	secondary	6.31e-06	7.00e-07
US electric grid	Vanadium	model/secondary	4.94e-06	5.48e-07
LPG Production	Nitrogen oxides	secondary	4.51e-06	5.01e-07
LPG Production	Vanadium	secondary	4.12e-06	4.58e-07
LPG Production	Benzene	secondary	3.38e-06	3.75e-07
LCD landfilling	Silver compounds	primary	2.52e-06	2.79e-07
LCD incineration	Barium cmpds	secondary	2.33e-06	2.58e-07
LCD landfilling	Barium cmpds	primary	1.96e-06	2.17e-07

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LCD incineration	Silver compounds	secondary	1.95e-06	2.17e-07
US electric grid	Hydrofluoric acid	model/secondary	1.91e-06	2.11e-07
LCD landfilling	Hydrochloric acid	primary	1.13e-06	1.25e-07
LPG Production	PM	secondary	1.02e-06	1.13e-07
LCD landfilling	Ammonia	primary	9.17e-07	1.02e-07
LPG Production	Arsenic	secondary	8.13e-07	9.02e-08
US electric grid	Formaldehyde	model/secondary	6.87e-07	7.62e-08
LPG Production	Formaldehyde	secondary	5.28e-07	5.86e-08
US electric grid	Benzene	model/secondary	4.94e-07	5.48e-08
US electric grid	Nitrous oxide	model/secondary	4.81e-07	5.34e-08
LCD incineration	Cadmium cmpds	secondary	3.54e-07	3.92e-08
LCD landfilling	Cadmium cmpds	primary	3.27e-07	3.62e-08
US electric grid	Phosphorus (yellow or white)	model/secondary	2.78e-07	3.09e-08
LPG Production	Hydrochloric acid	secondary	1.45e-07	1.61e-08
US electric grid	Zinc (elemental)	model/secondary	1.28e-07	1.42e-08
LPG Production	Nitrous oxide	secondary	1.28e-07	1.42e-08
LCD landfilling	Hydrogen sulfide	primary	1.11e-07	1.23e-08
US electric grid	Antimony	model/secondary	1.05e-07	1.17e-08
LCD landfilling	Chromium (VI)	primary	7.27e-08	8.07e-09
LPG Production	Phosphorus (yellow or white)	secondary	3.86e-08	4.29e-09
US electric grid	Chromium (VI)	model/secondary	3.80e-08	4.22e-09
US electric grid	Molybdenum	model/secondary	3.52e-08	3.90e-09
US electric grid	Methyl hydrazine	model/secondary	3.26e-08	3.62e-09
US electric grid	2-Chloroacetophenone	model/secondary	3.06e-08	3.39e-09
US electric grid	Bromomethane	model/secondary	3.02e-08	3.35e-09
LPG Production	Fluorides (F-)	secondary	2.97e-08	3.29e-09
LPG Production	Selenium	secondary	2.92e-08	3.24e-09
LPG Production	Hydrogen sulfide	secondary	2.42e-08	2.68e-09
LPG Production	Ammonia	secondary	2.33e-08	2.58e-09
US electric grid	Nickel	model/secondary	1.64e-08	1.82e-09
US electric grid	Cyanide (-1)	model/secondary	1.59e-08	1.76e-09
US electric grid	2,3,7,8-TCDD	model/secondary	1.20e-08	1.33e-09
LCD landfilling	Selenium	primary	1.05e-08	1.16e-09
US electric grid	Naphthalene	model/secondary	9.69e-09	1.08e-09
US electric grid	Barium	model/secondary	8.25e-09	9.15e-10
LPG Production	Hydrofluoric acid	secondary	7.91e-09	8.77e-10
US electric grid	Carbon disulfide	model/secondary	6.50e-09	7.21e-10
LPG Production	Molybdenum	secondary	6.49e-09	7.20e-10
LPG Production	Chromium (VI)	secondary	6.21e-09	6.89e-10
LPG Production	Ethane	secondary	6.11e-09	6.78e-10
US electric grid	Benzyl chloride	model/secondary	4.97e-09	5.52e-10
LPG Production	Zinc (elemental)	secondary	4.72e-09	5.24e-10
LCD incineration	Mercury compounds	secondary	4.57e-09	5.07e-10
LCD landfilling	Carbon tetrachloride	primary	4.07e-09	4.52e-10
LCD landfilling	Mercury compounds	primary	3.96e-09	4.39e-10
US electric grid	Cadmium	model/secondary	3.88e-09	4.30e-10
LPG Production	Hexane	secondary	3.55e-09	3.94e-10
US electric grid	Chloroform	model/secondary	3.51e-09	3.89e-10
US electric grid	Propionaldehyde	model/secondary	3.24e-09	3.60e-10
US electric grid	Manganese	model/secondary	3.23e-09	3.58e-10
LCD landfilling	Chloroform	primary	3.18e-09	3.53e-10

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LCD incineration	Carbon tetrachloride	secondary	3.16e-09	3.50e-10
LPG Production	Phenol	secondary	2.82e-09	3.12e-10
US electric grid	Fluoride	model/secondary	2.77e-09	3.07e-10
LPG Production	Pentane	secondary	2.56e-09	2.84e-10
US electric grid	Beryllium	model/secondary	2.06e-09	2.29e-10
LCD landfilling	Toluene	primary	1.98e-09	2.20e-10
US electric grid	Acrolein	model/secondary	1.84e-09	2.04e-10
US electric grid	Lead	model/secondary	1.81e-09	2.00e-10
LPG Production	PM-10	secondary	1.77e-09	1.97e-10
US electric grid	Cobalt	model/secondary	1.72e-09	1.91e-10
LPG Production	Nickel	secondary	1.62e-09	1.80e-10
US electric grid	Copper	model/secondary	1.58e-09	1.76e-10
US electric grid	Methyl chloride	model/secondary	1.53e-09	1.69e-10
LPG Production	Aluminum (+3)	secondary	1.12e-09	1.24e-10
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	1.10e-09	1.22e-10
US electric grid	Acetaldehyde	model/secondary	8.76e-10	9.72e-11
US electric grid	Hexane	model/secondary	8.51e-10	9.44e-11
LPG Production	Antimony	secondary	8.44e-10	9.37e-11
US electric grid	Dimethyl sulfate	model/secondary	6.10e-10	6.76e-11
US electric grid	Mercury	model/secondary	5.32e-10	5.90e-11
LCD incineration	Lead cmpds	secondary	5.19e-10	5.75e-11
LCD landfilling	Lead cmpds	primary	4.80e-10	5.33e-11
LPG Production	Nitrate	secondary	4.77e-10	5.29e-11
LCD landfilling	Xylene (mixed isomers)	primary	4.08e-10	4.53e-11
US electric grid	Toluene	model/secondary	3.01e-10	3.34e-11
US electric grid	Isophorone	model/secondary	2.95e-10	3.27e-11
LCD landfilling	Tetrachloroethylene	primary	2.90e-10	3.21e-11
LCD landfilling	1,2-Dichloroethane	primary	2.77e-10	3.07e-11
US electric grid	Methyl ethyl ketone	model/secondary	2.36e-10	2.62e-11
US electric grid	Tetrachloroethylene	model/secondary	2.33e-10	2.59e-11
US electric grid	1,2-Dichloroethane	model/secondary	2.07e-10	2.30e-11
US electric grid	Methyl methacrylate	model/secondary	2.02e-10	2.24e-11
US electric grid	Styrene	model/secondary	1.78e-10	1.98e-11
LCD landfilling	Trichloroethylene	primary	1.72e-10	1.91e-11
US electric grid	Bromoform	model/secondary	1.66e-10	1.84e-11
US electric grid	Dichloromethane	model/secondary	1.64e-10	1.82e-11
LPG Production	Copper	secondary	1.37e-10	1.52e-11
LPG Production	Methyl hydrazine	secondary	1.35e-10	1.50e-11
LPG Production	Silicon	secondary	1.33e-10	1.48e-11
LCD incineration	Trichloroethylene	secondary	1.33e-10	1.48e-11
US electric grid	Chlorobenzene	model/secondary	1.33e-10	1.48e-11
LPG Production	2-Chloroacetophenone	secondary	1.27e-10	1.41e-11
LPG Production	Dimethylbenzanthracene	secondary	1.26e-10	1.39e-11
LPG Production	Bromomethane	secondary	1.25e-10	1.39e-11
LCD landfilling	Ethylbenzene	primary	1.07e-10	1.19e-11
US electric grid	2,4-Dinitrotoluene	model/secondary	1.07e-10	1.18e-11
LPG Production	Naphthalene	secondary	1.03e-10	1.14e-11
US electric grid	Acetophenone	model/secondary	9.79e-11	1.09e-11
LPG Production	Lead	secondary	9.74e-11	1.08e-11

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Manganese	secondary	8.79e-11	9.75e-12
LPG Production	Beryllium	secondary	8.45e-11	9.37e-12
LPG Production	Barium	secondary	7.34e-11	8.14e-12
LPG Production	Cyanide (-1)	secondary	6.59e-11	7.31e-12
LPG Production	Barium cmpds	secondary	6.25e-11	6.93e-12
US electric grid	Ethylbenzene	model/secondary	5.24e-11	5.82e-12
LCD landfilling	Dichloromethane	primary	4.84e-11	5.36e-12
LPG Production	Cadmium	secondary	3.63e-11	4.02e-12
LCD landfilling	Vinyl chloride	primary	3.62e-11	4.01e-12
LCD incineration	Vinyl chloride	secondary	2.81e-11	3.11e-12
LPG Production	Carbon disulfide	secondary	2.70e-11	2.99e-12
US electric grid	Methyl tert-butyl ether	model/secondary	2.65e-11	2.93e-12
LPG Production	Benzyl chloride	secondary	2.06e-11	2.29e-12
US electric grid	Phenol	model/secondary	2.02e-11	2.24e-12
LPG Production	Cobalt	secondary	1.98e-11	2.19e-12
US electric grid	Vinyl acetate	model/secondary	1.88e-11	2.09e-12
US electric grid	Phenanthrene	model/secondary	1.77e-11	1.97e-12
US electric grid	Ethylene dibromide	model/secondary	1.75e-11	1.94e-12
US electric grid	Xylene (mixed isomers)	model/secondary	1.56e-11	1.73e-12
LPG Production	Aluminum (elemental)	secondary	1.52e-11	1.69e-12
LPG Production	Chloroform	secondary	1.46e-11	1.61e-12
US electric grid	Chromium (III)	model/secondary	1.40e-11	1.55e-12
LPG Production	Propionaldehyde	secondary	1.35e-11	1.49e-12
LCD incineration	o-xylene	secondary	9.08e-12	1.01e-12
US electric grid	2,3,7,8-TCDF	model/secondary	8.26e-12	9.16e-13
LCD landfilling	Chromium (III)	primary	7.92e-12	8.78e-13
US electric grid	1,1,1-Trichloroethane	model/secondary	7.68e-12	8.52e-13
LPG Production	Acrolein	secondary	7.64e-12	8.48e-13
LPG Production	Methyl chloride	secondary	6.34e-12	7.03e-13
US electric grid	Acenaphthene	model/secondary	5.39e-12	5.98e-13
US electric grid	Ethyl Chloride	model/secondary	5.09e-12	5.65e-13
LPG Production	Di(2-ethylhexyl)phthalate	secondary	4.57e-12	5.07e-13
US electric grid	Cumene	model/secondary	4.31e-12	4.78e-13
LPG Production	Acetaldehyde	secondary	3.64e-12	4.03e-13
LPG Production	Mercury	secondary	3.42e-12	3.80e-13
LPG Production	Cadmium cmpds	secondary	2.74e-12	3.04e-13
US electric grid	Biphenyl	model/secondary	2.57e-12	2.85e-13
LPG Production	Dimethyl sulfate	secondary	2.53e-12	2.81e-13
LPG Production	Toluene	secondary	2.45e-12	2.72e-13
US electric grid	Acenaphthylene	model/secondary	1.60e-12	1.77e-13
US electric grid	Benzo[a]pyrene	model/secondary	1.51e-12	1.68e-13
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	1.51e-12	1.67e-13
LPG Production	1,4-Dichlorobenzene	secondary	1.43e-12	1.58e-13
US electric grid	Anthracene	model/secondary	1.40e-12	1.55e-13
LPG Production	Isophorone	secondary	1.22e-12	1.36e-13
LPG Production	Aromatic hydrocarbons	secondary	1.10e-12	1.22e-13
US electric grid	Benzo[a]anthracene	model/secondary	1.00e-12	1.11e-13
LPG Production	Methyl ethyl ketone	secondary	9.79e-13	1.09e-13
LPG Production	Tetrachloroethylene	secondary	9.67e-13	1.07e-13
LPG Production	1,2-Dichloroethane	secondary	8.60e-13	9.54e-14
LPG Production	Methyl methacrylate	secondary	8.36e-13	9.28e-14

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Styrene	secondary	7.39e-13	8.20e-14
US electric grid	Chrysene	model/secondary	7.27e-13	8.07e-14
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	7.13e-13	7.91e-14
LPG Production	Bromoform	secondary	6.90e-13	7.66e-14
LPG Production	Dichloromethane	secondary	6.81e-13	7.55e-14
LPG Production	Chromium (III)	secondary	6.76e-13	7.50e-14
US electric grid	Fluorene	model/secondary	5.66e-13	6.28e-14
LPG Production	Chlorobenzene	secondary	5.52e-13	6.12e-14
LPG Production	Copper (+1 & +2)	secondary	5.16e-13	5.72e-14
US electric grid	Fluoranthene	model/secondary	4.52e-13	5.02e-14
LPG Production	2,4-Dinitrotoluene	secondary	4.43e-13	4.91e-14
LPG Production	Acetophenone	secondary	4.06e-13	4.51e-14
US electric grid	Dibenzo[a,h]anthracene	model/secondary	3.88e-13	4.31e-14
US electric grid	2-Methylnaphthalene	model/secondary	3.78e-13	4.19e-14
US electric grid	Pyrene	model/secondary	3.74e-13	4.15e-14
US electric grid	5-Methyl chrysene	model/secondary	2.79e-13	3.10e-14
LPG Production	o-xylene	secondary	2.70e-13	3.00e-14
US electric grid	o-xylene	model/secondary	2.69e-13	2.98e-14
US electric grid	Benzo[g,h,i]perylene	model/secondary	2.55e-13	2.83e-14
LPG Production	Ethylbenzene	secondary	2.19e-13	2.43e-14
LPG Production	Methyl tert-butyl ether	secondary	1.10e-13	1.22e-14
LPG Production	Zinc (+2)	secondary	9.24e-14	1.03e-14
LPG Production	Phenanthrene	secondary	8.93e-14	9.90e-15
LPG Production	Vinyl acetate	secondary	7.82e-14	8.67e-15
LPG Production	3-Methylcholanthrene	secondary	7.56e-14	8.38e-15
LPG Production	Ethylene dibromide	secondary	7.25e-14	8.04e-15
LPG Production	2-Methylnaphthalene	secondary	4.73e-14	5.25e-15
LPG Production	Chlorine	secondary	4.19e-14	4.65e-15
LPG Production	1,1,1-Trichloroethane	secondary	2.98e-14	3.31e-15
LPG Production	Acenaphthene	secondary	2.77e-14	3.07e-15
LPG Production	Ethyl Chloride	secondary	2.11e-14	2.34e-15
LPG Production	Cumene	secondary	1.79e-14	1.98e-15
LPG Production	Benzo[a]pyrene	secondary	1.69e-14	1.87e-15
LPG Production	Biphenyl	secondary	1.07e-14	1.18e-15
LPG Production	Lead cmpds	secondary	9.19e-15	1.02e-15
LPG Production	Dibenzo[a,h]anthracene	secondary	8.77e-15	9.72e-16
LPG Production	Acenaphthylene	secondary	8.43e-15	9.35e-16
LPG Production	Anthracene	secondary	8.31e-15	9.22e-16
LPG Production	Nickel cmpds	secondary	7.77e-15	8.62e-16
LPG Production	Benzo[a]anthracene	secondary	7.51e-15	8.33e-16
LPG Production	Benzo[b,j,k]fluoranthene	secondary	5.80e-15	6.43e-16
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	5.59e-15	6.20e-16
LPG Production	Chrysene	secondary	4.74e-15	5.26e-16
LPG Production	HALON-1301	secondary	4.00e-15	4.44e-16
LPG Production	Benzo[b]fluoranthene	secondary	3.00e-15	3.33e-16
LPG Production	Mercury compounds	secondary	2.79e-15	3.09e-16
LPG Production	Fluorene	secondary	2.60e-15	2.88e-16
LPG Production	Pyrene	secondary	2.25e-15	2.49e-16
LPG Production	Benzo[g,h,i]perylene	secondary	2.19e-15	2.42e-16

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LPG Production	Fluoranthene	secondary	2.12e-15	2.35e-16
LPG Production	5-Methyl chrysene	secondary	1.16e-15	1.29e-16
LPG Production	Halogenated matter (organic)	secondary	9.19e-16	1.02e-16
LPG Production	Halogenated hydrocarbons (unspecified)	secondary	2.30e-18	2.55e-19
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	-3.90e-18	-4.33e-19
LCD incineration	Halogenated hydrocarbons (unspecified)	secondary	-4.13e-17	-4.58e-18
Fuel Oil #4 Prod.	Halogenated hydrocarbons (unspecified)	secondary	-9.44e-16	-1.05e-16
Natural Gas Prod.	Halogenated matter (organic)	secondary	-1.56e-15	-1.73e-16
Natural Gas Prod.	Mercury compounds	secondary	-4.74e-15	-5.25e-16
Natural Gas Prod.	HALON-1301	secondary	-6.79e-15	-7.54e-16
Natural Gas Prod.	Nickel cmpds	secondary	-1.32e-14	-1.46e-15
Natural Gas Prod.	Lead cmpds	secondary	-1.56e-14	-1.73e-15
LCD incineration	Halogenated matter (organic)	secondary	-2.38e-14	-2.64e-15
LCD incineration	HALON-1301	secondary	-1.03e-13	-1.15e-14
Natural Gas Prod.	5-Methyl chrysene	secondary	-1.69e-13	-1.88e-14
LCD incineration	Nickel cmpds	secondary	-2.01e-13	-2.23e-14
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	-3.78e-13	-4.19e-14
Natural Gas Prod.	Fluoranthene	secondary	-4.85e-13	-5.38e-14
Natural Gas Prod.	Fluorene	secondary	-5.43e-13	-6.02e-14
LCD incineration	Benzo[b]fluoranthene	secondary	-6.58e-13	-7.30e-14
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	-6.99e-13	-7.76e-14
Natural Gas Prod.	Pyrene	secondary	-8.10e-13	-8.99e-14
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	-8.45e-13	-9.38e-14
Natural Gas Prod.	Copper (+1 & +2)	secondary	-8.77e-13	-9.72e-14
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	-1.06e-12	-1.17e-13
Fuel Oil #4 Prod.	Mercury compounds	secondary	-1.15e-12	-1.27e-13
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	-1.15e-12	-1.27e-13
Fuel Oil #4 Prod.	Fluoranthene	secondary	-1.24e-12	-1.38e-13
Fuel Oil #4 Prod.	Pyrene	secondary	-1.26e-12	-1.40e-13
Fuel Oil #4 Prod.	Benzo[b]fluoranthene	secondary	-1.49e-12	-1.66e-13
Fuel Oil #4 Prod.	Fluorene	secondary	-1.53e-12	-1.70e-13
Natural Gas Prod.	Biphenyl	secondary	-1.55e-12	-1.72e-13
Fuel Oil #4 Prod.	HALON-1301	secondary	-1.64e-12	-1.82e-13
Natural Gas Prod.	Chrysene	secondary	-1.80e-12	-1.99e-13
LCD incineration	Dibenzo[a,h]anthracene	secondary	-1.83e-12	-2.02e-13
Natural Gas Prod.	Aromatic hydrocarbons	secondary	-1.87e-12	-2.08e-13
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	-2.11e-12	-2.34e-13
Natural Gas Prod.	Acenaphthylene	secondary	-2.32e-12	-2.57e-13
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	-2.49e-12	-2.76e-13
Natural Gas Prod.	Cumene	secondary	-2.61e-12	-2.89e-13
Fuel Oil #4 Prod.	Chrysene	secondary	-2.63e-12	-2.92e-13
Natural Gas Prod.	Anthracene	secondary	-2.69e-12	-2.99e-13
Natural Gas Prod.	Benzo[a]anthracene	secondary	-2.83e-12	-3.14e-13
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	-3.03e-12	-3.36e-13
Natural Gas Prod.	Ethyl Chloride	secondary	-3.08e-12	-3.42e-13
Fuel Oil #4 Prod.	Nickel cmpds	secondary	-3.19e-12	-3.54e-13
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	-3.50e-12	-3.88e-13
Fuel Oil #4 Prod.	Lead cmpds	secondary	-3.78e-12	-4.19e-13
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	-3.97e-12	-4.40e-13
Fuel Oil #4 Prod.	Dibenzo[a,h]anthracene	secondary	-4.32e-12	-4.79e-13
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-4.35e-12	-4.82e-13

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Cadmium cmpds	secondary	-4.65e-12	-5.16e-13
Fuel Oil #4 Prod.	Anthracene	secondary	-4.72e-12	-5.24e-13
Fuel Oil #4 Prod.	Acenaphthylene	secondary	-4.90e-12	-5.43e-13
Natural Gas Prod.	Acenaphthene	secondary	-5.87e-12	-6.52e-13
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	-5.88e-12	-6.52e-13
Fuel Oil #4 Prod.	Biphenyl	secondary	-6.43e-12	-7.13e-13
Natural Gas Prod.	Benzo[a]pyrene	secondary	-6.53e-12	-7.25e-13
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	-9.76e-12	-1.08e-12
Natural Gas Prod.	Ethylene dibromide	secondary	-1.06e-11	-1.17e-12
Fuel Oil #4 Prod.	Cumene	secondary	-1.08e-11	-1.20e-12
LCD incineration	2-Methylnaphthalene	secondary	-1.13e-11	-1.25e-12
Natural Gas Prod.	Vinyl acetate	secondary	-1.14e-11	-1.26e-12
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	-1.27e-11	-1.41e-12
LCD incineration	Copper (+1 & +2)	secondary	-1.34e-11	-1.48e-12
Fuel Oil #4 Prod.	Acenaphthene	secondary	-1.51e-11	-1.67e-12
Natural Gas Prod.	Methyl tert-butyl ether	secondary	-1.60e-11	-1.78e-12
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-1.80e-11	-1.99e-12
LCD incineration	3-Methylcholanthrene	secondary	-1.80e-11	-2.00e-12
Fuel Oil #4 Prod.	Chlorine	secondary	-2.08e-11	-2.31e-12
Natural Gas Prod.	Phenanthrene	secondary	-2.33e-11	-2.59e-12
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	-2.40e-11	-2.66e-12
LCD incineration	Chlorine	secondary	-2.51e-11	-2.79e-12
LCD incineration	Benzo[g,h,i]perylene	secondary	-2.63e-11	-2.92e-12
Natural Gas Prod.	Aluminum (elemental)	secondary	-2.81e-11	-3.12e-12
LCD incineration	Aromatic hydrocarbons	secondary	-2.86e-11	-3.17e-12
LCD incineration	Zinc (+2)	secondary	-2.90e-11	-3.22e-12
LCD incineration	Dichlorobenzene (mixed isomers)	secondary	-3.18e-11	-3.52e-12
Natural Gas Prod.	Ethylbenzene	secondary	-3.20e-11	-3.55e-12
Natural Gas Prod.	2-Methylnaphthalene	secondary	-3.58e-11	-3.97e-12
Fuel Oil #4 Prod.	3-Methylcholanthrene	secondary	-3.83e-11	-4.25e-12
Fuel Oil #4 Prod.	Zinc (+2)	secondary	-4.24e-11	-4.70e-12
LCD incineration	5-Methyl chrysene	secondary	-4.24e-11	-4.70e-12
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	-4.37e-11	-4.85e-12
Fuel Oil #4 Prod.	Vinyl acetate	secondary	-4.71e-11	-5.23e-12
LCD incineration	Pyrene	secondary	-5.06e-11	-5.62e-12
Fuel Oil #4 Prod.	Phenanthrene	secondary	-5.20e-11	-5.76e-12
Natural Gas Prod.	Chromium (III)	secondary	-5.33e-11	-5.91e-12
Natural Gas Prod.	3-Methylcholanthrene	secondary	-5.72e-11	-6.35e-12
Natural Gas Prod.	Acetophenone	secondary	-5.93e-11	-6.57e-12
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	-6.45e-11	-7.16e-12
LCD incineration	Fluoranthene	secondary	-6.52e-11	-7.23e-12
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	-6.62e-11	-7.34e-12
Natural Gas Prod.	Chlorobenzene	secondary	-8.05e-11	-8.93e-12
LCD incineration	Fluorene	secondary	-8.35e-11	-9.27e-12
LCD incineration	Indeno(1,2,3-cd)pyrene	secondary	-9.04e-11	-1.00e-11
LCD incineration	Chrysene	secondary	-9.73e-11	-1.08e-11
Natural Gas Prod.	Dichloromethane	secondary	-9.93e-11	-1.10e-11
Natural Gas Prod.	Bromoform	secondary	-1.01e-10	-1.12e-11
Natural Gas Prod.	Barium cmpds	secondary	-1.06e-10	-1.18e-11

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Styrene	secondary	-1.08e-10	-1.19e-11
LCD incineration	Benzo[a]anthracene	secondary	-1.18e-10	-1.31e-11
Natural Gas Prod.	Methyl methacrylate	secondary	-1.22e-10	-1.35e-11
Natural Gas Prod.	1,2-Dichloroethane	secondary	-1.25e-10	-1.39e-11
Fuel Oil #4 Prod.	Ethylbenzene	secondary	-1.32e-10	-1.46e-11
Natural Gas Prod.	Tetrachloroethylene	secondary	-1.41e-10	-1.56e-11
Natural Gas Prod.	Methyl ethyl ketone	secondary	-1.43e-10	-1.58e-11
Fuel Oil #4 Prod.	o-xylene	secondary	-1.43e-10	-1.58e-11
Natural Gas Prod.	Isophorone	secondary	-1.78e-10	-1.98e-11
Fuel Oil #4 Prod.	Chromium (III)	secondary	-2.04e-10	-2.27e-11
LCD incineration	Anthracene	secondary	-2.05e-10	-2.28e-11
LCD incineration	Benzo[b,j,k]fluoranthene	secondary	-2.12e-10	-2.35e-11
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	-2.12e-10	-2.35e-11
LCD incineration	Benzo[a]pyrene	secondary	-2.31e-10	-2.57e-11
LCD incineration	Acenaphthylene	secondary	-2.41e-10	-2.68e-11
Fuel Oil #4 Prod.	Acetophenone	secondary	-2.45e-10	-2.72e-11
Natural Gas Prod.	Silicon	secondary	-2.46e-10	-2.73e-11
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	-2.67e-10	-2.96e-11
Natural Gas Prod.	Chlorine	secondary	-3.13e-10	-3.48e-11
Fuel Oil #4 Prod.	Chlorobenzene	secondary	-3.33e-10	-3.69e-11
Natural Gas Prod.	Zinc (+2)	secondary	-3.47e-10	-3.85e-11
Natural Gas Prod.	Dimethyl sulfate	secondary	-3.69e-10	-4.09e-11
LCD incineration	Biphenyl	secondary	-3.90e-10	-4.32e-11
Fuel Oil #4 Prod.	Dichloromethane	secondary	-4.11e-10	-4.56e-11
Fuel Oil #4 Prod.	Bromoform	secondary	-4.16e-10	-4.62e-11
Fuel Oil #4 Prod.	Styrene	secondary	-4.46e-10	-4.94e-11
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	-4.53e-10	-5.03e-11
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	-5.04e-10	-5.59e-11
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	-5.19e-10	-5.75e-11
Natural Gas Prod.	Acetaldehyde	secondary	-5.30e-10	-5.88e-11
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	-5.83e-10	-6.47e-11
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	-5.90e-10	-6.54e-11
Natural Gas Prod.	Mercury	secondary	-6.23e-10	-6.92e-11
LCD incineration	Cumene	secondary	-6.53e-10	-7.25e-11
LCD incineration	Acenaphthene	secondary	-6.59e-10	-7.31e-11
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	-6.66e-10	-7.39e-11
LCD incineration	Aluminum (elemental)	secondary	-7.02e-10	-7.79e-11
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	-7.23e-10	-8.02e-11
Fuel Oil #4 Prod.	Isophorone	secondary	-7.37e-10	-8.18e-11
LCD incineration	Ethyl Chloride	secondary	-7.72e-10	-8.57e-11
Natural Gas Prod.	Methyl chloride	secondary	-9.24e-10	-1.03e-10
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	-1.08e-09	-1.20e-10
LCD incineration	1,1,1-Trichloroethane	secondary	-1.09e-09	-1.21e-10
Natural Gas Prod.	Acrolein	secondary	-1.11e-09	-1.24e-10
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	-1.12e-09	-1.25e-10
Fuel Oil #4 Prod.	Toluene	secondary	-1.35e-09	-1.49e-10
Natural Gas Prod.	o-xylene	secondary	-1.52e-09	-1.69e-10
Fuel Oil #4 Prod.	Dimethyl sulfate	secondary	-1.53e-09	-1.69e-10
Natural Gas Prod.	Cobalt	secondary	-1.75e-09	-1.94e-10
Natural Gas Prod.	Aluminum (+3)	secondary	-1.90e-09	-2.10e-10
Natural Gas Prod.	Propionaldehyde	secondary	-1.96e-09	-2.18e-10

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Mercury	secondary	-2.05e-09	-2.28e-10
Natural Gas Prod.	Chloroform	secondary	-2.12e-09	-2.35e-10
Fuel Oil #4 Prod.	Acetaldehyde	secondary	-2.19e-09	-2.43e-10
LCD incineration	Xylene (mixed isomers)	secondary	-2.22e-09	-2.46e-10
LCD incineration	Phenanthrene	secondary	-2.61e-09	-2.89e-10
LCD incineration	Ethylene dibromide	secondary	-2.65e-09	-2.94e-10
Fuel Oil #4 Prod.	Di(2-ethylhexyl)phthalate	secondary	-2.75e-09	-3.05e-10
Natural Gas Prod.	Toluene	secondary	-2.86e-09	-3.17e-10
LCD incineration	Vinyl acetate	secondary	-2.86e-09	-3.17e-10
Natural Gas Prod.	Benzyl chloride	secondary	-3.01e-09	-3.34e-10
Natural Gas Prod.	PM-10	secondary	-3.27e-09	-3.63e-10
Fuel Oil #4 Prod.	Methyl chloride	secondary	-3.82e-09	-4.24e-10
Natural Gas Prod.	Carbon disulfide	secondary	-3.93e-09	-4.36e-10
LCD incineration	Methyl tert-butyl ether	secondary	-4.01e-09	-4.45e-10
Fuel Oil #4 Prod.	Acrolein	secondary	-4.61e-09	-5.11e-10
Natural Gas Prod.	Phenol	secondary	-4.83e-09	-5.36e-10
Natural Gas Prod.	Cadmium	secondary	-5.28e-09	-5.86e-10
LCD incineration	Silicon	secondary	-6.14e-09	-6.81e-10
LCD incineration	Ethylbenzene	secondary	-7.87e-09	-8.73e-10
Fuel Oil #4 Prod.	Propionaldehyde	secondary	-8.11e-09	-9.00e-10
Fuel Oil #4 Prod.	Chloroform	secondary	-8.78e-09	-9.74e-10
Natural Gas Prod.	Cyanide (-1)	secondary	-9.61e-09	-1.07e-09
Natural Gas Prod.	Nitrate	secondary	-9.96e-09	-1.10e-09
Fuel Oil #4 Prod.	Aluminum (elemental)	secondary	-1.06e-08	-1.18e-09
LCD incineration	Chromium (III)	secondary	-1.13e-08	-1.26e-09
Fuel Oil #4 Prod.	Cobalt	secondary	-1.22e-08	-1.36e-09
Fuel Oil #4 Prod.	Benzyl chloride	secondary	-1.24e-08	-1.38e-09
Natural Gas Prod.	Manganese	secondary	-1.31e-08	-1.45e-09
LCD incineration	Chloroacetophenone	secondary	-1.35e-08	-1.50e-09
Natural Gas Prod.	Beryllium	secondary	-1.41e-08	-1.57e-09
Natural Gas Prod.	Lead	secondary	-1.43e-08	-1.59e-09
LCD incineration	Acetophenone	secondary	-1.49e-08	-1.65e-09
LCD incineration	2,4-Dinitrotoluene	secondary	-1.62e-08	-1.79e-09
Fuel Oil #4 Prod.	Carbon disulfide	secondary	-1.63e-08	-1.80e-09
Natural Gas Prod.	Copper	secondary	-1.75e-08	-1.94e-09
Natural Gas Prod.	Bromomethane	secondary	-1.83e-08	-2.03e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	-1.85e-08	-2.05e-09
Natural Gas Prod.	Barium	secondary	-1.95e-08	-2.17e-09
Natural Gas Prod.	Methyl hydrazine	secondary	-1.98e-08	-2.19e-09
LCD incineration	Chlorobenzene	secondary	-2.02e-08	-2.24e-09
Fuel Oil #4 Prod.	Cadmium	secondary	-2.16e-08	-2.39e-09
LCD incineration	Dichloromethane	secondary	-2.49e-08	-2.76e-09
LCD incineration	Bromoform	secondary	-2.52e-08	-2.80e-09
Fuel Oil #4 Prod.	Barium cmpds	secondary	-2.57e-08	-2.85e-09
LCD incineration	Styrene	secondary	-2.70e-08	-3.00e-09
LCD incineration	Aluminum (+3)	secondary	-2.89e-08	-3.20e-09
LCD incineration	Methyl methacrylate	secondary	-3.06e-08	-3.39e-09
LCD incineration	1,2-Dichloroethane	secondary	-3.12e-08	-3.46e-09
LCD incineration	Dimethylbenzanthracene	secondary	-3.12e-08	-3.47e-09

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LCD incineration	Tetrachloroethylene	secondary	-3.51e-08	-3.90e-09
LCD incineration	Methyl ethyl ketone	secondary	-3.58e-08	-3.97e-09
Fuel Oil #4 Prod.	Barium	secondary	-3.61e-08	-4.00e-09
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	-3.97e-08	-4.41e-09
Natural Gas Prod.	Naphthalene	secondary	-4.37e-08	-4.84e-09
Natural Gas Prod.	Hydrogen sulfide	secondary	-4.46e-08	-4.94e-09
LCD incineration	Isophorone	secondary	-4.47e-08	-4.96e-09
LCD incineration	Toluene	secondary	-4.73e-08	-5.24e-09
Fuel Oil #4 Prod.	Beryllium	secondary	-5.06e-08	-5.62e-09
Fuel Oil #4 Prod.	Manganese	secondary	-5.28e-08	-5.86e-09
Fuel Oil #4 Prod.	Naphthalene	secondary	-5.36e-08	-5.94e-09
Natural Gas Prod.	Nickel	secondary	-5.78e-08	-6.41e-09
Fuel Oil #4 Prod.	Lead	secondary	-5.88e-08	-6.52e-09
Fuel Oil #4 Prod.	Dimethylbenzanthracene	secondary	-6.37e-08	-7.06e-09
Fuel Oil #4 Prod.	Bromomethane	secondary	-7.56e-08	-8.39e-09
LCD incineration	Phenol	secondary	-7.60e-08	-8.43e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	-7.65e-08	-8.49e-09
LCD incineration	PM-10	secondary	-8.16e-08	-9.05e-09
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	-8.17e-08	-9.06e-09
LCD incineration	Mercury	secondary	-8.42e-08	-9.34e-09
Fuel Oil #4 Prod.	Copper	secondary	-8.86e-08	-9.82e-09
LCD incineration	Dimethyl sulfate	secondary	-9.25e-08	-1.03e-08
Fuel Oil #4 Prod.	Silicon	secondary	-9.29e-08	-1.03e-08
Natural Gas Prod.	Dimethylbenzanthracene	secondary	-9.51e-08	-1.06e-08
LCD incineration	Acetaldehyde	secondary	-1.33e-07	-1.47e-08
Natural Gas Prod.	Antimony	secondary	-1.48e-07	-1.64e-08
LCD incineration	Di(2-ethylhexyl)phthalate	secondary	-1.67e-07	-1.85e-08
Fuel Oil #4 Prod.	Nitrate	secondary	-2.08e-07	-2.31e-08
LCD incineration	Methyl chloride	secondary	-2.32e-07	-2.57e-08
LCD incineration	Cobalt	secondary	-2.48e-07	-2.76e-08
LCD incineration	Copper	secondary	-2.67e-07	-2.96e-08
LCD incineration	Acrolein	secondary	-2.79e-07	-3.10e-08
Fuel Oil #4 Prod.	Antimony	secondary	-4.22e-07	-4.68e-08
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	-4.59e-07	-5.09e-08
Natural Gas Prod.	Chromium (VI)	secondary	-4.90e-07	-5.43e-08
LCD incineration	Propionaldehyde	secondary	-4.92e-07	-5.46e-08
LCD incineration	Chloroform	secondary	-5.30e-07	-5.88e-08
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	-5.86e-07	-6.50e-08
LCD incineration	Pentane	secondary	-6.12e-07	-6.78e-08
LCD incineration	Cadmium	secondary	-7.25e-07	-8.04e-08
LCD incineration	Benzyl chloride	secondary	-7.55e-07	-8.37e-08
Natural Gas Prod.	Molybdenum	secondary	-7.66e-07	-8.50e-08
LCD incineration	Barium	secondary	-8.87e-07	-9.84e-08
LCD incineration	Hexane	secondary	-9.76e-07	-1.08e-07
LCD incineration	Carbon disulfide	secondary	-9.86e-07	-1.09e-07
LCD incineration	Hydrogen sulfide	secondary	-1.03e-06	-1.14e-07
Fuel Oil #4 Prod.	Nickel	secondary	-1.09e-06	-1.20e-07
Natural Gas Prod.	Hydrofluoric acid	secondary	-1.15e-06	-1.28e-07
Fuel Oil #4 Prod.	Phenol	secondary	-1.16e-06	-1.28e-07
Fuel Oil #4 Prod.	PM-10	secondary	-1.24e-06	-1.37e-07
Fuel Oil #4 Prod.	Pentane	secondary	-1.30e-06	-1.44e-07

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LCD incineration	Naphthalene	secondary	-1.33e-06	-1.48e-07
LCD incineration	Ethane	secondary	-1.46e-06	-1.62e-07
Fuel Oil #4 Prod.	Hexane	secondary	-1.80e-06	-2.00e-07
Fuel Oil #4 Prod.	Chromium (VI)	secondary	-1.88e-06	-2.08e-07
Natural Gas Prod.	Pentane	secondary	-1.94e-06	-2.15e-07
LCD incineration	Nitrate	secondary	-2.33e-06	-2.58e-07
Fuel Oil #4 Prod.	Zinc (elemental)	secondary	-2.35e-06	-2.61e-07
LCD incineration	Cyanide (-1)	secondary	-2.41e-06	-2.67e-07
Natural Gas Prod.	Hexane	secondary	-2.69e-06	-2.98e-07
Natural Gas Prod.	Zinc (elemental)	secondary	-2.81e-06	-3.12e-07
LCD incineration	Beryllium	secondary	-2.97e-06	-3.30e-07
Fuel Oil #4 Prod.	Ethane	secondary	-3.10e-06	-3.43e-07
LCD incineration	Manganese	secondary	-3.17e-06	-3.52e-07
Natural Gas Prod.	Selenium	secondary	-4.02e-06	-4.46e-07
Fuel Oil #4 Prod.	Molybdenum	secondary	-4.28e-06	-4.75e-07
Natural Gas Prod.	Fluorides (F-)	secondary	-4.50e-06	-4.99e-07
LCD incineration	Bromomethane	secondary	-4.59e-06	-5.09e-07
Natural Gas Prod.	Ethane	secondary	-4.63e-06	-5.13e-07
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	-4.77e-06	-5.29e-07
LCD incineration	Methyl hydrazine	secondary	-4.95e-06	-5.49e-07
LCD incineration	Molybdenum	secondary	-6.45e-06	-7.16e-07
Natural Gas Prod.	Nitrous oxide	secondary	-7.65e-06	-8.48e-07
LCD incineration	Nickel	secondary	-8.94e-06	-9.91e-07
Natural Gas Prod.	Formaldehyde	secondary	-9.17e-06	-1.02e-06
Fuel Oil #4 Prod.	Ammonia	secondary	-1.15e-05	-1.27e-06
LCD incineration	Antimony	secondary	-1.40e-05	-1.55e-06
LCD incineration	Zinc (elemental)	secondary	-1.65e-05	-1.83e-06
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	-1.68e-05	-1.87e-06
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	-1.76e-05	-1.95e-06
Fuel Oil #4 Prod.	Selenium	secondary	-1.77e-05	-1.97e-06
Natural Gas Prod.	Hydrochloric acid	secondary	-2.11e-05	-2.35e-06
Natural Gas Prod.	Vanadium	secondary	-2.30e-05	-2.56e-06
Fuel Oil #4 Prod.	Phosphorus (yellow or white)	secondary	-2.63e-05	-2.92e-06
LCD incineration	Phosphorus (yellow or white)	secondary	-3.56e-05	-3.95e-06
LCD incineration	Ammonia	secondary	-4.82e-05	-5.34e-06
Fuel Oil #4 Prod.	Nitrous oxide	secondary	-8.16e-05	-9.05e-06
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	-8.74e-05	-9.69e-06
LCD incineration	Chromium (VI)	secondary	-1.04e-04	-1.15e-05
Natural Gas Prod.	Arsenic	secondary	-1.04e-04	-1.16e-05
Natural Gas Prod.	Ammonia	secondary	-1.41e-04	-1.56e-05
Natural Gas Prod.	Sulfur oxides	secondary	-1.83e-04	-2.02e-05
Natural Gas Prod.	PM	secondary	-2.74e-04	-3.04e-05
LCD incineration	Hydrofluoric acid	secondary	-2.89e-04	-3.21e-05
LCD incineration	Formaldehyde	secondary	-2.90e-04	-3.21e-05
Fuel Oil #4 Prod.	Formaldehyde	secondary	-3.65e-04	-4.05e-05
Fuel Oil #4 Prod.	Arsenic	secondary	-5.00e-04	-5.55e-05
Fuel Oil #4 Prod.	PM	secondary	-5.75e-04	-6.37e-05
LCD incineration	Vanadium	secondary	-7.60e-04	-8.43e-05
LCD incineration	Selenium	secondary	-9.94e-04	-1.10e-04

Table M-34. LCD LCIA Results for the Chronic Public Health Effects Impact Category

Process Group	Material	LCI Data Type	Chronic Public Toxicity (tox-kg)	% of Total
LCD incineration	Fluorides (F-)	secondary	-1.02e-03	-1.13e-04
LCD incineration	Nitrous oxide	secondary	-1.35e-03	-1.50e-04
Fuel Oil #4 Prod.	Benzene	secondary	-1.71e-03	-1.90e-04
LCD incineration	Benzene	secondary	-2.08e-03	-2.31e-04
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	-2.55e-03	-2.83e-04
Fuel Oil #4 Prod.	Vanadium	secondary	-2.86e-03	-3.17e-04
LCD incineration	Hydrochloric acid	secondary	-3.08e-03	-3.41e-04
Fuel Oil #4 Prod.	Sulfur oxides	secondary	-3.48e-03	-3.86e-04
Fuel Oil #4 Prod.	Methane	secondary	-3.70e-03	-4.10e-04
Natural Gas Prod.	Nitrogen oxides	secondary	-6.17e-03	-6.85e-04
Fuel Oil #4 Prod.	Carbon monoxide	secondary	-1.08e-02	-1.19e-03
LCD incineration	Carbon monoxide	secondary	-1.55e-02	-1.72e-03
LCD incineration	Nitrogen oxides	secondary	-1.86e-02	-2.07e-03
LCD incineration	Methane	secondary	-1.97e-02	-2.18e-03
Natural Gas Prod.	Carbon monoxide	secondary	-2.27e-02	-2.52e-03
LCD incineration	PM	secondary	-2.40e-02	-2.66e-03
LCD incineration	Arsenic	secondary	-2.50e-02	-2.78e-03
Natural Gas Prod.	Benzene	secondary	-2.51e-02	-2.78e-03
Natural Gas Prod.	Methane	secondary	-3.32e-02	-3.68e-03
LCD incineration	Sulfur oxides	secondary	-3.50e-02	-3.88e-03
Total End-of-life			**-6.30e-02**	**-6.99e-03**
Total All Life-cycle Stages			**9.02e+02**	**1.00e+02**

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Hydrogen sulfide	secondary	3.17e+04	4.18e-01
ABS Production	Hydrogen sulfide	secondary	2.36e+04	3.11e-01
Invar	Hydrogen sulfide	secondary	1.69e+04	2.24e-01
Ferrite mfg.	Hydrogen sulfide	secondary	1.21e+04	1.59e-01
Polycarbonate Production	Ethanethiol	secondary	1.05e+04	1.39e-01
Aluminum Prod.	Hydrogen sulfide	secondary	8.78e+03	1.16e-01
Lead	Hydrogen sulfide	secondary	6.91e+03	9.12e-02
ABS Production	Ethanethiol	secondary	4.82e+03	6.37e-02
Polycarbonate Production	Hydrogen sulfide	secondary	4.30e+03	5.68e-02
Invar	Acetaldehyde	secondary	4.27e+03	5.64e-02
Steel Prod., cold-rolled, semi-finished	Acetaldehyde	secondary	2.48e+03	3.28e-02
Ferrite mfg.	Acetaldehyde	secondary	7.11e+02	9.38e-03
Lead	Acetaldehyde	secondary	5.50e+02	7.26e-03
Styrene-butadiene Copolymer Prod.	Hydrogen sulfide	secondary	4.82e+02	6.37e-03
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	4.15e+02	5.48e-03
Aluminum Prod.	Acetic acid	secondary	1.14e+02	1.50e-03
Invar	Acetic acid	secondary	9.41e+01	1.24e-03
Steel Prod., cold-rolled, semi-finished	Acetic acid	secondary	5.51e+01	7.27e-04
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	4.82e+01	6.37e-04
Aluminum Prod.	Xylene (mixed isomers)	secondary	3.04e+01	4.01e-04
ABS Production	Formaldehyde	secondary	2.86e+01	3.77e-04
Ferrite mfg.	Acetic acid	secondary	2.35e+01	3.10e-04
Lead	Acetic acid	secondary	1.96e+01	2.59e-04
Aluminum Prod.	Toluene	secondary	1.39e+01	1.83e-04
Invar	Phenol	secondary	1.37e+01	1.81e-04
Ferrite mfg.	Phenol	secondary	1.33e+01	1.76e-04
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	1.30e+01	1.71e-04
Invar	Xylene (mixed isomers)	secondary	1.19e+01	1.58e-04
Aluminum Prod.	Ammonia	secondary	9.03e+00	1.19e-04
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	8.98e+00	1.19e-04
ABS Production	Ethanol	secondary	8.17e+00	1.08e-04
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	7.41e+00	9.78e-05
Lead	Ammonia	secondary	6.93e+00	9.15e-05
Lead	Xylene (mixed isomers)	secondary	5.59e+00	7.37e-05
Invar	Toluene	secondary	4.74e+00	6.25e-05
Ferrite mfg.	Toluene	secondary	4.62e+00	6.10e-05
Invar	Ethanol	secondary	3.58e+00	4.73e-05
Invar	Ammonia	secondary	3.55e+00	4.69e-05
Ferrite mfg.	Xylene (mixed isomers)	secondary	3.10e+00	4.09e-05
Invar	Formaldehyde	secondary	2.86e+00	3.77e-05
Ferrite mfg.	Formaldehyde	secondary	2.79e+00	3.68e-05
Steel Prod., cold-rolled, semi-finished	Ethanol	secondary	2.08e+00	2.74e-05
Polycarbonate Production	Chlorine	secondary	2.01e+00	2.66e-05
Invar	Ethanethiol	secondary	1.98e+00	2.62e-05
Ferrite mfg.	Ethanethiol	secondary	1.94e+00	2.56e-05
ABS Production	Chlorine	secondary	1.85e+00	2.44e-05
Ferrite mfg.	Ammonia	secondary	1.17e+00	1.55e-05
Styrene-butadiene Copolymer Prod.	Chlorine	secondary	9.01e-01	1.19e-05
ABS Production	Ammonia	secondary	8.49e-01	1.12e-05
Invar	Methanol	secondary	6.43e-01	8.49e-06

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Ferrite mfg.	Ethanol	secondary	5.85e-01	7.73e-06
Lead	Ethanol	secondary	4.54e-01	5.99e-06
Steel Prod., cold-rolled, semi-finished	Methanol	secondary	4.11e-01	5.43e-06
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	2.58e-01	3.41e-06
Styrene-butadiene Copolymer Prod.	Ammonia	secondary	2.07e-01	2.74e-06
Invar	Benzene	secondary	1.27e-01	1.68e-06
Ferrite mfg.	Methanol	secondary	1.16e-01	1.53e-06
Aluminum Prod.	Phenol	secondary	1.03e-01	1.36e-06
Ferrite mfg.	Benzene	secondary	8.64e-02	1.14e-06
Steel Prod., cold-rolled, semi-finished	Naphthalene	secondary	7.46e-02	9.84e-07
Aluminum Prod.	Benzene	secondary	6.00e-02	7.92e-07
Lead	Methanol	secondary	5.60e-02	7.39e-07
Lead	Benzene	secondary	4.09e-02	5.40e-07
Invar	Propionic acid	secondary	3.92e-02	5.18e-07
Invar	Acetone	secondary	1.59e-02	2.10e-07
Steel Prod., cold-rolled, semi-finished	Acetone	secondary	9.25e-03	1.22e-07
Ferrite mfg.	Acetone	secondary	2.61e-03	3.44e-08
Lead	Acetone	secondary	2.01e-03	2.65e-08
Invar	Chlorine	secondary	6.89e-04	9.09e-09
Ferrite mfg.	Chlorine	secondary	6.72e-04	8.88e-09
Steel Prod., cold-rolled, semi-finished	Isopropylpropionate	secondary	6.34e-04	8.36e-09
Ferrite mfg.	Isopropylpropionate	secondary	6.22e-04	8.21e-09
Lead	Acrolein	secondary	3.46e-04	4.57e-09
Steel Prod., cold-rolled, semi-finished	Chlorine	secondary	8.13e-05	1.07e-09
Invar	Propionaldehyde	secondary	4.43e-05	5.85e-10
Steel Prod., cold-rolled, semi-finished	Propionaldehyde	secondary	4.43e-05	5.85e-10
Ferrite mfg.	Propionaldehyde	secondary	4.33e-05	5.71e-10
Invar	Acrolein	secondary	1.44e-07	1.90e-12
Total Materials Processing			**1.29e+05**	**1.70e+00**
Manufacturing Life-cycle Stage				
LPG Production	Hydrogen sulfide	secondary	7.15e+06	9.43e+01
Fuel Oil #6 Prod.	Hydrogen sulfide	secondary	7.40e+04	9.77e-01
Fuel Oil #2 Prod.	Hydrogen sulfide	secondary	2.36e+04	3.11e-01
LPG Production	Acetaldehyde	secondary	1.42e+04	1.87e-01
CRT tube mfg.	Toluene	primary	6.41e+03	8.46e-02
US electric grid	Acetaldehyde	model/secondary	3.03e+03	4.00e-02
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	2.76e+03	3.65e-02
Japanese Electric Grid	Acetaldehyde	model/secondary	2.42e+03	3.19e-02
LPG Production	Formaldehyde	secondary	2.39e+03	3.16e-02
LPG Production	Ammonia	secondary	2.18e+03	2.88e-02
LPG Production	Propionaldehyde	secondary	7.28e+02	9.61e-03
CRT tube mfg.	Xylene (mixed isomers)	primary	6.31e+02	8.33e-03
Natural Gas Prod.	Ammonia	secondary	1.57e+02	2.07e-03
Natural Gas Prod.	Hydrogen sulfide	secondary	1.57e+02	2.07e-03
US electric grid	Propionaldehyde	model/secondary	1.56e+02	2.06e-03
LPG Production	Benzene	secondary	1.33e+02	1.76e-03
Japanese Electric Grid	Propionaldehyde	model/secondary	1.24e+02	1.64e-03
Fuel Oil #6 Prod.	Acetaldehyde	secondary	1.14e+02	1.51e-03
PWB Mfg.	Formaldehyde	model/secondary	7.94e+01	1.05e-03
Fuel Oil #2 Prod.	Acetaldehyde	secondary	4.44e+01	5.86e-04
LPG Production	Acrolein	secondary	2.82e+01	3.72e-04

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Natural Gas Prod.	Acetaldehyde	secondary	2.46e+01	3.24e-04
Fuel Oil #6 Prod.	Formaldehyde	secondary	2.45e+01	3.23e-04
LPG Production	Benzyl chloride	secondary	2.24e+01	2.95e-04
Japanese Electric Grid	Formaldehyde	model/secondary	2.09e+01	2.76e-04
Natural Gas Prod.	Benzene	secondary	1.18e+01	1.55e-04
Fuel Oil #6 Prod.	Ammonia	secondary	1.17e+01	1.55e-04
Fuel Oil #2 Prod.	Formaldehyde	secondary	7.87e+00	1.04e-04
Fuel Oil #2 Prod.	Ammonia	secondary	6.43e+00	8.49e-05
LPG Production	Toluene	secondary	6.21e+00	8.19e-05
US electric grid	Acrolein	model/secondary	6.03e+00	7.96e-05
Fuel Oil #6 Prod.	Propionaldehyde	secondary	5.87e+00	7.76e-05
LPG Production	Carbon disulfide	secondary	4.84e+00	6.39e-05
Japanese Electric Grid	Acrolein	model/secondary	4.81e+00	6.36e-05
US electric grid	Benzyl chloride	model/secondary	4.78e+00	6.31e-05
Fuel Oil #4 Prod.	Acetaldehyde	secondary	4.74e+00	6.25e-05
LPG Production	Methyl ethyl ketone	secondary	3.85e+00	5.08e-05
Japanese Electric Grid	Benzyl chloride	model/secondary	3.82e+00	5.04e-05
LPG Production	Isophorone	secondary	3.54e+00	4.67e-05
US electric grid	Formaldehyde	model/secondary	2.76e+00	3.65e-05
LPG Production	Phenol	secondary	2.75e+00	3.63e-05
LPG Production	Styrene	secondary	2.47e+00	3.25e-05
Japanese Electric Grid	Toluene	model/secondary	2.39e+00	3.15e-05
Fuel Oil #2 Prod.	Propionaldehyde	secondary	2.28e+00	3.02e-05
LPG Production	Naphthalene	secondary	1.75e+00	2.31e-05
LPG Production	o-xylene	secondary	1.33e+00	1.75e-05
Natural Gas Prod.	Propionaldehyde	secondary	1.26e+00	1.67e-05
Japanese Electric Grid	Naphthalene	model/secondary	1.11e+00	1.46e-05
US electric grid	Carbon disulfide	model/secondary	1.04e+00	1.37e-05
Fuel Oil #4 Prod.	Formaldehyde	secondary	9.18e-01	1.21e-05
LPG Production	Cumene	secondary	8.89e-01	1.17e-05
Japanese Electric Grid	Carbon disulfide	model/secondary	8.27e-01	1.09e-05
US electric grid	Methyl ethyl ketone	model/secondary	8.23e-01	1.09e-05
Fuel Oil #6 Prod.	Benzene	secondary	7.61e-01	1.00e-05
US electric grid	Isophorone	model/secondary	7.57e-01	9.99e-06
US electric grid	Toluene	model/secondary	6.78e-01	8.95e-06
LPG Production	Methyl methacrylate	secondary	6.71e-01	8.85e-06
Japanese Electric Grid	Methyl ethyl ketone	model/secondary	6.57e-01	8.67e-06
Japanese Electric Grid	Isophorone	model/secondary	6.04e-01	7.97e-06
LPG Production	Methyl hydrazine	secondary	6.00e-01	7.92e-06
Fuel Oil #4 Prod.	Ammonia	secondary	5.97e-01	7.88e-06
US electric grid	Phenol	model/secondary	5.89e-01	7.77e-06
US electric grid	Styrene	model/secondary	5.27e-01	6.96e-06
Natural Gas Prod.	Formaldehyde	secondary	4.95e-01	6.53e-06
Japanese Electric Grid	Phenol	model/secondary	4.70e-01	6.20e-06
LPG Production	2-Chloroacetophenone	secondary	4.69e-01	6.20e-06
Japanese Electric Grid	Styrene	model/secondary	4.21e-01	5.56e-06
LPG Production	1,4-Dichlorobenzene	secondary	4.12e-01	5.44e-06
Fuel Oil #2 Prod.	Benzene	secondary	3.96e-01	5.22e-06
Fuel Oil #4 Prod.	Propionaldehyde	secondary	2.44e-01	3.22e-06
Fuel Oil #6 Prod.	Acrolein	secondary	2.27e-01	3.00e-06
US electric grid	Cumene	model/secondary	1.90e-01	2.51e-06

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Fuel Oil #6 Prod.	Benzyl chloride	secondary	1.80e-01	2.38e-06
LPG Production	Chlorobenzene	secondary	1.48e-01	1.95e-06
US electric grid	Naphthalene	model/secondary	1.46e-01	1.93e-06
US electric grid	Methyl methacrylate	model/secondary	1.43e-01	1.89e-06
US electric grid	Methyl hydrazine	model/secondary	1.28e-01	1.69e-06
LPG Production	Vinyl acetate	secondary	1.27e-01	1.68e-06
Japanese Electric Grid	Methyl methacrylate	model/secondary	1.15e-01	1.51e-06
Japanese Electric Grid	Methyl hydrazine	model/secondary	1.03e-01	1.35e-06
US electric grid	2-Chloroacetophenone	model/secondary	1.00e-01	1.33e-06
Natural Gas Prod.	o-xylene	secondary	8.89e-02	1.17e-06
Fuel Oil #2 Prod.	Acrolein	secondary	8.84e-02	1.17e-06
US electric grid	Xylene (mixed isomers)	model/secondary	8.70e-02	1.15e-06
Natural Gas Prod.	Toluene	secondary	8.63e-02	1.14e-06
Japanese Electric Grid	2-Chloroacetophenone	model/secondary	8.02e-02	1.06e-06
Fuel Oil #2 Prod.	Benzyl chloride	secondary	7.01e-02	9.26e-07
Japanese Electric Grid	Xylene (mixed isomers)	model/secondary	6.95e-02	9.17e-07
LPG Production	Acetophenone	secondary	6.71e-02	8.85e-07
Natural Gas Prod.	Acrolein	secondary	4.89e-02	6.45e-07
Fuel Oil #6 Prod.	Toluene	secondary	4.18e-02	5.52e-07
Fuel Oil #6 Prod.	Carbon disulfide	secondary	3.91e-02	5.16e-07
Natural Gas Prod.	Benzyl chloride	secondary	3.88e-02	5.12e-07
Fuel Oil #4 Prod.	Benzene	secondary	3.74e-02	4.94e-07
LPG Production	Tetrachloroethylene	secondary	3.47e-02	4.59e-07
US electric grid	Chlorobenzene	model/secondary	3.16e-02	4.17e-07
Fuel Oil #6 Prod.	Methyl ethyl ketone	secondary	3.10e-02	4.10e-07
Fuel Oil #6 Prod.	Isophorone	secondary	2.85e-02	3.77e-07
US electric grid	Vinyl acetate	model/secondary	2.73e-02	3.60e-07
LPG Production	1,1,1-Trichloroethane	secondary	2.53e-02	3.34e-07
Japanese Electric Grid	Chlorobenzene	model/secondary	2.52e-02	3.33e-07
Japanese Electric Grid	o-xylene	model/secondary	2.48e-02	3.27e-07
LPG Production	Chlorine	secondary	2.32e-02	3.06e-07
Fuel Oil #6 Prod.	Phenol	secondary	2.22e-02	2.93e-07
Japanese Electric Grid	Vinyl acetate	model/secondary	2.17e-02	2.87e-07
Fuel Oil #6 Prod.	Styrene	secondary	1.99e-02	2.63e-07
Fuel Oil #2 Prod.	Toluene	secondary	1.89e-02	2.49e-07
US electric grid	Benzene	model/secondary	1.73e-02	2.28e-07
Fuel Oil #2 Prod.	Carbon disulfide	secondary	1.52e-02	2.01e-07
US electric grid	Acetophenone	model/secondary	1.43e-02	1.89e-07
Japanese Electric Grid	Benzene	model/secondary	1.41e-02	1.87e-07
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	1.22e-02	1.61e-07
Fuel Oil #2 Prod.	Methyl ethyl ketone	secondary	1.21e-02	1.59e-07
Japanese Electric Grid	Acetophenone	model/secondary	1.15e-02	1.51e-07
Fuel Oil #2 Prod.	Isophorone	secondary	1.11e-02	1.46e-07
LPG Production	1,2-Dichloroethane	secondary	1.07e-02	1.42e-07
Fuel Oil #6 Prod.	Naphthalene	secondary	1.06e-02	1.40e-07
Fuel Oil #4 Prod.	Acrolein	secondary	9.43e-03	1.24e-07
Natural Gas Prod.	Naphthalene	secondary	8.83e-03	1.17e-07
Fuel Oil #2 Prod.	Phenol	secondary	8.63e-03	1.14e-07
Natural Gas Prod.	Carbon disulfide	secondary	8.40e-03	1.11e-07
Fuel Oil #6 Prod.	o-xylene	secondary	8.28e-03	1.09e-07
Fuel Oil #2 Prod.	Styrene	secondary	7.73e-03	1.02e-07

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Fuel Oil #4 Prod.	Benzyl chloride	secondary	7.48e-03	9.87e-08
US electric grid	Tetrachloroethylene	model/secondary	7.43e-03	9.81e-08
Fuel Oil #6 Prod.	Cumene	secondary	7.17e-03	9.46e-08
Natural Gas Prod.	Methyl ethyl ketone	secondary	6.67e-03	8.81e-08
Natural Gas Prod.	Isophorone	secondary	6.13e-03	8.10e-08
Japanese Electric Grid	Tetrachloroethylene	model/secondary	5.94e-03	7.83e-08
US electric grid	1,1,1-Trichloroethane	model/secondary	5.79e-03	7.64e-08
Fuel Oil #6 Prod.	Methyl methacrylate	secondary	5.41e-03	7.14e-08
Fuel Oil #2 Prod.	Naphthalene	secondary	5.24e-03	6.92e-08
Fuel Oil #6 Prod.	Methyl hydrazine	secondary	4.84e-03	6.39e-08
Natural Gas Prod.	Phenol	secondary	4.77e-03	6.30e-08
Natural Gas Prod.	Styrene	secondary	4.28e-03	5.65e-08
Fuel Oil #2 Prod.	o-xylene	secondary	3.99e-03	5.27e-08
Fuel Oil #6 Prod.	2-Chloroacetophenone	secondary	3.79e-03	5.00e-08
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	3.71e-03	4.90e-08
LPG Production	Dichloromethane	secondary	3.04e-03	4.01e-08
Fuel Oil #2 Prod.	Cumene	secondary	2.79e-03	3.68e-08
Fuel Oil #6 Prod.	1,4-Dichlorobenzene	secondary	2.36e-03	3.11e-08
US electric grid	1,2-Dichloroethane	model/secondary	2.30e-03	3.03e-08
Fuel Oil #2 Prod.	Methyl methacrylate	secondary	2.10e-03	2.78e-08
Natural Gas Prod.	Chlorine	secondary	2.06e-03	2.72e-08
Fuel Oil #4 Prod.	Toluene	secondary	1.89e-03	2.49e-08
Fuel Oil #2 Prod.	Methyl hydrazine	secondary	1.88e-03	2.48e-08
Japanese Electric Grid	1,2-Dichloroethane	model/secondary	1.83e-03	2.42e-08
Fuel Oil #4 Prod.	Carbon disulfide	secondary	1.62e-03	2.14e-08
Natural Gas Prod.	Cumene	secondary	1.54e-03	2.03e-08
Fuel Oil #2 Prod.	2-Chloroacetophenone	secondary	1.47e-03	1.94e-08
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	1.29e-03	1.70e-08
Fuel Oil #2 Prod.	1,4-Dichlorobenzene	secondary	1.22e-03	1.62e-08
Fuel Oil #6 Prod.	Chlorobenzene	secondary	1.19e-03	1.57e-08
Fuel Oil #4 Prod.	Isophorone	secondary	1.18e-03	1.56e-08
US electric grid	o-xylene	model/secondary	1.17e-03	1.55e-08
Natural Gas Prod.	Methyl methacrylate	secondary	1.16e-03	1.54e-08
Natural Gas Prod.	Methyl hydrazine	secondary	1.04e-03	1.37e-08
Fuel Oil #6 Prod.	Vinyl acetate	secondary	1.03e-03	1.36e-08
Fuel Oil #4 Prod.	Phenol	secondary	9.20e-04	1.21e-08
Fuel Oil #4 Prod.	Styrene	secondary	8.25e-04	1.09e-08
Natural Gas Prod.	2-Chloroacetophenone	secondary	8.14e-04	1.07e-08
US electric grid	Dichloromethane	model/secondary	6.50e-04	8.58e-09
LPG Production	Chloroform	secondary	6.09e-04	8.04e-09
Fuel Oil #6 Prod.	Acetophenone	secondary	5.41e-04	7.14e-09
Japanese Electric Grid	Dichloromethane	model/secondary	5.19e-04	6.85e-09
Fuel Oil #4 Prod.	Naphthalene	secondary	5.05e-04	6.67e-09
Fuel Oil #2 Prod.	Chlorobenzene	secondary	4.63e-04	6.11e-09
Fuel Oil #2 Prod.	Vinyl acetate	secondary	4.00e-04	5.28e-09
Fuel Oil #4 Prod.	o-xylene	secondary	3.89e-04	5.13e-09
Fuel Oil #4 Prod.	Cumene	secondary	2.97e-04	3.92e-09
Fuel Oil #6 Prod.	Tetrachloroethylene	secondary	2.80e-04	3.70e-09
Natural Gas Prod.	Chlorobenzene	secondary	2.56e-04	3.38e-09
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	2.24e-04	2.96e-09
Natural Gas Prod.	Vinyl acetate	secondary	2.21e-04	2.92e-09

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Fuel Oil #2 Prod.	Acetophenone	secondary	2.10e-04	2.78e-09
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	2.04e-04	2.70e-09
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	2.01e-04	2.65e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	1.57e-04	2.07e-09
US electric grid	Chloroform	model/secondary	1.30e-04	1.72e-09
Fuel Oil #6 Prod.	Chlorine	secondary	1.29e-04	1.70e-09
Natural Gas Prod.	Acetophenone	secondary	1.16e-04	1.54e-09
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	1.16e-04	1.53e-09
Fuel Oil #2 Prod.	Tetrachloroethylene	secondary	1.09e-04	1.44e-09
Japanese Electric Grid	Chloroform	model/secondary	1.04e-04	1.37e-09
Fuel Oil #6 Prod.	1,2-Dichloroethane	secondary	8.66e-05	1.14e-09
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	7.94e-05	1.05e-09
Fuel Oil #2 Prod.	Chlorine	secondary	6.80e-05	8.97e-10
Natural Gas Prod.	Tetrachloroethylene	secondary	6.03e-05	7.96e-10
Fuel Oil #4 Prod.	Chlorobenzene	secondary	4.94e-05	6.52e-10
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	4.39e-05	5.79e-10
Fuel Oil #4 Prod.	Vinyl acetate	secondary	4.26e-05	5.63e-10
Fuel Oil #2 Prod.	1,2-Dichloroethane	secondary	3.37e-05	4.44e-10
Fuel Oil #6 Prod.	Dichloromethane	secondary	2.45e-05	3.24e-10
Fuel Oil #4 Prod.	Acetophenone	secondary	2.24e-05	2.96e-10
Natural Gas Prod.	1,2-Dichloroethane	secondary	1.86e-05	2.46e-10
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	1.16e-05	1.53e-10
Fuel Oil #2 Prod.	Dichloromethane	secondary	9.53e-06	1.26e-10
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	8.47e-06	1.12e-10
Fuel Oil #4 Prod.	Chlorine	secondary	6.40e-06	8.44e-11
Natural Gas Prod.	Dichloromethane	secondary	5.27e-06	6.96e-11
Fuel Oil #6 Prod.	Chloroform	secondary	4.91e-06	6.48e-11
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	3.59e-06	4.74e-11
Fuel Oil #2 Prod.	Chloroform	secondary	1.91e-06	2.52e-11
Natural Gas Prod.	Chloroform	secondary	1.06e-06	1.39e-11
Fuel Oil #4 Prod.	Dichloromethane	secondary	1.02e-06	1.34e-11
Fuel Oil #4 Prod.	Chloroform	secondary	2.04e-07	2.69e-12
Total Manufacturing			**7.41e+06**	**9.78e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Acetaldehyde	model/secondary	1.90e+05	2.50e+00
US electric grid	Propionaldehyde	model/secondary	9.76e+03	1.29e-01
US electric grid	Acrolein	model/secondary	3.78e+02	4.99e-03
US electric grid	Benzyl chloride	model/secondary	3.00e+02	3.96e-03
US electric grid	Formaldehyde	model/secondary	1.73e+02	2.29e-03
US electric grid	Carbon disulfide	model/secondary	6.49e+01	8.57e-04
US electric grid	Methyl ethyl ketone	model/secondary	5.16e+01	6.81e-04
US electric grid	Isophorone	model/secondary	4.74e+01	6.26e-04
US electric grid	Toluene	model/secondary	4.25e+01	5.61e-04
US electric grid	Phenol	model/secondary	3.69e+01	4.87e-04
US electric grid	Styrene	model/secondary	3.30e+01	4.36e-04
US electric grid	Cumene	model/secondary	1.19e+01	1.57e-04
US electric grid	Naphthalene	model/secondary	9.16e+00	1.21e-04
US electric grid	Methyl methacrylate	model/secondary	8.99e+00	1.19e-04
US electric grid	Methyl hydrazine	model/secondary	8.04e+00	1.06e-04
US electric grid	2-Chloroacetophenone	model/secondary	6.29e+00	8.31e-05
US electric grid	Xylene (mixed isomers)	model/secondary	5.45e+00	7.20e-05

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
US electric grid	Chlorobenzene	model/secondary	1.98e+00	2.61e-05
US electric grid	Vinyl acetate	model/secondary	1.71e+00	2.25e-05
US electric grid	Benzene	model/secondary	1.08e+00	1.43e-05
US electric grid	Acetophenone	model/secondary	8.99e-01	1.19e-05
US electric grid	Tetrachloroethylene	model/secondary	4.66e-01	6.15e-06
US electric grid	1,1,1-Trichloroethane	model/secondary	3.63e-01	4.79e-06
US electric grid	1,2-Dichloroethane	model/secondary	1.44e-01	1.90e-06
US electric grid	o-xylene	model/secondary	7.33e-02	9.68e-07
US electric grid	Dichloromethane	model/secondary	4.07e-02	5.38e-07
US electric grid	Chloroform	model/secondary	8.16e-03	1.08e-07
Total Use, Maintenance and Repair			**2.01e+05**	**2.65e+00**
End-of-life Life-cycle Stage				
CRT landfilling	Hydrogen sulfide	primary	5.37e+02	7.09e-03
LPG Production	Hydrogen sulfide	secondary	6.17e+01	8.14e-04
US electric grid	Acetaldehyde	model/secondary	1.90e+01	2.51e-04
US electric grid	Propionaldehyde	model/secondary	9.76e-01	1.29e-05
LPG Production	Acetaldehyde	secondary	1.22e-01	1.61e-06
CRT landfilling	Toluene	primary	7.98e-02	1.05e-06
CRT landfilling	Xylene (mixed isomers)	primary	4.07e-02	5.37e-07
US electric grid	Acrolein	model/secondary	3.78e-02	4.99e-07
US electric grid	Benzyl chloride	model/secondary	3.00e-02	3.96e-07
LPG Production	Formaldehyde	secondary	2.07e-02	2.73e-07
LPG Production	Ammonia	secondary	1.88e-02	2.49e-07
US electric grid	Formaldehyde	model/secondary	1.73e-02	2.29e-07
US electric grid	Carbon disulfide	model/secondary	6.50e-03	8.57e-08
LPG Production	Propionaldehyde	secondary	6.28e-03	8.30e-08
CRT landfilling	Benzene	primary	6.28e-03	8.29e-08
US electric grid	Methyl ethyl ketone	model/secondary	5.16e-03	6.81e-08
US electric grid	Isophorone	model/secondary	4.74e-03	6.26e-08
US electric grid	Toluene	model/secondary	4.25e-03	5.61e-08
US electric grid	Phenol	model/secondary	3.69e-03	4.87e-08
US electric grid	Styrene	model/secondary	3.31e-03	4.36e-08
US electric grid	Cumene	model/secondary	1.19e-03	1.57e-08
LPG Production	Benzene	secondary	1.15e-03	1.52e-08
US electric grid	Naphthalene	model/secondary	9.17e-04	1.21e-08
US electric grid	Methyl methacrylate	model/secondary	8.99e-04	1.19e-08
US electric grid	Methyl hydrazine	model/secondary	8.05e-04	1.06e-08
US electric grid	2-Chloroacetophenone	model/secondary	6.30e-04	8.31e-09
US electric grid	Xylene (mixed isomers)	model/secondary	5.45e-04	7.20e-09
CRT Incineration	Trichloroethylene	secondary	3.77e-04	4.98e-09
CRT landfilling	Trichloroethylene	primary	3.52e-04	4.64e-09
LPG Production	Acrolein	secondary	2.43e-04	3.21e-09
US electric grid	Chlorobenzene	model/secondary	1.98e-04	2.61e-09
LPG Production	Benzyl chloride	secondary	1.93e-04	2.55e-09
US electric grid	Vinyl acetate	model/secondary	1.71e-04	2.26e-09
CRT landfilling	Tetrachloroethylene	primary	1.65e-04	2.18e-09
US electric grid	Benzene	model/secondary	1.08e-04	1.43e-09
US electric grid	Acetophenone	model/secondary	8.99e-05	1.19e-09
CRT landfilling	1,2-Dichloroethane	primary	5.49e-05	7.25e-10
LPG Production	Toluene	secondary	5.36e-05	7.07e-10

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
US electric grid	Tetrachloroethylene	model/secondary	4.66e-05	6.15e-10
LPG Production	Carbon disulfide	secondary	4.18e-05	5.52e-10
US electric grid	1,1,1-Trichloroethane	model/secondary	3.63e-05	4.79e-10
LPG Production	Methyl ethyl ketone	secondary	3.32e-05	4.38e-10
LPG Production	Isophorone	secondary	3.05e-05	4.03e-10
LPG Production	Phenol	secondary	2.37e-05	3.13e-10
LPG Production	Styrene	secondary	2.13e-05	2.81e-10
LPG Production	Naphthalene	secondary	1.51e-05	1.99e-10
US electric grid	1,2-Dichloroethane	model/secondary	1.44e-05	1.90e-10
LPG Production	o-xylene	secondary	1.14e-05	1.51e-10
LPG Production	Cumene	secondary	7.67e-06	1.01e-10
US electric grid	o-xylene	model/secondary	7.34e-06	9.69e-11
LPG Production	Methyl methacrylate	secondary	5.79e-06	7.64e-11
LPG Production	Methyl hydrazine	secondary	5.18e-06	6.84e-11
US electric grid	Dichloromethane	model/secondary	4.08e-06	5.38e-11
LPG Production	2-Chloroacetophenone	secondary	4.05e-06	5.35e-11
LPG Production	1,4-Dichlorobenzene	secondary	3.56e-06	4.70e-11
CRT landfilling	Dichloromethane	primary	3.43e-06	4.52e-11
CRT landfilling	Chloroform	primary	2.11e-06	2.79e-11
CRT Incineration	Carbon tetrachloride	secondary	1.66e-06	2.20e-11
CRT landfilling	Carbon tetrachloride	primary	1.55e-06	2.05e-11
LPG Production	Chlorobenzene	secondary	1.27e-06	1.68e-11
LPG Production	Vinyl acetate	secondary	1.10e-06	1.45e-11
US electric grid	Chloroform	model/secondary	8.16e-07	1.08e-11
LPG Production	Acetophenone	secondary	5.79e-07	7.64e-12
LPG Production	Tetrachloroethylene	secondary	3.00e-07	3.96e-12
LPG Production	1,1,1-Trichloroethane	secondary	2.18e-07	2.88e-12
LPG Production	Chlorine	secondary	2.00e-07	2.64e-12
LPG Production	1,2-Dichloroethane	secondary	9.26e-08	1.22e-12
LPG Production	Dichloromethane	secondary	2.62e-08	3.46e-13
LPG Production	Chloroform	secondary	5.25e-09	6.94e-14
Natural Gas Prod.	Chloroform	secondary	-5.29e-07	-6.99e-12
Fuel Oil #4 Prod.	Chloroform	secondary	-2.19e-06	-2.89e-11
Natural Gas Prod.	Dichloromethane	secondary	-2.64e-06	-3.49e-11
Natural Gas Prod.	1,2-Dichloroethane	secondary	-9.33e-06	-1.23e-10
Fuel Oil #4 Prod.	Dichloromethane	secondary	-1.09e-05	-1.44e-10
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-2.20e-05	-2.91e-10
Natural Gas Prod.	Tetrachloroethylene	secondary	-3.02e-05	-3.99e-10
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	-3.86e-05	-5.09e-10
Natural Gas Prod.	Acetophenone	secondary	-5.83e-05	-7.70e-10
Fuel Oil #4 Prod.	Chlorine	secondary	-6.88e-05	-9.08e-10
CRT Incineration	Chlorine	secondary	-8.44e-05	-1.11e-09
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-9.10e-05	-1.20e-09
Natural Gas Prod.	Vinyl acetate	secondary	-1.11e-04	-1.46e-09
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	-1.25e-04	-1.65e-09
Natural Gas Prod.	Chlorobenzene	secondary	-1.28e-04	-1.69e-09
CRT Incineration	Chloroform	secondary	-1.33e-04	-1.76e-09
Fuel Oil #4 Prod.	Acetophenone	secondary	-2.41e-04	-3.18e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	-4.08e-04	-5.39e-09
Fuel Oil #4 Prod.	Vinyl acetate	secondary	-4.58e-04	-6.05e-09
Natural Gas Prod.	Methyl hydrazine	secondary	-5.22e-04	-6.89e-09

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Fuel Oil #4 Prod.	Chlorobenzene	secondary	-5.31e-04	-7.00e-09
Natural Gas Prod.	Methyl methacrylate	secondary	-5.83e-04	-7.70e-09
CRT Incineration	Dichloromethane	secondary	-6.72e-04	-8.87e-09
Natural Gas Prod.	Cumene	secondary	-7.73e-04	-1.02e-08
Natural Gas Prod.	Chlorine	secondary	-1.03e-03	-1.37e-08
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	-1.25e-03	-1.64e-08
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	-1.69e-03	-2.23e-08
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	-1.86e-03	-2.46e-08
Natural Gas Prod.	Styrene	secondary	-2.14e-03	-2.83e-08
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	-2.16e-03	-2.85e-08
CRT Incineration	1,2-Dichloroethane	secondary	-2.33e-03	-3.07e-08
Natural Gas Prod.	Phenol	secondary	-2.39e-03	-3.16e-08
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	-2.41e-03	-3.18e-08
Natural Gas Prod.	Isophorone	secondary	-3.08e-03	-4.06e-08
Fuel Oil #4 Prod.	Cumene	secondary	-3.20e-03	-4.22e-08
Natural Gas Prod.	Methyl ethyl ketone	secondary	-3.35e-03	-4.42e-08
Fuel Oil #4 Prod.	o-xylene	secondary	-4.18e-03	-5.52e-08
Natural Gas Prod.	Carbon disulfide	secondary	-4.21e-03	-5.56e-08
Natural Gas Prod.	Naphthalene	secondary	-4.43e-03	-5.84e-08
Fuel Oil #4 Prod.	Naphthalene	secondary	-5.43e-03	-7.17e-08
CRT Incineration	1,1,1-Trichloroethane	secondary	-5.62e-03	-7.42e-08
CRT Incineration	Tetrachloroethylene	secondary	-7.54e-03	-9.96e-08
Fuel Oil #4 Prod.	Styrene	secondary	-8.87e-03	-1.17e-07
Fuel Oil #4 Prod.	Phenol	secondary	-9.89e-03	-1.31e-07
Fuel Oil #4 Prod.	Isophorone	secondary	-1.27e-02	-1.68e-07
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	-1.38e-02	-1.83e-07
CRT Incineration	Acetophenone	secondary	-1.49e-02	-1.97e-07
Fuel Oil #4 Prod.	Carbon disulfide	secondary	-1.74e-02	-2.30e-07
Natural Gas Prod.	Benzyl chloride	secondary	-1.94e-02	-2.57e-07
Fuel Oil #4 Prod.	Toluene	secondary	-2.03e-02	-2.68e-07
Natural Gas Prod.	Acrolein	secondary	-2.45e-02	-3.24e-07
CRT Incineration	Vinyl acetate	secondary	-2.83e-02	-3.74e-07
CRT Incineration	Chlorobenzene	secondary	-3.28e-02	-4.33e-07
Natural Gas Prod.	Toluene	secondary	-4.33e-02	-5.71e-07
Natural Gas Prod.	o-xylene	secondary	-4.46e-02	-5.89e-07
CRT Incineration	Xylene (mixed isomers)	secondary	-5.26e-02	-6.95e-07
Fuel Oil #4 Prod.	Benzyl chloride	secondary	-8.04e-02	-1.06e-06
Fuel Oil #4 Prod.	Acrolein	secondary	-1.01e-01	-1.34e-06
CRT Incineration	Methyl hydrazine	secondary	-1.33e-01	-1.76e-06
CRT Incineration	Naphthalene	secondary	-1.38e-01	-1.82e-06
CRT Incineration	Methyl methacrylate	secondary	-1.49e-01	-1.97e-06
CRT Incineration	Cumene	secondary	-1.97e-01	-2.61e-06
Natural Gas Prod.	Formaldehyde	secondary	-2.48e-01	-3.28e-06
Fuel Oil #4 Prod.	Benzene	secondary	-4.02e-01	-5.31e-06
CRT Incineration	Benzene	secondary	-4.93e-01	-6.51e-06
CRT Incineration	Styrene	secondary	-5.48e-01	-7.23e-06
CRT Incineration	Phenol	secondary	-6.11e-01	-8.07e-06
Natural Gas Prod.	Propionaldehyde	secondary	-6.33e-01	-8.36e-06
CRT Incineration	Toluene	secondary	-6.67e-01	-8.81e-06
CRT Incineration	Isophorone	secondary	-7.86e-01	-1.04e-05
CRT Incineration	Methyl ethyl ketone	secondary	-8.55e-01	-1.13e-05

Table M-35. CRT LCIA Results for the Aesthetics Impacts Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
CRT Incineration	Carbon disulfide	secondary	-1.08e+00	-1.42e-05
Fuel Oil #4 Prod.	Propionaldehyde	secondary	-2.62e+00	-3.46e-05
CRT Incineration	Benzyl chloride	secondary	-4.97e+00	-6.56e-05
Natural Gas Prod.	Benzene	secondary	-5.89e+00	-7.78e-05
CRT Incineration	Acrolein	secondary	-6.26e+00	-8.27e-05
Fuel Oil #4 Prod.	Ammonia	secondary	-6.41e+00	-8.47e-05
CRT Incineration	Formaldehyde	secondary	-7.98e+00	-1.05e-04
Fuel Oil #4 Prod.	Formaldehyde	secondary	-9.86e+00	-1.30e-04
Natural Gas Prod.	Acetaldehyde	secondary	-1.23e+01	-1.63e-04
CRT Incineration	Ammonia	secondary	-2.08e+01	-2.75e-04
Fuel Oil #4 Prod.	Acetaldehyde	secondary	-5.09e+01	-6.72e-04
Natural Gas Prod.	Hydrogen sulfide	secondary	-7.86e+01	-1.04e-03
Natural Gas Prod.	Ammonia	secondary	-7.87e+01	-1.04e-03
CRT Incineration	Propionaldehyde	secondary	-1.62e+02	-2.14e-03
CRT Incineration	Hydrogen sulfide	secondary	-1.42e+03	-1.88e-02
CRT Incineration	Acetaldehyde	secondary		-4.15e-02
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	-2.97e+04	-3.92e-01
Total End-of-life			**-3.41e+04**	**-4.50e-01**
Total All Life-cycle Stages			**7.58e+06**	**1.00e+02**

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Hydrogen sulfide	secondary	1.55e+04	3.08e-01
Natural Gas Prod.	Ammonia	secondary	1.10e+04	2.17e-01
Natural Gas Prod.	Hydrogen sulfide	secondary	1.10e+04	2.17e-01
Polycarbonate Production	Ethanethiol	secondary	5.87e+03	1.16e-01
PMMA Sheet Prod.	Ethanethiol	secondary	4.37e+03	8.66e-02
PMMA Sheet Prod.	Hydrogen sulfide	secondary	3.58e+03	7.09e-02
Aluminum Prod.	Hydrogen sulfide	secondary	3.27e+03	6.48e-02
Polycarbonate Production	Hydrogen sulfide	secondary	2.40e+03	4.77e-02
Natural Gas Prod.	Acetaldehyde	secondary	1.72e+03	3.40e-02
Steel Prod., cold-rolled, semi-finished	Acetaldehyde	secondary	1.22e+03	2.41e-02
Natural Gas Prod.	Benzene	secondary	8.21e+02	1.63e-02
PET Resin Production	Hydrogen sulfide	secondary	2.12e+02	4.19e-03
Styrene-butadiene Copolymer Prod.	Hydrogen sulfide	secondary	2.11e+02	4.18e-03
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	2.03e+02	4.03e-03
Natural Gas Prod.	Propionaldehyde	secondary	8.82e+01	1.75e-03
Aluminum Prod.	Acetic acid	secondary	4.23e+01	8.38e-04
Natural Gas Prod.	Formaldehyde	secondary	3.46e+01	6.85e-04
Steel Prod., cold-rolled, semi-finished	Acetic acid	secondary	2.70e+01	5.35e-04
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	2.36e+01	4.69e-04
Aluminum Prod.	Xylene (mixed isomers)	secondary	1.13e+01	2.24e-04
PMMA Sheet Prod.	Ammonia	secondary	8.07e+00	1.60e-04
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	6.35e+00	1.26e-04
Natural Gas Prod.	o-xylene	secondary	6.21e+00	1.23e-04
Natural Gas Prod.	Toluene	secondary	6.03e+00	1.19e-04
Aluminum Prod.	Toluene	secondary	5.16e+00	1.02e-04
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	4.40e+00	8.73e-05
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	3.63e+00	7.20e-05
Natural Gas Prod.	Acrolein	secondary	3.41e+00	6.77e-05
Aluminum Prod.	Ammonia	secondary	3.36e+00	6.66e-05
Natural Gas Prod.	Benzyl chloride	secondary	2.71e+00	5.37e-05
Polycarbonate Production	Chlorine	secondary	1.12e+00	2.23e-05
Steel Prod., cold-rolled, semi-finished	Ethanol	secondary	1.02e+00	2.02e-05
PMMA Sheet Prod.	Chlorine	secondary	8.36e-01	1.66e-05
Natural Gas Prod.	Naphthalene	secondary	6.17e-01	1.22e-05
Natural Gas Prod.	Carbon disulfide	secondary	5.87e-01	1.16e-05
Natural Gas Prod.	Methyl ethyl ketone	secondary	4.66e-01	9.24e-06
Natural Gas Prod.	Isophorone	secondary	4.28e-01	8.50e-06
PET Resin Production	Chlorine	secondary	3.95e-01	7.84e-06
Styrene-butadiene Copolymer Prod.	Chlorine	secondary	3.94e-01	7.81e-06
Natural Gas Prod.	Phenol	secondary	3.33e-01	6.61e-06
Natural Gas Prod.	Styrene	secondary	2.99e-01	5.92e-06
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	2.59e-01	5.14e-06
Steel Prod., cold-rolled, semi-finished	Methanol	secondary	2.02e-01	4.00e-06
Natural Gas Prod.	Chlorine	secondary	1.44e-01	2.86e-06
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	1.27e-01	2.51e-06
Natural Gas Prod.	Cumene	secondary	1.08e-01	2.13e-06
PET Resin Production	Ammonia	secondary	9.10e-02	1.80e-06
Styrene-butadiene Copolymer Prod.	Ammonia	secondary	9.06e-02	1.80e-06
Natural Gas Prod.	Methyl methacrylate	secondary	8.13e-02	1.61e-06
Natural Gas Prod.	Methyl hydrazine	secondary	7.27e-02	1.44e-06

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Natural Gas Prod.	2-Chloroacetophenone	secondary	5.69e-02	1.13e-06
Aluminum Prod.	Phenol	secondary	3.82e-02	7.58e-07
Steel Prod., cold-rolled, semi-finished	Naphthalene	secondary	3.65e-02	7.24e-07
Aluminum Prod.	Benzene	secondary	2.23e-02	4.43e-07
Natural Gas Prod.	Chlorobenzene	secondary	1.79e-02	3.54e-07
Natural Gas Prod.	Vinyl acetate	secondary	1.54e-02	3.06e-07
Natural Gas Prod.	Acetophenone	secondary	8.13e-03	1.61e-07
Steel Prod., cold-rolled, semi-finished	Acetone	secondary	4.53e-03	8.99e-08
Natural Gas Prod.	Tetrachloroethylene	secondary	4.21e-03	8.35e-08
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	3.07e-03	6.08e-08
Natural Gas Prod.	1,2-Dichloroethane	secondary	1.30e-03	2.58e-08
Natural Gas Prod.	Dichloromethane	secondary	3.68e-04	7.30e-09
Steel Prod., cold-rolled, semi-finished	Isopropylpropionate	secondary	3.10e-04	6.16e-09
Natural Gas Prod.	Chloroform	secondary	7.38e-05	1.46e-09
Steel Prod., cold-rolled, semi-finished	Chlorine	secondary	3.98e-05	7.90e-10
Steel Prod., cold-rolled, semi-finished	Propionaldehyde	secondary	2.17e-05	4.31e-10
Total Materials Processing			**6.16e+04**	**1.22e+00**
Manufacturing Life-cycle Stage				
Monitor/module	Phosphine	primary	4.48e+06	8.89e+01
LPG Production	Hydrogen sulfide	secondary	3.43e+05	6.80e+00
Monitor/module	Ammonia	primary	6.24e+04	1.24e+00
Monitor/module	Acetic acid	primary	2.23e+04	4.42e-01
Japanese Electric Grid	Acetaldehyde	model/secondary	8.13e+03	1.61e-01
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	4.26e+03	8.44e-02
Fuel Oil #6 Prod.	Hydrogen sulfide	secondary	2.52e+03	5.00e-02
Fuel Oil #2 Prod.	Hydrogen sulfide	secondary	1.10e+03	2.18e-02
LPG Production	Acetaldehyde	secondary	6.79e+02	1.35e-02
Japanese Electric Grid	Propionaldehyde	model/secondary	4.18e+02	8.30e-03
US electric grid	Acetaldehyde	model/secondary	3.67e+02	7.29e-03
Natural Gas Prod.	Ammonia	secondary	2.47e+02	4.91e-03
Natural Gas Prod.	Hydrogen sulfide	secondary	2.47e+02	4.90e-03
LPG Production	Formaldehyde	secondary	1.15e+02	2.28e-03
LPG Production	Ammonia	secondary	1.05e+02	2.08e-03
Panel components	Toluene	primary	9.09e+01	1.80e-03
Backlight	Ethanol	primary	7.24e+01	1.44e-03
Japanese Electric Grid	Formaldehyde	model/secondary	7.02e+01	1.39e-03
Natural Gas Prod.	Acetaldehyde	secondary	3.87e+01	7.68e-04
PWB Mfg.	Formaldehyde	model/secondary	3.50e+01	6.94e-04
LPG Production	Propionaldehyde	secondary	3.49e+01	6.93e-04
US electric grid	Propionaldehyde	model/secondary	1.89e+01	3.75e-04
Natural Gas Prod.	Benzene	secondary	1.85e+01	3.67e-04
Japanese Electric Grid	Acrolein	model/secondary	1.62e+01	3.21e-04
Japanese Electric Grid	Benzyl chloride	model/secondary	1.28e+01	2.55e-04
Japanese Electric Grid	Toluene	model/secondary	8.03e+00	1.59e-04
Fuel Oil #4 Prod.	Acetaldehyde	secondary	7.30e+00	1.45e-04
LPG Production	Benzene	secondary	6.39e+00	1.27e-04
Fuel Oil #6 Prod.	Acetaldehyde	secondary	3.89e+00	7.71e-05
Japanese Electric Grid	Naphthalene	model/secondary	3.73e+00	7.39e-05
Japanese Electric Grid	Carbon disulfide	model/secondary	2.78e+00	5.52e-05
Monitor/module	Acetone	primary	2.59e+00	5.14e-05
Japanese Electric Grid	Methyl ethyl ketone	model/secondary	2.21e+00	4.38e-05

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Fuel Oil #2 Prod.	Acetaldehyde	secondary	2.07e+00	4.11e-05
Japanese Electric Grid	Isophorone	model/secondary	2.03e+00	4.03e-05
Natural Gas Prod.	Propionaldehyde	secondary	1.99e+00	3.95e-05
Japanese Electric Grid	Phenol	model/secondary	1.58e+00	3.13e-05
Japanese Electric Grid	Styrene	model/secondary	1.42e+00	2.81e-05
Fuel Oil #4 Prod.	Formaldehyde	secondary	1.41e+00	2.80e-05
LPG Production	Acrolein	secondary	1.35e+00	2.68e-05
Panel components	Methyl ethyl ketone	primary	1.08e+00	2.14e-05
LPG Production	Benzyl chloride	secondary	1.07e+00	2.13e-05
Fuel Oil #4 Prod.	Ammonia	secondary	9.19e-01	1.82e-05
Fuel Oil #6 Prod.	Formaldehyde	secondary	8.33e-01	1.65e-05
Natural Gas Prod.	Formaldehyde	secondary	7.80e-01	1.55e-05
US electric grid	Acrolein	model/secondary	7.31e-01	1.45e-05
US electric grid	Benzyl chloride	model/secondary	5.80e-01	1.15e-05
Fuel Oil #6 Prod.	Ammonia	secondary	4.00e-01	7.93e-06
Japanese Electric Grid	Methyl methacrylate	model/secondary	3.85e-01	7.64e-06
Fuel Oil #4 Prod.	Propionaldehyde	secondary	3.75e-01	7.44e-06
Fuel Oil #2 Prod.	Formaldehyde	secondary	3.67e-01	7.29e-06
Japanese Electric Grid	Methyl hydrazine	model/secondary	3.45e-01	6.84e-06
US electric grid	Formaldehyde	model/secondary	3.35e-01	6.65e-06
Fuel Oil #2 Prod.	Ammonia	secondary	3.00e-01	5.95e-06
LPG Production	Toluene	secondary	2.98e-01	5.91e-06
Japanese Electric Grid	2-Chloroacetophenone	model/secondary	2.70e-01	5.35e-06
Japanese Electric Grid	Xylene (mixed isomers)	model/secondary	2.34e-01	4.63e-06
LPG Production	Carbon disulfide	secondary	2.32e-01	4.61e-06
Fuel Oil #6 Prod.	Propionaldehyde	secondary	2.00e-01	3.97e-06
LPG Production	Methyl ethyl ketone	secondary	1.85e-01	3.66e-06
LPG Production	Isophorone	secondary	1.70e-01	3.36e-06
Natural Gas Prod.	o-xylene	secondary	1.40e-01	2.78e-06
Natural Gas Prod.	Toluene	secondary	1.36e-01	2.70e-06
LPG Production	Phenol	secondary	1.32e-01	2.62e-06
US electric grid	Carbon disulfide	model/secondary	1.26e-01	2.49e-06
LPG Production	Styrene	secondary	1.18e-01	2.35e-06
Fuel Oil #2 Prod.	Propionaldehyde	secondary	1.07e-01	2.11e-06
US electric grid	Methyl ethyl ketone	model/secondary	9.98e-02	1.98e-06
US electric grid	Isophorone	model/secondary	9.18e-02	1.82e-06
Japanese Electric Grid	Chlorobenzene	model/secondary	8.48e-02	1.68e-06
LPG Production	Naphthalene	secondary	8.39e-02	1.66e-06
Japanese Electric Grid	o-xylene	model/secondary	8.34e-02	1.65e-06
US electric grid	Toluene	model/secondary	8.22e-02	1.63e-06
Natural Gas Prod.	Acrolein	secondary	7.71e-02	1.53e-06
Japanese Electric Grid	Vinyl acetate	model/secondary	7.31e-02	1.45e-06
US electric grid	Phenol	model/secondary	7.14e-02	1.42e-06
US electric grid	Styrene	model/secondary	6.40e-02	1.27e-06
LPG Production	o-xylene	secondary	6.36e-02	1.26e-06
Natural Gas Prod.	Benzyl chloride	secondary	6.11e-02	1.21e-06
Panel components	Ethylacetate	primary	5.82e-02	1.15e-06
Fuel Oil #4 Prod.	Benzene	secondary	5.77e-02	1.14e-06
Japanese Electric Grid	Benzene	model/secondary	4.76e-02	9.43e-07
LPG Production	Cumene	secondary	4.26e-02	8.45e-07
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	4.11e-02	8.15e-07

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Japanese Electric Grid	Acetophenone	model/secondary	3.85e-02	7.64e-07
LPG Production	Methyl methacrylate	secondary	3.22e-02	6.38e-07
LPG Production	Methyl hydrazine	secondary	2.88e-02	5.71e-07
Fuel Oil #6 Prod.	Benzene	secondary	2.59e-02	5.13e-07
US electric grid	Cumene	model/secondary	2.31e-02	4.57e-07
LPG Production	2-Chloroacetophenone	secondary	2.25e-02	4.47e-07
Japanese Electric Grid	Tetrachloroethylene	model/secondary	2.00e-02	3.96e-07
LPG Production	1,4-Dichlorobenzene	secondary	1.98e-02	3.92e-07
Fuel Oil #2 Prod.	Benzene	secondary	1.85e-02	3.66e-07
US electric grid	Naphthalene	model/secondary	1.77e-02	3.52e-07
US electric grid	Methyl methacrylate	model/secondary	1.74e-02	3.45e-07
US electric grid	Methyl hydrazine	model/secondary	1.56e-02	3.09e-07
Fuel Oil #4 Prod.	Acrolein	secondary	1.45e-02	2.88e-07
Natural Gas Prod.	Naphthalene	secondary	1.39e-02	2.76e-07
Natural Gas Prod.	Carbon disulfide	secondary	1.32e-02	2.63e-07
US electric grid	2-Chloroacetophenone	model/secondary	1.22e-02	2.42e-07
Fuel Oil #4 Prod.	Benzyl chloride	secondary	1.15e-02	2.28e-07
US electric grid	Xylene (mixed isomers)	model/secondary	1.06e-02	2.09e-07
Natural Gas Prod.	Methyl ethyl ketone	secondary	1.05e-02	2.09e-07
Natural Gas Prod.	Isophorone	secondary	9.67e-03	1.92e-07
Fuel Oil #6 Prod.	Acrolein	secondary	7.74e-03	1.54e-07
Natural Gas Prod.	Phenol	secondary	7.52e-03	1.49e-07
LPG Production	Chlorobenzene	secondary	7.08e-03	1.40e-07
Natural Gas Prod.	Styrene	secondary	6.74e-03	1.34e-07
Japanese Electric Grid	1,2-Dichloroethane	model/secondary	6.17e-03	1.22e-07
Fuel Oil #6 Prod.	Benzyl chloride	secondary	6.14e-03	1.22e-07
LPG Production	Vinyl acetate	secondary	6.11e-03	1.21e-07
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	5.85e-03	1.16e-07
Fuel Oil #2 Prod.	Acrolein	secondary	4.13e-03	8.18e-08
US electric grid	Chlorobenzene	model/secondary	3.83e-03	7.59e-08
US electric grid	Vinyl acetate	model/secondary	3.31e-03	6.56e-08
Fuel Oil #2 Prod.	Benzyl chloride	secondary	3.27e-03	6.49e-08
Natural Gas Prod.	Chlorine	secondary	3.25e-03	6.45e-08
LPG Production	Acetophenone	secondary	3.22e-03	6.38e-08
Fuel Oil #4 Prod.	Toluene	secondary	2.91e-03	5.77e-08
Fuel Oil #4 Prod.	Carbon disulfide	secondary	2.50e-03	4.95e-08
Natural Gas Prod.	Cumene	secondary	2.43e-03	4.82e-08
US electric grid	Benzene	model/secondary	2.10e-03	4.16e-08
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	1.98e-03	3.93e-08
Natural Gas Prod.	Methyl methacrylate	secondary	1.83e-03	3.64e-08
Fuel Oil #4 Prod.	Isophorone	secondary	1.82e-03	3.61e-08
Japanese Electric Grid	Dichloromethane	model/secondary	1.75e-03	3.46e-08
US electric grid	Acetophenone	model/secondary	1.74e-03	3.45e-08
LPG Production	Tetrachloroethylene	secondary	1.67e-03	3.31e-08
Natural Gas Prod.	Methyl hydrazine	secondary	1.64e-03	3.25e-08
Fuel Oil #6 Prod.	Toluene	secondary	1.42e-03	2.83e-08
Fuel Oil #4 Prod.	Phenol	secondary	1.42e-03	2.81e-08
Fuel Oil #6 Prod.	Carbon disulfide	secondary	1.33e-03	2.64e-08
Natural Gas Prod.	2-Chloroacetophenone	secondary	1.28e-03	2.55e-08
Fuel Oil #4 Prod.	Styrene	secondary	1.27e-03	2.52e-08
LPG Production	1,1,1-Trichloroethane	secondary	1.21e-03	2.41e-08

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
LPG Production	Chlorine	secondary	1.11e-03	2.21e-08
Fuel Oil #6 Prod.	Methyl ethyl ketone	secondary	1.06e-03	2.10e-08
Fuel Oil #6 Prod.	Isophorone	secondary	9.71e-04	1.93e-08
US electric grid	Tetrachloroethylene	model/secondary	9.02e-04	1.79e-08
Fuel Oil #2 Prod.	Toluene	secondary	8.82e-04	1.75e-08
Fuel Oil #4 Prod.	Naphthalene	secondary	7.79e-04	1.54e-08
Fuel Oil #6 Prod.	Phenol	secondary	7.56e-04	1.50e-08
Fuel Oil #2 Prod.	Carbon disulfide	secondary	7.09e-04	1.41e-08
US electric grid	1,1,1-Trichloroethane	model/secondary	7.02e-04	1.39e-08
Fuel Oil #6 Prod.	Styrene	secondary	6.77e-04	1.34e-08
Fuel Oil #4 Prod.	o-xylene	secondary	5.99e-04	1.19e-08
Fuel Oil #2 Prod.	Methyl ethyl ketone	secondary	5.63e-04	1.12e-08
Fuel Oil #2 Prod.	Isophorone	secondary	5.18e-04	1.03e-08
LPG Production	1,2-Dichloroethane	secondary	5.15e-04	1.02e-08
Fuel Oil #4 Prod.	Cumene	secondary	4.58e-04	9.08e-09
Natural Gas Prod.	Chlorobenzene	secondary	4.03e-04	8.00e-09
Fuel Oil #2 Prod.	Phenol	secondary	4.03e-04	7.99e-09
Fuel Oil #2 Prod.	Styrene	secondary	3.61e-04	7.16e-09
Fuel Oil #6 Prod.	Naphthalene	secondary	3.61e-04	7.16e-09
Japanese Electric Grid	Chloroform	model/secondary	3.50e-04	6.94e-09
Natural Gas Prod.	Vinyl acetate	secondary	3.48e-04	6.91e-09
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	3.46e-04	6.85e-09
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	3.09e-04	6.13e-09
Fuel Oil #6 Prod.	o-xylene	secondary	2.82e-04	5.59e-09
US electric grid	1,2-Dichloroethane	model/secondary	2.78e-04	5.52e-09
Fuel Oil #2 Prod.	Naphthalene	secondary	2.45e-04	4.85e-09
Fuel Oil #6 Prod.	Cumene	secondary	2.44e-04	4.84e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	2.42e-04	4.80e-09
Fuel Oil #2 Prod.	o-xylene	secondary	1.86e-04	3.69e-09
Fuel Oil #6 Prod.	Methyl methacrylate	secondary	1.84e-04	3.65e-09
Natural Gas Prod.	Acetophenone	secondary	1.83e-04	3.64e-09
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	1.79e-04	3.54e-09
Fuel Oil #6 Prod.	Methyl hydrazine	secondary	1.65e-04	3.27e-09
LPG Production	Dichloromethane	secondary	1.46e-04	2.89e-09
US electric grid	o-xylene	model/secondary	1.42e-04	2.82e-09
Fuel Oil #2 Prod.	Cumene	secondary	1.30e-04	2.58e-09
Fuel Oil #6 Prod.	2-Chloroacetophenone	secondary	1.29e-04	2.56e-09
Fuel Oil #2 Prod.	Methyl methacrylate	secondary	9.82e-05	1.95e-09
Natural Gas Prod.	Tetrachloroethylene	secondary	9.50e-05	1.88e-09
Fuel Oil #2 Prod.	Methyl hydrazine	secondary	8.79e-05	1.74e-09
Fuel Oil #6 Prod.	1,4-Dichlorobenzene	secondary	8.02e-05	1.59e-09
US electric grid	Dichloromethane	model/secondary	7.89e-05	1.56e-09
Fuel Oil #4 Prod.	Chlorobenzene	secondary	7.60e-05	1.51e-09
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	6.92e-05	1.37e-09
Fuel Oil #2 Prod.	2-Chloroacetophenone	secondary	6.87e-05	1.36e-09
Fuel Oil #4 Prod.	Vinyl acetate	secondary	6.57e-05	1.30e-09
Fuel Oil #2 Prod.	1,4-Dichlorobenzene	secondary	5.72e-05	1.13e-09
Fuel Oil #6 Prod.	Chlorobenzene	secondary	4.05e-05	8.04e-10
Fuel Oil #6 Prod.	Vinyl acetate	secondary	3.50e-05	6.94e-10
Fuel Oil #4 Prod.	Acetophenone	secondary	3.46e-05	6.85e-10
Natural Gas Prod.	1,2-Dichloroethane	secondary	2.93e-05	5.82e-10

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
LPG Production	Chloroform	secondary	2.92e-05	5.79e-10
Fuel Oil #2 Prod.	Chlorobenzene	secondary	2.16e-05	4.28e-10
Fuel Oil #2 Prod.	Vinyl acetate	secondary	1.87e-05	3.70e-10
Fuel Oil #6 Prod.	Acetophenone	secondary	1.84e-05	3.65e-10
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	1.79e-05	3.55e-10
US electric grid	Chloroform	model/secondary	1.58e-05	3.13e-10
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	1.30e-05	2.59e-10
Fuel Oil #4 Prod.	Chlorine	secondary	9.86e-06	1.95e-10
Fuel Oil #2 Prod.	Acetophenone	secondary	9.82e-06	1.95e-10
Fuel Oil #6 Prod.	Tetrachloroethylene	secondary	9.54e-06	1.89e-10
Natural Gas Prod.	Dichloromethane	secondary	8.31e-06	1.65e-10
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	6.95e-06	1.38e-10
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	5.53e-06	1.10e-10
Fuel Oil #2 Prod.	Tetrachloroethylene	secondary	5.09e-06	1.01e-10
Fuel Oil #6 Prod.	Chlorine	secondary	4.39e-06	8.71e-11
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	3.71e-06	7.35e-11
Fuel Oil #2 Prod.	Chlorine	secondary	3.17e-06	6.29e-11
Fuel Oil #6 Prod.	1,2-Dichloroethane	secondary	2.95e-06	5.85e-11
Natural Gas Prod.	Chloroform	secondary	1.66e-06	3.30e-11
Fuel Oil #2 Prod.	1,2-Dichloroethane	secondary	1.57e-06	3.12e-11
Fuel Oil #4 Prod.	Dichloromethane	secondary	1.57e-06	3.11e-11
Fuel Oil #6 Prod.	Dichloromethane	secondary	8.35e-07	1.66e-11
Fuel Oil #2 Prod.	Dichloromethane	secondary	4.45e-07	8.82e-12
Fuel Oil #4 Prod.	Chloroform	secondary	3.14e-07	6.22e-12
Fuel Oil #6 Prod.	Chloroform	secondary	1.67e-07	3.32e-12
Fuel Oil #2 Prod.	Chloroform	secondary	8.91e-08	1.77e-12
Total Manufacturing			**4.93e+06**	**9.77e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Acetaldehyde	model/secondary	7.08e+04	1.40e+00
US electric grid	Propionaldehyde	model/secondary	3.64e+03	7.22e-02
US electric grid	Acrolein	model/secondary	1.41e+02	2.80e-03
US electric grid	Benzyl chloride	model/secondary	1.12e+02	2.22e-03
US electric grid	Formaldehyde	model/secondary	6.46e+01	1.28e-03
US electric grid	Carbon disulfide	model/secondary	2.42e+01	4.80e-04
US electric grid	Methyl ethyl ketone	model/secondary	1.92e+01	3.82e-04
US electric grid	Isophorone	model/secondary	1.77e+01	3.51e-04
US electric grid	Toluene	model/secondary	1.58e+01	3.14e-04
US electric grid	Phenol	model/secondary	1.38e+01	2.73e-04
US electric grid	Styrene	model/secondary	1.23e+01	2.45e-04
US electric grid	Cumene	model/secondary	4.45e+00	8.81e-05
US electric grid	Naphthalene	model/secondary	3.42e+00	6.78e-05
US electric grid	Methyl methacrylate	model/secondary	3.35e+00	6.65e-05
US electric grid	Methyl hydrazine	model/secondary	3.00e+00	5.95e-05
US electric grid	2-Chloroacetophenone	model/secondary	2.35e+00	4.66e-05
US electric grid	Xylene (mixed isomers)	model/secondary	2.03e+00	4.04e-05
US electric grid	Chlorobenzene	model/secondary	7.38e-01	1.46e-05
US electric grid	Vinyl acetate	model/secondary	6.37e-01	1.26e-05
US electric grid	Benzene	model/secondary	4.04e-01	8.02e-06
US electric grid	Acetophenone	model/secondary	3.35e-01	6.65e-06
US electric grid	Tetrachloroethylene	model/secondary	1.74e-01	3.45e-06
US electric grid	1,1,1-Trichloroethane	model/secondary	1.35e-01	2.68e-06

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
US electric grid	1,2-Dichloroethane	model/secondary	5.37e-02	1.06e-06
US electric grid	o-xylene	model/secondary	2.74e-02	5.43e-07
US electric grid	Dichloromethane	model/secondary	1.52e-02	3.01e-07
US electric grid	Chloroform	model/secondary	3.05e-03	6.04e-08
Total Use, Maintenance and Repair			**7.49e+04**	**1.49e+00**
End-of-life Life-cycle Stage				
LCD landfilling	Hydrogen sulfide	primary	1.29e+02	2.56e-03
LPG Production	Hydrogen sulfide	secondary	2.81e+01	5.58e-04
US electric grid	Acetaldehyde	model/secondary	1.34e+01	2.66e-04
US electric grid	Propionaldehyde	model/secondary	6.91e-01	1.37e-05
LPG Production	Acetaldehyde	secondary	5.58e-02	1.11e-06
US electric grid	Acrolein	model/secondary	2.68e-02	5.31e-07
US electric grid	Benzyl chloride	model/secondary	2.12e-02	4.21e-07
LCD landfilling	Toluene	primary	1.92e-02	3.81e-07
US electric grid	Formaldehyde	model/secondary	1.23e-02	2.43e-07
LCD landfilling	Xylene (mixed isomers)	primary	9.80e-03	1.94e-07
LPG Production	Formaldehyde	secondary	9.43e-03	1.87e-07
LPG Production	Ammonia	secondary	8.59e-03	1.70e-07
US electric grid	Carbon disulfide	model/secondary	4.60e-03	9.12e-08
US electric grid	Methyl ethyl ketone	model/secondary	3.65e-03	7.24e-08
US electric grid	Isophorone	model/secondary	3.36e-03	6.66e-08
US electric grid	Toluene	model/secondary	3.01e-03	5.96e-08
LPG Production	Propionaldehyde	secondary	2.87e-03	5.69e-08
US electric grid	Phenol	model/secondary	2.61e-03	5.18e-08
US electric grid	Styrene	model/secondary	2.34e-03	4.64e-08
LCD landfilling	Benzene	primary	1.51e-03	3.00e-08
US electric grid	Cumene	model/secondary	8.43e-04	1.67e-08
US electric grid	Naphthalene	model/secondary	6.49e-04	1.29e-08
US electric grid	Methyl methacrylate	model/secondary	6.37e-04	1.26e-08
US electric grid	Methyl hydrazine	model/secondary	5.70e-04	1.13e-08
LPG Production	Benzene	secondary	5.25e-04	1.04e-08
US electric grid	2-Chloroacetophenone	model/secondary	4.46e-04	8.84e-09
US electric grid	Xylene (mixed isomers)	model/secondary	3.86e-04	7.66e-09
US electric grid	Chlorobenzene	model/secondary	1.40e-04	2.78e-09
US electric grid	Vinyl acetate	model/secondary	1.21e-04	2.40e-09
LPG Production	Acrolein	secondary	1.11e-04	2.20e-09
LPG Production	Benzyl chloride	secondary	8.81e-05	1.75e-09
LCD landfilling	Trichloroethylene	primary	8.47e-05	1.68e-09
US electric grid	Benzene	model/secondary	7.67e-05	1.52e-09
LCD incineration	Trichloroethylene	secondary	6.57e-05	1.30e-09
US electric grid	Acetophenone	model/secondary	6.37e-05	1.26e-09
LCD landfilling	Tetrachloroethylene	primary	3.98e-05	7.90e-10
US electric grid	Tetrachloroethylene	model/secondary	3.30e-05	6.54e-10
US electric grid	1,1,1-Trichloroethane	model/secondary	2.57e-05	5.09e-10
LPG Production	Toluene	secondary	2.45e-05	4.85e-10
LPG Production	Carbon disulfide	secondary	1.91e-05	3.78e-10
LPG Production	Methyl ethyl ketone	secondary	1.52e-05	3.00e-10
LPG Production	Isophorone	secondary	1.39e-05	2.76e-10
LCD landfilling	1,2-Dichloroethane	primary	1.32e-05	2.62e-10
LPG Production	Phenol	secondary	1.08e-05	2.15e-10

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
US electric grid	1,2-Dichloroethane	model/secondary	1.02e-05	2.02e-10
LPG Production	Styrene	secondary	9.71e-06	1.93e-10
LPG Production	Naphthalene	secondary	6.89e-06	1.37e-10
LPG Production	o-xylene	secondary	5.22e-06	1.04e-10
US electric grid	o-xylene	model/secondary	5.19e-06	1.03e-10
LPG Production	Cumene	secondary	3.50e-06	6.94e-11
US electric grid	Dichloromethane	model/secondary	2.88e-06	5.72e-11
LPG Production	Methyl methacrylate	secondary	2.64e-06	5.24e-11
LPG Production	Methyl hydrazine	secondary	2.36e-06	4.69e-11
LPG Production	2-Chloroacetophenone	secondary	1.85e-06	3.67e-11
LPG Production	1,4-Dichlorobenzene	secondary	1.62e-06	3.22e-11
LCD landfilling	Dichloromethane	primary	8.25e-07	1.64e-11
LPG Production	Chlorobenzene	secondary	5.81e-07	1.15e-11
US electric grid	Chloroform	model/secondary	5.78e-07	1.15e-11
LCD landfilling	Chloroform	primary	5.08e-07	1.01e-11
LPG Production	Vinyl acetate	secondary	5.02e-07	9.95e-12
LCD landfilling	Carbon tetrachloride	primary	3.74e-07	7.41e-12
LCD incineration	Carbon tetrachloride	secondary	2.90e-07	5.75e-12
LPG Production	Acetophenone	secondary	2.64e-07	5.24e-12
LPG Production	Tetrachloroethylene	secondary	1.37e-07	2.71e-12
LPG Production	1,1,1-Trichloroethane	secondary	9.97e-08	1.98e-12
LPG Production	Chlorine	secondary	9.13e-08	1.81e-12
LPG Production	1,2-Dichloroethane	secondary	4.23e-08	8.38e-13
LPG Production	Dichloromethane	secondary	1.20e-08	2.37e-13
LPG Production	Chloroform	secondary	2.40e-09	4.75e-14
Natural Gas Prod.	Chloroform	secondary	-3.50e-07	-6.93e-12
Fuel Oil #4 Prod.	Chloroform	secondary	-1.45e-06	-2.87e-11
Natural Gas Prod.	Dichloromethane	secondary	-1.74e-06	-3.46e-11
Natural Gas Prod.	1,2-Dichloroethane	secondary	-6.16e-06	-1.22e-10
Fuel Oil #4 Prod.	Dichloromethane	secondary	-7.22e-06	-1.43e-10
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-1.45e-05	-2.88e-10
Natural Gas Prod.	Tetrachloroethylene	secondary	-2.00e-05	-3.96e-10
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	-2.55e-05	-5.05e-10
Natural Gas Prod.	Acetophenone	secondary	-3.85e-05	-7.64e-10
Fuel Oil #4 Prod.	Chlorine	secondary	-4.54e-05	-9.01e-10
LCD incineration	Chlorine	secondary	-5.47e-05	-1.08e-09
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-6.01e-05	-1.19e-09
Natural Gas Prod.	Vinyl acetate	secondary	-7.32e-05	-1.45e-09
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	-8.25e-05	-1.64e-09
Natural Gas Prod.	Chlorobenzene	secondary	-8.47e-05	-1.68e-09
LCD incineration	Chloroform	secondary	-8.73e-05	-1.73e-09
Fuel Oil #4 Prod.	Acetophenone	secondary	-1.59e-04	-3.16e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	-2.70e-04	-5.35e-09
Fuel Oil #4 Prod.	Vinyl acetate	secondary	-3.03e-04	-6.00e-09
Natural Gas Prod.	Methyl hydrazine	secondary	-3.45e-04	-6.83e-09
Fuel Oil #4 Prod.	Chlorobenzene	secondary	-3.50e-04	-6.95e-09
Natural Gas Prod.	Methyl methacrylate	secondary	-3.85e-04	-7.64e-09
LCD incineration	Dichloromethane	secondary	-4.37e-04	-8.66e-09
Natural Gas Prod.	Cumene	secondary	-5.10e-04	-1.01e-08
Natural Gas Prod.	Chlorine	secondary	-6.83e-04	-1.35e-08
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	-8.23e-04	-1.63e-08

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	-1.11e-03	-2.21e-08
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	-1.23e-03	-2.44e-08
Natural Gas Prod.	Styrene	secondary	-1.42e-03	-2.81e-08
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	-1.43e-03	-2.83e-08
LCD incineration	1,2-Dichloroethane	secondary	-1.53e-03	-3.04e-08
Natural Gas Prod.	Phenol	secondary	-1.58e-03	-3.13e-08
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	-1.59e-03	-3.16e-08
Natural Gas Prod.	Isophorone	secondary	-2.03e-03	-4.03e-08
Fuel Oil #4 Prod.	Cumene	secondary	-2.11e-03	-4.18e-08
Natural Gas Prod.	Methyl ethyl ketone	secondary	-2.21e-03	-4.38e-08
Fuel Oil #4 Prod.	o-xylene	secondary	-2.76e-03	-5.47e-08
Natural Gas Prod.	Carbon disulfide	secondary	-2.78e-03	-5.52e-08
Natural Gas Prod.	Naphthalene	secondary	-2.92e-03	-5.80e-08
Fuel Oil #4 Prod.	Naphthalene	secondary	-3.59e-03	-7.11e-08
LCD incineration	1,1,1-Trichloroethane	secondary	-3.64e-03	-7.23e-08
LCD incineration	Tetrachloroethylene	secondary	-4.97e-03	-9.86e-08
Fuel Oil #4 Prod.	Styrene	secondary	-5.86e-03	-1.16e-07
Fuel Oil #4 Prod.	Phenol	secondary	-6.53e-03	-1.30e-07
Fuel Oil #4 Prod.	Isophorone	secondary	-8.40e-03	-1.67e-07
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	-9.13e-03	-1.81e-07
LCD incineration	Acetophenone	secondary	-9.66e-03	-1.91e-07
Fuel Oil #4 Prod.	Carbon disulfide	secondary	-1.15e-02	-2.28e-07
Natural Gas Prod.	Benzyl chloride	secondary	-1.28e-02	-2.55e-07
Fuel Oil #4 Prod.	Toluene	secondary	-1.34e-02	-2.66e-07
Natural Gas Prod.	Acrolein	secondary	-1.62e-02	-3.21e-07
LCD incineration	Vinyl acetate	secondary	-1.83e-02	-3.64e-07
LCD incineration	Chlorobenzene	secondary	-2.12e-02	-4.21e-07
Natural Gas Prod.	Toluene	secondary	-2.86e-02	-5.66e-07
Natural Gas Prod.	o-xylene	secondary	-2.94e-02	-5.84e-07
Fuel Oil #4 Prod.	Benzyl chloride	secondary	-5.31e-02	-1.05e-06
LCD incineration	Xylene (mixed isomers)	secondary	-5.48e-02	-1.09e-06
Fuel Oil #4 Prod.	Acrolein	secondary	-6.69e-02	-1.33e-06
LCD incineration	Methyl hydrazine	secondary	-8.64e-02	-1.71e-06
LCD incineration	Naphthalene	secondary	-8.91e-02	-1.77e-06
LCD incineration	Methyl methacrylate	secondary	-9.66e-02	-1.91e-06
LCD incineration	Cumene	secondary	-1.28e-01	-2.54e-06
Natural Gas Prod.	Formaldehyde	secondary	-1.64e-01	-3.25e-06
Fuel Oil #4 Prod.	Benzene	secondary	-2.66e-01	-5.27e-06
LCD incineration	Benzene	secondary	-3.23e-01	-6.40e-06
LCD incineration	Styrene	secondary	-3.55e-01	-7.04e-06
LCD incineration	Phenol	secondary	-3.96e-01	-7.86e-06
Natural Gas Prod.	Propionaldehyde	secondary	-4.18e-01	-8.29e-06
LCD incineration	Toluene	secondary	-4.73e-01	-9.38e-06
LCD incineration	Isophorone	secondary	-5.09e-01	-1.01e-05
LCD incineration	Methyl ethyl ketone	secondary	-5.54e-01	-1.10e-05
LCD incineration	Carbon disulfide	secondary	-6.97e-01	-1.38e-05
Fuel Oil #4 Prod.	Propionaldehyde	secondary	-1.73e+00	-3.43e-05
LCD incineration	Benzyl chloride	secondary	-3.22e+00	-6.38e-05
Natural Gas Prod.	Benzene	secondary	-3.89e+00	-7.72e-05
LCD incineration	Acrolein	secondary	-4.06e+00	-8.05e-05
Fuel Oil #4 Prod.	Ammonia	secondary	-4.24e+00	-8.40e-05

Table M-36. LCD LCIA Results for the Aesthetics Impact Category

Process Group	Material	LCI Data Type	Odor (m3)	% of Total
LCD incineration	Formaldehyde	secondary	-5.17e+00	-1.03e-04
Fuel Oil #4 Prod.	Formaldehyde	secondary	-6.51e+00	-1.29e-04
Natural Gas Prod.	Acetaldehyde	secondary	-8.13e+00	-1.61e-04
LCD incineration	Ammonia	secondary	-1.35e+01	-2.68e-04
Fuel Oil #4 Prod.	Acetaldehyde	secondary	-3.36e+01	-6.67e-04
Natural Gas Prod.	Hydrogen sulfide	secondary	-5.19e+01	-1.03e-03
Natural Gas Prod.	Ammonia	secondary	-5.20e+01	-1.03e-03
LCD incineration	Propionaldehyde	secondary	-1.05e+02	-2.08e-03
LCD incineration	Hydrogen sulfide	secondary	-1.20e+03	-2.37e-02
LCD incineration	Acetaldehyde	secondary	-2.04e+03	-4.04e-02
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	-1.96e+04	-3.89e-01
Total End-of-life			**-2.30e+04**	**-4.56e-01**
Total All Life-cycle Stages			**5.04e+06**	**1.00e+02**

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Materials Processing Life-cycle Stage				
Aluminum Prod.	Aluminum (+3)	secondary	2.76e-02	1.23e+01
Aluminum Prod.	Copper (+1 & +2)	secondary	2.13e-02	9.46e+00
Invar	Copper (+1 & +2)	secondary	1.11e-02	4.96e+00
Invar	Aluminum (+3)	secondary	9.89e-03	4.40e+00
Invar	Zinc (+2)	secondary	9.00e-03	4.00e+00
Lead	Aluminum (+3)	secondary	8.03e-03	3.57e+00
Ferrite mfg.	Zinc (+2)	secondary	6.81e-03	3.03e+00
Aluminum Prod.	Zinc (+2)	secondary	6.44e-03	2.86e+00
ABS Production	Ammonia	secondary	6.17e-03	2.74e+00
Lead	Copper (+1 & +2)	secondary	6.15e-03	2.73e+00
Steel Prod., cold-rolled, semi-finished	Phosphorus (yellow or white)	secondary	4.60e-03	2.04e+00
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	2.80e-03	1.24e+00
Lead	Zinc (+2)	secondary	1.83e-03	8.16e-01
Polycarbonate Production	Copper (+1 & +2)	secondary	1.23e-03	5.45e-01
Steel Prod., cold-rolled, semi-finished	Copper (+1 & +2)	secondary	1.02e-03	4.52e-01
Ferrite mfg.	Aluminum (+3)	secondary	9.68e-04	4.31e-01
Aluminum Prod.	Barium sulfate	secondary	9.07e-04	4.03e-01
ABS Production	Aluminum (+3)	secondary	8.82e-04	3.92e-01
Invar	Ammonia	secondary	8.20e-04	3.65e-01
Ferrite mfg.	Copper (+1 & +2)	secondary	7.04e-04	3.13e-01
ABS Production	Copper (+1 & +2)	secondary	5.62e-04	2.50e-01
Styrene-butadiene Copolymer Prod.	Copper (+1 & +2)	secondary	5.49e-04	2.44e-01
Aluminum Prod.	Titanium tetrachloride	secondary	4.56e-04	2.03e-01
Polycarbonate Production	Mercury compounds	secondary	4.30e-04	1.91e-01
Aluminum Prod.	Strontium (Sr II)	secondary	3.19e-04	1.42e-01
Steel Prod., cold-rolled, semi-finished	Aluminum (+3)	secondary	2.74e-04	1.22e-01
Ferrite mfg.	Ammonia	secondary	2.64e-04	1.18e-01
Lead	Barium sulfate	secondary	2.29e-04	1.02e-01
Steel Prod., cold-rolled, semi-finished	Nitrogen dioxide	secondary	1.98e-04	8.79e-02
ABS Production	Mercury compounds	secondary	1.97e-04	8.77e-02
Steel Prod., cold-rolled, semi-finished	Zinc (+2)	secondary	1.96e-04	8.72e-02
Styrene-butadiene Copolymer Prod.	Mercury compounds	secondary	1.93e-04	8.57e-02
Steel Prod., cold-rolled, semi-finished	Fluorides (F-)	secondary	1.93e-04	8.57e-02
Aluminum Prod.	Lead cmpds	secondary	1.72e-04	7.64e-02
Polycarbonate Production	Zinc (+2)	secondary	1.71e-04	7.59e-02
Invar	Strontium (Sr II)	secondary	1.65e-04	7.36e-02
Invar	Titanium tetrachloride	secondary	1.62e-04	7.22e-02
Aluminum Prod.	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	1.55e-04	6.89e-02
Steel Prod., cold-rolled, semi-finished	Strontium (Sr II)	secondary	1.49e-04	6.63e-02
Lead	Titanium tetrachloride	secondary	1.33e-04	5.93e-02
Polycarbonate Production	Chlorine	secondary	1.22e-04	5.42e-02
Polycarbonate Production	Ammonia	secondary	1.19e-04	5.28e-02
Aluminum Prod.	Cadmium cmpds	secondary	1.16e-04	5.16e-02
Aluminum Prod.	Barium cmpds	secondary	9.35e-05	4.16e-02
Aluminum Prod.	Nitrate	secondary	9.13e-05	4.06e-02
Steel Prod., cold-rolled, semi-finished	Mercury compounds	secondary	8.00e-05	3.56e-02
ABS Production	Zinc (+2)	secondary	7.82e-05	3.48e-02
Styrene-butadiene Copolymer Prod.	Zinc (+2)	secondary	7.64e-05	3.40e-02
Invar	Barium sulfate	secondary	6.91e-05	3.08e-02

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Barium sulfate	secondary	6.87e-05	3.05e-02
Ferrite mfg.	Barium sulfate	secondary	6.75e-05	3.00e-02
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	6.51e-05	2.89e-02
Lead	Strontium (Sr II)	secondary	6.40e-05	2.84e-02
ABS Production	Nitrate	secondary	6.01e-05	2.67e-02
Invar	Lead cmpds	secondary	5.87e-05	2.61e-02
ABS Production	Chlorine	secondary	5.59e-05	2.49e-02
Polycarbonate Production	Phenol	secondary	5.55e-05	2.47e-02
Styrene-butadiene Copolymer Prod.	Chlorine	secondary	5.46e-05	2.43e-02
Lead	Lead cmpds	secondary	5.41e-05	2.41e-02
Invar	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	5.40e-05	2.40e-02
Polystyrene Prod., high-impact	Ammonia	secondary	5.18e-05	2.30e-02
Ferrite mfg.	Strontium (Sr II)	secondary	4.84e-05	2.15e-02
Lead	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	4.68e-05	2.08e-02
Invar	Barium cmpds	secondary	3.86e-05	1.72e-02
Aluminum Prod.	Nickel cmpds	secondary	3.82e-05	1.70e-02
Aluminum Prod.	Chromium (III)	secondary	3.20e-05	1.42e-02
Invar	Nickel cmpds	secondary	3.03e-05	1.35e-02
Steel Prod., cold-rolled, semi-finished	Silver compounds	secondary	2.83e-05	1.26e-02
Aluminum Prod.	Aromatic hydrocarbons	secondary	2.83e-05	1.26e-02
Invar	Xylene (mixed isomers)	secondary	2.44e-05	1.08e-02
Lead	Barium cmpds	secondary	2.43e-05	1.08e-02
Aluminum Prod.	Manganese cmpds	secondary	2.28e-05	1.01e-02
Ferrite mfg.	Phosphorus (yellow or white)	secondary	2.21e-05	9.85e-03
Invar	Manganese cmpds	secondary	2.10e-05	9.36e-03
Ferrite mfg.	Xylene (mixed isomers)	secondary	1.93e-05	8.56e-03
Invar	Phosphorus (yellow or white)	secondary	1.86e-05	8.29e-03
Aluminum Prod.	Fluoride	secondary	1.82e-05	8.09e-03
Lead	Nitrate	secondary	1.80e-05	8.01e-03
Steel Prod., cold-rolled, semi-finished	Lead cmpds	secondary	1.74e-05	7.74e-03
Aluminum Prod.	Vanadium (V3+, V5+)	secondary	1.63e-05	7.24e-03
Aluminum Prod.	Selenium	secondary	1.59e-05	7.05e-03
Steel Prod., cold-rolled, semi-finished	Barium cmpds	secondary	1.55e-05	6.90e-03
Ferrite mfg.	Titanium tetrachloride	secondary	1.50e-05	6.66e-03
Invar	Aromatic hydrocarbons	secondary	1.47e-05	6.52e-03
Styrene-butadiene Copolymer Prod.	Aluminum (+3)	secondary	1.44e-05	6.39e-03
Ferrite mfg.	Manganese cmpds	secondary	1.32e-05	5.87e-03
Steel Prod., cold-rolled, semi-finished	Aromatic hydrocarbons	secondary	1.30e-05	5.78e-03
Aluminum Prod.	Xylene (mixed isomers)	secondary	1.26e-05	5.61e-03
Invar	Cadmium cmpds	secondary	1.26e-05	5.60e-03
Invar	Chromium (III)	secondary	1.14e-05	5.09e-03
Lead	Nickel cmpds	secondary	1.12e-05	4.99e-03
Steel Prod., cold-rolled, semi-finished	Tin (Sn++, Sn4+)	secondary	1.04e-05	4.63e-03
Ferrite mfg.	Lead cmpds	secondary	1.02e-05	4.55e-03
Lead	Chromium (III)	secondary	9.38e-06	4.17e-03
Lead	Fluoride	secondary	8.91e-06	3.96e-03
Invar	Fluoride	secondary	8.80e-06	3.91e-03
Aluminum Prod.	Arsenic cmpds	secondary	8.57e-06	3.81e-03
Invar	Silver compounds	secondary	8.56e-06	3.81e-03
Ferrite mfg.	Silver compounds	secondary	8.35e-06	3.72e-03

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Ferrite mfg.	Nitrate	secondary	8.08e-06	3.59e-03
Polycarbonate Production	Aluminum (+3)	secondary	8.02e-06	3.56e-03
Ferrite mfg.	Barium cmpds	secondary	7.00e-06	3.11e-03
Aluminum Prod.	Benzene	secondary	6.79e-06	3.02e-03
Lead	Manganese cmpds	secondary	6.47e-06	2.88e-03
Invar	Toluene	secondary	6.23e-06	2.77e-03
Invar	Vanadium (V3+, V5+)	secondary	6.00e-06	2.67e-03
Styrene-butadiene Copolymer Prod.	Nitrate	secondary	5.79e-06	2.58e-03
Invar	Selenium	secondary	5.69e-06	2.53e-03
Lead	Vanadium (V3+, V5+)	secondary	4.75e-06	2.11e-03
Lead	Selenium	secondary	4.63e-06	2.06e-03
Aluminum Prod.	Toluene	secondary	4.24e-06	1.89e-03
Ferrite mfg.	Aromatic hydrocarbons	secondary	4.10e-06	1.82e-03
Aluminum Prod.	Phenol	secondary	3.79e-06	1.69e-03
Invar	Benzene	secondary	3.63e-06	1.61e-03
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	3.55e-06	1.58e-03
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	3.54e-06	1.58e-03
ABS Production	Phenol	secondary	3.49e-06	1.55e-03
Invar	Arsenic cmpds	secondary	3.05e-06	1.35e-03
Invar	Tin (Sn++, Sn4+)	secondary	3.03e-06	1.35e-03
Steel Prod., cold-rolled, semi-finished	Chlorine	secondary	3.01e-06	1.34e-03
Styrene-butadiene Copolymer Prod.	Phenol	secondary	2.93e-06	1.30e-03
Invar	Cobalt (Co I, Co II, Co III)	secondary	2.88e-06	1.28e-03
Steel Prod., cold-rolled, semi-finished	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	2.84e-06	1.26e-03
Steel Prod., cold-rolled, semi-finished	Cadmium cmpds	secondary	2.68e-06	1.19e-03
Lead	Arsenic cmpds	secondary	2.49e-06	1.11e-03
Lead	Xylene (mixed isomers)	secondary	2.44e-06	1.08e-03
Steel Prod., cold-rolled, semi-finished	Cyanide (-1)	secondary	2.37e-06	1.05e-03
Steel Prod., cold-rolled, semi-finished	Boric acid	secondary	2.27e-06	1.01e-03
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	2.22e-06	9.87e-04
Steel Prod., cold-rolled, semi-finished	Manganese cmpds	secondary	2.10e-06	9.32e-04
Invar	Phenol	secondary	1.99e-06	8.85e-04
Ferrite mfg.	Fluoride	secondary	1.85e-06	8.21e-04
Lead	Cobalt (Co I, Co II, Co III)	secondary	1.84e-06	8.16e-04
Invar	Ethylbenzene	secondary	1.77e-06	7.87e-04
Steel Prod., cold-rolled, semi-finished	Ethylbenzene	secondary	1.76e-06	7.81e-04
Ferrite mfg.	Nickel cmpds	secondary	1.60e-06	7.10e-04
Lead	Mercury compounds	secondary	1.39e-06	6.20e-04
Lead	Benzene	secondary	1.32e-06	5.86e-04
Aluminum Prod.	Nitrites	secondary	1.25e-06	5.58e-04
Steel Prod., cold-rolled, semi-finished	Chromium (VI)	secondary	1.23e-06	5.48e-04
Steel Prod., cold-rolled, semi-finished	Nickel cmpds	secondary	1.19e-06	5.31e-04
Ferrite mfg.	Benzene	secondary	1.08e-06	4.82e-04
Ferrite mfg.	Chromium (III)	secondary	1.08e-06	4.81e-04
Polystyrene Prod., high-impact	Phenol	secondary	1.07e-06	4.75e-04
ABS Production	Nickel cmpds	secondary	1.01e-06	4.49e-04
Polycarbonate Production	Nickel (+2)	secondary	9.23e-07	4.11e-04
Polycarbonate Production	Nitrate	secondary	9.23e-07	4.11e-04
Lead	Toluene	secondary	8.22e-07	3.66e-04
Lead	Phenol	secondary	8.16e-07	3.63e-04

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Chromium (III)	secondary	8.02e-07	3.57e-04
Ferrite mfg.	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	7.99e-07	3.55e-04
Ferrite mfg.	Vanadium (V3+, V5+)	secondary	6.83e-07	3.04e-04
Ferrite mfg.	Toluene	secondary	6.82e-07	3.04e-04
Invar	Boric acid	secondary	6.44e-07	2.86e-04
Ferrite mfg.	Boric acid	secondary	6.29e-07	2.80e-04
Polystyrene Prod., high-impact	Nitrate	secondary	6.05e-07	2.69e-04
Steel Prod., cold-rolled, semi-finished	Vanadium (V3+, V5+)	secondary	5.94e-07	2.64e-04
Ferrite mfg.	Cadmium cmpds	secondary	5.89e-07	2.62e-04
Invar	Cyanide (-1)	secondary	5.64e-07	2.51e-04
Invar	Nitrites	secondary	5.52e-07	2.46e-04
Ferrite mfg.	Selenium	secondary	5.52e-07	2.45e-04
Ferrite mfg.	Phenol	secondary	5.50e-07	2.45e-04
Steel Prod., cold-rolled, semi-finished	Titanium tetrachloride	secondary	5.28e-07	2.35e-04
Ferrite mfg.	Ethylbenzene	secondary	5.20e-07	2.31e-04
Invar	Nitrates/nitrites	secondary	4.69e-07	2.09e-04
Styrene-butadiene Copolymer Prod.	Nickel (+2)	secondary	4.14e-07	1.84e-04
Ferrite mfg.	Cyanide (-1)	secondary	3.97e-07	1.77e-04
Aluminum Prod.	Cyanide (-1)	secondary	3.79e-07	1.69e-04
Invar	Boron (B III)	secondary	3.27e-07	1.46e-04
Ferrite mfg.	Arsenic cmpds	secondary	2.96e-07	1.31e-04
Steel Prod., cold-rolled, semi-finished	Arsenic cmpds	secondary	2.77e-07	1.23e-04
Lead	Nitrites	secondary	2.65e-07	1.18e-04
Invar	Chlorine	secondary	2.51e-07	1.12e-04
Ferrite mfg.	Chlorine	secondary	2.45e-07	1.09e-04
Steel Prod., cold-rolled, semi-finished	Rubidium ion (Rb+)	secondary	2.42e-07	1.08e-04
Lead	Boron (B III)	secondary	1.97e-07	8.74e-05
Steel Prod., cold-rolled, semi-finished	Nitrates/nitrites	secondary	1.94e-07	8.63e-05
Ferrite mfg.	Cobalt (Co I, Co II, Co III)	secondary	1.76e-07	7.82e-05
Steel Prod., cold-rolled, semi-finished	Selenium	secondary	1.59e-07	7.09e-05
Invar	Mercury compounds	secondary	9.86e-08	4.39e-05
Ferrite mfg.	Mercury compounds	secondary	9.63e-08	4.28e-05
Invar	Rubidium ion (Rb+)	secondary	7.31e-08	3.25e-05
Ferrite mfg.	Rubidium ion (Rb+)	secondary	7.14e-08	3.17e-05
Steel Prod., cold-rolled, semi-finished	Boron (B III)	secondary	7.04e-08	3.13e-05
Ferrite mfg.	Nitrites	secondary	3.83e-08	1.71e-05
Invar	Chromium (VI)	secondary	3.25e-08	1.45e-05
Steel Prod., cold-rolled, semi-finished	Phosphorus pentoxide	secondary	3.11e-08	1.38e-05
Ferrite mfg.	Chromium (VI)	secondary	2.76e-08	1.23e-05
Ferrite mfg.	Boron (B III)	secondary	2.32e-08	1.03e-05
Steel Prod., cold-rolled, semi-finished	Hydrazine	secondary	2.30e-08	1.02e-05
Steel Prod., cold-rolled, semi-finished	Morpholine	secondary	1.88e-08	8.35e-06
Aluminum Prod.	Chromium (VI)	secondary	9.21e-09	4.09e-06
Invar	Phosphorus pentoxide	secondary	9.09e-09	4.04e-06
Ferrite mfg.	Phosphorus pentoxide	secondary	8.87e-09	3.94e-06
Invar	Hydrazine	secondary	6.52e-09	2.90e-06
Ferrite mfg.	Hydrazine	secondary	6.37e-09	2.83e-06
Invar	Morpholine	secondary	5.32e-09	2.36e-06
Ferrite mfg.	Morpholine	secondary	5.19e-09	2.31e-06
Lead	Chromium (VI)	secondary	4.46e-09	1.99e-06

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Invar	Hypochlorous acid	secondary	3.54e-09	1.58e-06
Steel Prod., cold-rolled, semi-finished	Hypochlorous acid	secondary	3.52e-09	1.56e-06
Ferrite mfg.	Hypochlorous acid	secondary	3.46e-09	1.54e-06
Steel Prod., cold-rolled, semi-finished	Cobalt (Co I, Co II, Co III)	secondary	3.14e-09	1.40e-06
Invar	Dichloromethane	secondary	2.00e-09	8.88e-07
Steel Prod., cold-rolled, semi-finished	Dichloromethane	secondary	1.98e-09	8.82e-07
Ferrite mfg.	Dichloromethane	secondary	1.95e-09	8.67e-07
Aluminum Prod.	Triethylene glycol	secondary	1.73e-09	7.71e-07
Invar	Acetic acid	secondary	1.51e-09	6.73e-07
Ferrite mfg.	Acetic acid	secondary	1.48e-09	6.57e-07
Invar	Triethylene glycol	secondary	1.38e-09	6.14e-07
Steel Prod., cold-rolled, semi-finished	Triethylene glycol	secondary	1.37e-09	6.09e-07
Ferrite mfg.	Triethylene glycol	secondary	1.35e-09	5.99e-07
Lead	Triethylene glycol	secondary	1.30e-09	5.76e-07
Steel Prod., cold-rolled, semi-finished	Nitrites	secondary	4.82e-10	2.14e-07
Invar	Halogenated matter (organic)	secondary	2.74e-10	1.22e-07
Ferrite mfg.	Halogenated matter (organic)	secondary	2.68e-10	1.19e-07
Steel Prod., cold-rolled, semi-finished	Edetic acid (EDTA)	secondary	1.27e-10	5.66e-08
Invar	Edetic acid (EDTA)	secondary	3.60e-11	1.60e-08
Ferrite mfg.	Edetic acid (EDTA)	secondary	3.52e-11	1.56e-08
Ferrite mfg.	Tin (Sn++, Sn4+)	secondary	7.28e-12	3.24e-09
Invar	Chloroform	secondary	3.23e-12	1.44e-09
Steel Prod., cold-rolled, semi-finished	Chloroform	secondary	3.21e-12	1.43e-09
Ferrite mfg.	Chloroform	secondary	3.15e-12	1.40e-09
Steel Prod., cold-rolled, semi-finished	Lithium salts	secondary	2.38e-12	1.06e-09
Invar	Trichloroethylene	secondary	1.61e-12	7.16e-10
Steel Prod., cold-rolled, semi-finished	Trichloroethylene	secondary	1.60e-12	7.10e-10
Ferrite mfg.	Trichloroethylene	secondary	1.57e-12	6.99e-10
Invar	Lithium salts	secondary	6.75e-13	3.00e-10
Ferrite mfg.	Lithium salts	secondary	6.59e-13	2.93e-10
Invar	Formaldehyde	secondary	1.22e-13	5.42e-11
Ferrite mfg.	Formaldehyde	secondary	1.19e-13	5.29e-11
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	1.18e-13	5.23e-11
Steel Prod., cold-rolled, semi-finished	Tetrachloroethylene	secondary	8.60e-14	3.82e-11
Invar	Tetrachloroethylene	secondary	8.47e-14	3.77e-11
Ferrite mfg.	Tetrachloroethylene	secondary	8.27e-14	3.68e-11
Invar	1,1,1-Trichloroethane	secondary	6.01e-14	2.67e-11
Steel Prod., cold-rolled, semi-finished	1,1,1-Trichloroethane	secondary	5.94e-14	2.64e-11
Ferrite mfg.	1,1,1-Trichloroethane	secondary	5.86e-14	2.60e-11
Invar	Hexachloroethane	secondary	3.60e-16	1.60e-13
Steel Prod., cold-rolled, semi-finished	Hexachloroethane	secondary	3.58e-16	1.59e-13
Ferrite mfg.	Hexachloroethane	secondary	3.52e-16	1.56e-13
Total Materials Processing			**1.36e-01**	**6.04e+01**
Manufacturing Life-cycle Stage				
CRT tube mfg.	Phosphorus (yellow or white)	primary	5.94e-02	2.64e+01
CRT tube mfg.	Fluoride	primary	6.91e-03	3.07e+00
Glass/frit	Fluorides (F-)	primary	5.87e-03	2.61e+00
CRT tube mfg.	Zinc (elemental)	primary	5.12e-03	2.28e+00
CRT tube mfg.	Copper	primary	4.78e-03	2.13e+00

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
LPG Production	Phenol	secondary	4.25e-03	1.89e+00
LPG Production	Aluminum (+3)	secondary	2.46e-03	1.09e+00
CRT tube mfg.	Nickel	primary	1.59e-04	7.05e-02
LPG Production	Nitrate	secondary	1.21e-04	5.39e-02
Glass/frit	Lead	primary	8.68e-05	3.86e-02
LPG Production	Fluorides (F-)	secondary	6.81e-05	3.03e-02
LPG Production	Copper (+1 & +2)	secondary	1.55e-05	6.89e-03
Fuel Oil #6 Prod.	Phenol	secondary	1.44e-05	6.39e-03
Fuel Oil #2 Prod.	Phenol	secondary	1.19e-05	5.30e-03
Fuel Oil #6 Prod.	Aluminum (+3)	secondary	8.32e-06	3.70e-03
CRT tube mfg.	Manganese	primary	7.21e-06	3.21e-03
Fuel Oil #2 Prod.	Aluminum (+3)	secondary	6.90e-06	3.07e-03
CRT tube mfg.	Lead	primary	6.03e-06	2.68e-03
LPG Production	Zinc (+2)	secondary	4.34e-06	1.93e-03
CRT tube mfg.	Molybdenum	primary	3.77e-06	1.68e-03
CRT tube mfg.	Cyanide (-1)	primary	1.21e-06	5.39e-04
Fuel Oil #4 Prod.	Phenol	secondary	9.69e-07	4.31e-04
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	5.61e-07	2.49e-04
Fuel Oil #6 Prod.	Fluorides (F-)	secondary	5.50e-07	2.44e-04
Fuel Oil #6 Prod.	Nitrate	secondary	4.85e-07	2.16e-04
Fuel Oil #2 Prod.	Nitrate	secondary	3.45e-07	1.54e-04
Fuel Oil #2 Prod.	Fluorides (F-)	secondary	2.14e-07	9.50e-05
Natural Gas Prod.	Zinc (+2)	secondary	1.94e-07	8.61e-05
LPG Production	Aromatic hydrocarbons	secondary	1.75e-07	7.78e-05
Glass/frit	Nickel	primary	1.64e-07	7.30e-05
LPG Production	Barium cmpds	secondary	1.42e-07	6.32e-05
Natural Gas Prod.	Fluorides (F-)	secondary	1.19e-07	5.30e-05
Glass/frit	Nitrates/nitrites	primary	1.14e-07	5.09e-05
LPG Production	Chromium (VI)	secondary	1.02e-07	4.52e-05
Glass/frit	Chromium	primary	9.86e-08	4.39e-05
Natural Gas Prod.	Phenol	secondary	8.65e-08	3.85e-05
LPG Production	Chromium (III)	secondary	7.28e-08	3.24e-05
LPG Production	Cadmium cmpds	secondary	6.89e-08	3.06e-05
Fuel Oil #6 Prod.	Copper (+1 & +2)	secondary	5.24e-08	2.33e-05
Natural Gas Prod.	Aluminum (+3)	secondary	4.97e-08	2.21e-05
Fuel Oil #2 Prod.	Copper (+1 & +2)	secondary	4.34e-08	1.93e-05
Natural Gas Prod.	Nitrate	secondary	3.01e-08	1.34e-05
Fuel Oil #4 Prod.	Nitrate	secondary	2.93e-08	1.31e-05
LPG Production	Lead cmpds	secondary	2.30e-08	1.02e-05
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	2.28e-08	1.01e-05
LPG Production	Toluene	secondary	2.14e-08	9.51e-06
Fuel Oil #6 Prod.	Zinc (+2)	secondary	1.97e-08	8.75e-06
Fuel Oil #2 Prod.	Zinc (+2)	secondary	1.25e-08	5.57e-06
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	3.53e-09	1.57e-06
Natural Gas Prod.	Chromium (VI)	secondary	3.06e-09	1.36e-06
LPG Production	Nickel cmpds	secondary	2.78e-09	1.24e-06
Natural Gas Prod.	Chromium (III)	secondary	2.20e-09	9.77e-07
LPG Production	Mercury compounds	secondary	1.25e-09	5.56e-07
Fuel Oil #4 Prod.	Zinc (+2)	secondary	1.10e-09	4.90e-07
LPG Production	Cyanide (-1)	secondary	8.17e-10	3.63e-07

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Fuel Oil #6 Prod.	Aromatic hydrocarbons	secondary	5.92e-10	2.63e-07
Fuel Oil #2 Prod.	Aromatic hydrocarbons	secondary	4.91e-10	2.18e-07
Fuel Oil #6 Prod.	Barium cmpds	secondary	4.81e-10	2.14e-07
Fuel Oil #2 Prod.	Barium cmpds	secondary	3.99e-10	1.77e-07
Natural Gas Prod.	Copper (+1 & +2)	secondary	3.13e-10	1.39e-07
Fuel Oil #6 Prod.	Chromium (VI)	secondary	2.51e-10	1.12e-07
LPG Production	Halogenated matter (organic)	secondary	2.33e-10	1.04e-07
Fuel Oil #6 Prod.	Cadmium cmpds	secondary	2.33e-10	1.04e-07
Fuel Oil #2 Prod.	Cadmium cmpds	secondary	1.93e-10	8.59e-08
Fuel Oil #6 Prod.	Chromium (III)	secondary	1.80e-10	8.01e-08
Fuel Oil #2 Prod.	Chromium (VI)	secondary	1.48e-10	6.58e-08
Fuel Oil #2 Prod.	Chromium (III)	secondary	1.06e-10	4.72e-08
Fuel Oil #6 Prod.	Lead cmpds	secondary	7.78e-11	3.46e-08
Fuel Oil #6 Prod.	Toluene	secondary	7.23e-11	3.22e-08
Fuel Oil #2 Prod.	Lead cmpds	secondary	6.45e-11	2.87e-08
Fuel Oil #2 Prod.	Toluene	secondary	6.00e-11	2.67e-08
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	3.99e-11	1.78e-08
Fuel Oil #4 Prod.	Barium cmpds	secondary	3.24e-11	1.44e-08
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	1.57e-11	6.98e-09
Fuel Oil #4 Prod.	Chromium (VI)	secondary	1.34e-11	5.95e-09
Fuel Oil #4 Prod.	Chromium (III)	secondary	9.60e-12	4.27e-09
Fuel Oil #6 Prod.	Nickel cmpds	secondary	9.42e-12	4.19e-09
Fuel Oil #2 Prod.	Nickel cmpds	secondary	7.81e-12	3.47e-09
Fuel Oil #4 Prod.	Lead cmpds	secondary	5.24e-12	2.33e-09
Fuel Oil #4 Prod.	Toluene	secondary	4.88e-12	2.17e-09
Fuel Oil #6 Prod.	Mercury compounds	secondary	4.23e-12	1.88e-09
Natural Gas Prod.	Aromatic hydrocarbons	secondary	3.54e-12	1.57e-09
Fuel Oil #2 Prod.	Mercury compounds	secondary	3.51e-12	1.56e-09
Natural Gas Prod.	Barium cmpds	secondary	2.87e-12	1.28e-09
Fuel Oil #6 Prod.	Cyanide (-1)	secondary	2.76e-12	1.23e-09
Fuel Oil #2 Prod.	Cyanide (-1)	secondary	2.29e-12	1.02e-09
Natural Gas Prod.	Cadmium cmpds	secondary	1.39e-12	6.19e-10
Fuel Oil #6 Prod.	Halogenated matter (organic)	secondary	7.89e-13	3.51e-10
Fuel Oil #2 Prod.	Halogenated matter (organic)	secondary	6.55e-13	2.91e-10
Fuel Oil #4 Prod.	Nickel cmpds	secondary	6.35e-13	2.82e-10
Natural Gas Prod.	Lead cmpds	secondary	4.65e-13	2.07e-10
Natural Gas Prod.	Toluene	secondary	4.32e-13	1.92e-10
Fuel Oil #4 Prod.	Mercury compounds	secondary	2.85e-13	1.27e-10
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	1.86e-13	8.28e-11
Natural Gas Prod.	Nickel cmpds	secondary	5.63e-14	2.50e-11
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	5.32e-14	2.37e-11
Natural Gas Prod.	Mercury compounds	secondary	2.53e-14	1.12e-11
Natural Gas Prod.	Cyanide (-1)	secondary	1.65e-14	7.34e-12
Natural Gas Prod.	Halogenated matter (organic)	secondary	4.72e-15	2.10e-12
Total Manufacturing			**8.93e-02**	**3.97e+01**
Use, Maintenance and Repair Life-cycle Stage				
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
CRT landfilling	Ammonia	primary	7.71e-05	3.43e-02

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
CRT Incineration	Silver compounds	secondary	5.15e-06	2.29e-03
CRT landfilling	Silver compounds	primary	4.80e-06	2.14e-03
CRT Incineration	Barium cmpds	secondary	1.14e-07	5.07e-05
CRT landfilling	Cadmium cmpds	primary	9.64e-08	4.29e-05
CRT Incineration	Cadmium cmpds	secondary	9.33e-08	4.15e-05
CRT landfilling	Barium cmpds	primary	9.07e-08	4.03e-05
LPG Production	Phenol	secondary	3.67e-08	1.63e-05
CRT Incineration	Chromium (VI)	secondary	2.19e-08	9.72e-06
LPG Production	Aluminum (+3)	secondary	2.12e-08	9.44e-06
CRT landfilling	Mercury compounds	primary	2.04e-08	9.07e-06
CRT Incineration	Mercury compounds	secondary	2.00e-08	8.89e-06
CRT landfilling	Arsenic cmpds	primary	1.84e-08	8.20e-06
CRT Incineration	Arsenic cmpds	secondary	1.77e-08	7.89e-06
CRT landfilling	Chromium (VI)	primary	1.66e-08	7.39e-06
CRT Incineration	Lead cmpds	secondary	1.60e-08	7.10e-06
CRT Incineration	Chromium (III)	secondary	1.57e-08	6.97e-06
CRT landfilling	Lead cmpds	primary	1.56e-08	6.92e-06
CRT landfilling	Chromium (III)	primary	1.19e-08	5.30e-06
CRT landfilling	Xylene (mixed isomers)	primary	4.17e-09	1.86e-06
CRT Incineration	o-xylene	secondary	2.68e-09	1.19e-06
CRT Incineration	Toluene	secondary	2.53e-09	1.12e-06
CRT landfilling	Toluene	primary	2.36e-09	1.05e-06
LPG Production	Nitrate	secondary	1.05e-09	4.65e-07
CRT Incineration	Ethylbenzene	secondary	9.51e-10	4.23e-07
CRT landfilling	Ethylbenzene	primary	8.86e-10	3.94e-07
LPG Production	Fluorides (F-)	secondary	5.88e-10	2.61e-07
CRT Incineration	Tetrachloroethylene	secondary	1.45e-10	6.45e-08
CRT landfilling	Tetrachloroethylene	primary	1.35e-10	6.02e-08
LPG Production	Copper (+1 & +2)	secondary	1.34e-10	5.94e-08
CRT Incineration	Benzene	secondary	9.63e-11	4.28e-08
CRT landfilling	Benzene	primary	8.98e-11	3.99e-08
CRT Incineration	Selenium	secondary	8.22e-11	3.66e-08
CRT landfilling	Selenium	primary	8.08e-11	3.59e-08
CRT Incineration	Carbon tetrachloride	secondary	5.89e-11	2.62e-08
CRT landfilling	Carbon tetrachloride	primary	5.49e-11	2.44e-08
CRT Incineration	Trichloroethylene	secondary	4.45e-11	1.98e-08
CRT landfilling	Trichloroethylene	primary	4.15e-11	1.84e-08
LPG Production	Zinc (+2)	secondary	3.74e-11	1.66e-08
CRT Incineration	Chloroform	secondary	2.38e-11	1.06e-08
CRT Incineration	Vinyl chloride	secondary	2.38e-11	1.06e-08
CRT landfilling	Chloroform	primary	2.22e-11	9.89e-09
CRT landfilling	Vinyl chloride	primary	2.22e-11	9.86e-09
CRT Incineration	1,2-Dichloroethane	secondary	1.25e-11	5.57e-09
CRT landfilling	1,2-Dichloroethane	primary	1.17e-11	5.19e-09
CRT Incineration	Dichloromethane	secondary	8.25e-12	3.67e-09
CRT landfilling	Dichloromethane	primary	7.69e-12	3.42e-09
LPG Production	Aromatic hydrocarbons	secondary	1.51e-12	6.72e-10
LPG Production	Barium cmpds	secondary	1.23e-12	5.46e-10
LPG Production	Chromium (VI)	secondary	8.76e-13	3.90e-10
LPG Production	Chromium (III)	secondary	6.29e-13	2.80e-10

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
LPG Production	Cadmium cmpds	secondary	5.94e-13	2.64e-10
LPG Production	Lead cmpds	secondary	1.98e-13	8.82e-11
LPG Production	Toluene	secondary	1.85e-13	8.21e-11
LPG Production	Nickel cmpds	secondary	2.40e-14	1.07e-11
LPG Production	Mercury compounds	secondary	1.08e-14	4.80e-12
LPG Production	Cyanide (-1)	secondary	7.05e-15	3.14e-12
LPG Production	Halogenated matter (organic)	secondary	2.01e-15	8.96e-13
Natural Gas Prod.	Halogenated matter (organic)	secondary	-2.37e-15	-1.05e-12
Natural Gas Prod.	Cyanide (-1)	secondary	-8.28e-15	-3.68e-12
Natural Gas Prod.	Mercury compounds	secondary	-1.27e-14	-5.64e-12
Natural Gas Prod.	Nickel cmpds	secondary	-2.82e-14	-1.25e-11
CRT Incineration	Halogenated matter (organic)	secondary	-3.67e-14	-1.63e-11
CRT Incineration	Cyanide (-1)	secondary	-1.29e-13	-5.71e-11
Natural Gas Prod.	Toluene	secondary	-2.17e-13	-9.64e-11
Natural Gas Prod.	Lead cmpds	secondary	-2.33e-13	-1.04e-10
CRT Incineration	Nickel cmpds	secondary	-4.38e-13	-1.95e-10
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	-5.72e-13	-2.54e-10
Natural Gas Prod.	Cadmium cmpds	secondary	-6.98e-13	-3.10e-10
Natural Gas Prod.	Barium cmpds	secondary	-1.44e-12	-6.41e-10
Natural Gas Prod.	Aromatic hydrocarbons	secondary	-1.77e-12	-7.89e-10
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	-2.00e-12	-8.91e-10
Fuel Oil #4 Prod.	Mercury compounds	secondary	-3.06e-12	-1.36e-09
Fuel Oil #4 Prod.	Nickel cmpds	secondary	-6.82e-12	-3.03e-09
CRT Incineration	Aromatic hydrocarbons	secondary	-2.75e-11	-1.22e-08
Fuel Oil #4 Prod.	Toluene	secondary	-5.24e-11	-2.33e-08
Fuel Oil #4 Prod.	Lead cmpds	secondary	-5.64e-11	-2.51e-08
Fuel Oil #4 Prod.	Chromium (III)	secondary	-1.03e-10	-4.59e-08
Fuel Oil #4 Prod.	Chromium (VI)	secondary	-1.44e-10	-6.40e-08
Natural Gas Prod.	Copper (+1 & +2)	secondary	-1.57e-10	-6.98e-08
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	-1.69e-10	-7.51e-08
Fuel Oil #4 Prod.	Barium cmpds	secondary	-3.48e-10	-1.55e-07
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	-4.29e-10	-1.91e-07
Natural Gas Prod.	Chromium (III)	secondary	-1.10e-09	-4.90e-07
Natural Gas Prod.	Chromium (VI)	secondary	-1.54e-09	-6.83e-07
CRT Incineration	Copper (+1 & +2)	secondary	-2.44e-09	-1.08e-06
CRT Incineration	Zinc (+2)	secondary	-8.28e-09	-3.68e-06
Fuel Oil #4 Prod.	Zinc (+2)	secondary	-1.19e-08	-5.27e-06
Natural Gas Prod.	Nitrate	secondary	-1.51e-08	-6.71e-06
Natural Gas Prod.	Aluminum (+3)	secondary	-2.49e-08	-1.11e-05
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	-3.80e-08	-1.69e-05
Natural Gas Prod.	Phenol	secondary	-4.34e-08	-1.93e-05
Natural Gas Prod.	Fluorides (F-)	secondary	-5.98e-08	-2.66e-05
Natural Gas Prod.	Zinc (+2)	secondary	-9.71e-08	-4.32e-05
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	-2.45e-07	-1.09e-04
Fuel Oil #4 Prod.	Nitrate	secondary	-3.15e-07	-1.40e-04
CRT Incineration	Aluminum (+3)	secondary	-3.87e-07	-1.72e-04
CRT Incineration	Phenol	secondary	-6.69e-07	-2.97e-04
CRT Incineration	Nitrate	secondary	-3.60e-06	-1.60e-03
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	-6.03e-06	-2.68e-03

Table M-37. CRT LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Phenol	secondary	-1.04e-05	-4.63e-03
CRT Incineration	Fluorides (F-)	secondary	-1.51e-05	-6.73e-03
CRT Incineration	Ammonia	secondary	-3.00e-04	-1.34e-01
Total End-of-life			**-2.50e-04**	**-1.11e-01**
Total All Life-cycle Stages			**2.25e-01**	**1.00e+02**

Table M-38. LCD LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Materials Processing Life-cycle Stage				
PMMA Sheet Prod.	Ammonia	secondary	3.29e-02	6.34e-01
Aluminum Prod.	Aluminum (+3)	secondary	1.03e-02	1.98e-01
Aluminum Prod.	Copper (+1 & +2)	secondary	7.92e-03	1.53e-01
Aluminum Prod.	Zinc (+2)	secondary	2.40e-03	4.62e-02
Steel Prod., cold-rolled, semi-finished	Phosphorus (yellow or white)	secondary	2.25e-03	4.34e-02
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	1.37e-03	2.64e-02
Polycarbonate Production	Copper (+1 & +2)	secondary	6.84e-04	1.32e-02
PMMA Sheet Prod.	Copper (+1 & +2)	secondary	5.09e-04	9.81e-03
Steel Prod., cold-rolled, semi-finished	Copper (+1 & +2)	secondary	4.98e-04	9.60e-03
Aluminum Prod.	Barium sulfate	secondary	3.38e-04	6.51e-03
PET Resin Production	Copper (+1 & +2)	secondary	2.41e-04	4.64e-03
Polycarbonate Production	Mercury compounds	secondary	2.40e-04	4.63e-03
Styrene-butadiene Copolymer Prod.	Copper (+1 & +2)	secondary	2.40e-04	4.63e-03
PMMA Sheet Prod.	Mercury compounds	secondary	1.79e-04	3.44e-03
Aluminum Prod.	Titanium tetrachloride	secondary	1.70e-04	3.28e-03
Steel Prod., cold-rolled, semi-finished	Aluminum (+3)	secondary	1.34e-04	2.58e-03
Aluminum Prod.	Strontium (Sr II)	secondary	1.19e-04	2.29e-03
Steel Prod., cold-rolled, semi-finished	Nitrogen dioxide	secondary	9.68e-05	1.87e-03
Steel Prod., cold-rolled, semi-finished	Zinc (+2)	secondary	9.60e-05	1.85e-03
Polycarbonate Production	Zinc (+2)	secondary	9.53e-05	1.84e-03
Steel Prod., cold-rolled, semi-finished	Fluorides (F-)	secondary	9.44e-05	1.82e-03
Styrene-butadiene Copolymer Prod.	Mercury compounds	secondary	8.42e-05	1.62e-03
Steel Prod., cold-rolled, semi-finished	Strontium (Sr II)	secondary	7.31e-05	1.41e-03
PMMA Sheet Prod.	Zinc (+2)	secondary	7.08e-05	1.37e-03
Polycarbonate Production	Chlorine	secondary	6.81e-05	1.31e-03
Polycarbonate Production	Ammonia	secondary	6.63e-05	1.28e-03
Aluminum Prod.	Lead cmpds	secondary	6.40e-05	1.23e-03
Aluminum Prod.	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	5.76e-05	1.11e-03
PMMA Sheet Prod.	Chlorine	secondary	5.06e-05	9.77e-04
Aluminum Prod.	Cadmium cmpds	secondary	4.32e-05	8.34e-04
Steel Prod., cold-rolled, semi-finished	Mercury compounds	secondary	3.92e-05	7.56e-04
Aluminum Prod.	Barium cmpds	secondary	3.48e-05	6.72e-04
Aluminum Prod.	Nitrate	secondary	3.40e-05	6.55e-04
Steel Prod., cold-rolled, semi-finished	Barium sulfate	secondary	3.36e-05	6.49e-04
PET Resin Production	Zinc (+2)	secondary	3.35e-05	6.47e-04
Styrene-butadiene Copolymer Prod.	Zinc (+2)	secondary	3.34e-05	6.44e-04
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	3.19e-05	6.15e-04
Polycarbonate Production	Phenol	secondary	3.10e-05	5.98e-04
PET Resin Production	Chlorine	secondary	2.40e-05	4.62e-04
Styrene-butadiene Copolymer Prod.	Chlorine	secondary	2.39e-05	4.61e-04
Aluminum Prod.	Nickel cmpds	secondary	1.42e-05	2.74e-04
Steel Prod., cold-rolled, semi-finished	Silver compounds	secondary	1.39e-05	2.68e-04
Natural Gas Prod.	Zinc (+2)	secondary	1.35e-05	2.61e-04
Aluminum Prod.	Chromium (III)	secondary	1.19e-05	2.30e-04
Aluminum Prod.	Aromatic hydrocarbons	secondary	1.05e-05	2.03e-04
PMMA Sheet Prod.	Phenol	secondary	1.04e-05	2.00e-04
Steel Prod., cold-rolled, semi-finished	Lead cmpds	secondary	8.52e-06	1.64e-04
Aluminum Prod.	Manganese cmpds	secondary	8.48e-06	1.64e-04

Table M-38. LCD LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Fluorides (F-)	secondary	8.33e-06	1.61e-04
PMMA Sheet Prod.	Cyanide (-1)	secondary	7.67e-06	1.48e-04
Steel Prod., cold-rolled, semi-finished	Barium cmpds	secondary	7.60e-06	1.47e-04
Aluminum Prod.	Fluoride	secondary	6.78e-06	1.31e-04
Steel Prod., cold-rolled, semi-finished	Aromatic hydrocarbons	secondary	6.37e-06	1.23e-04
Styrene-butadiene Copolymer Prod.	Aluminum (+3)	secondary	6.28e-06	1.21e-04
Aluminum Prod.	Vanadium (V3+, V5+)	secondary	6.06e-06	1.17e-04
Natural Gas Prod.	Phenol	secondary	6.04e-06	1.17e-04
Aluminum Prod.	Selenium	secondary	5.90e-06	1.14e-04
Steel Prod., cold-rolled, semi-finished	Tin (Sn++, Sn4+)	secondary	5.10e-06	9.84e-05
Aluminum Prod.	Xylene (mixed isomers)	secondary	4.70e-06	9.06e-05
Polycarbonate Production	Aluminum (+3)	secondary	4.48e-06	8.63e-05
Natural Gas Prod.	Aluminum (+3)	secondary	3.47e-06	6.69e-05
PMMA Sheet Prod.	Aluminum (+3)	secondary	3.33e-06	6.42e-05
Aluminum Prod.	Arsenic cmpds	secondary	3.19e-06	6.15e-05
Styrene-butadiene Copolymer Prod.	Nitrate	secondary	2.53e-06	4.88e-05
Aluminum Prod.	Benzene	secondary	2.53e-06	4.88e-05
PMMA Sheet Prod.	Nitrates/nitrites	secondary	2.22e-06	4.28e-05
Natural Gas Prod.	Nitrate	secondary	2.10e-06	4.05e-05
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	1.74e-06	3.35e-05
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	1.74e-06	3.35e-05
Aluminum Prod.	Toluene	secondary	1.58e-06	3.04e-05
PET Resin Production	Aluminum (+3)	secondary	1.58e-06	3.04e-05
Steel Prod., cold-rolled, semi-finished	Chlorine	secondary	1.47e-06	2.84e-05
Aluminum Prod.	Phenol	secondary	1.41e-06	2.72e-05
Steel Prod., cold-rolled, semi-finished	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	1.39e-06	2.69e-05
Steel Prod., cold-rolled, semi-finished	Cadmium cmpds	secondary	1.31e-06	2.53e-05
Styrene-butadiene Copolymer Prod.	Phenol	secondary	1.28e-06	2.47e-05
PET Resin Production	Phenol	secondary	1.18e-06	2.27e-05
Steel Prod., cold-rolled, semi-finished	Cyanide (-1)	secondary	1.16e-06	2.24e-05
Steel Prod., cold-rolled, semi-finished	Boric acid	secondary	1.11e-06	2.15e-05
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	1.09e-06	2.10e-05
Steel Prod., cold-rolled, semi-finished	Manganese cmpds	secondary	1.03e-06	1.98e-05
PMMA Sheet Prod.	Nickel cmpds	secondary	9.15e-07	1.76e-05
Steel Prod., cold-rolled, semi-finished	Ethylbenzene	secondary	8.61e-07	1.66e-05
Steel Prod., cold-rolled, semi-finished	Chromium (VI)	secondary	6.04e-07	1.16e-05
Steel Prod., cold-rolled, semi-finished	Nickel cmpds	secondary	5.85e-07	1.13e-05
Polycarbonate Production	Nickel (+2)	secondary	5.16e-07	9.95e-06
Polycarbonate Production	Nitrate	secondary	5.16e-07	9.95e-06
Aluminum Prod.	Nitrites	secondary	4.67e-07	9.01e-06
Steel Prod., cold-rolled, semi-finished	Chromium (III)	secondary	3.93e-07	7.58e-06
Steel Prod., cold-rolled, semi-finished	Vanadium (V3+, V5+)	secondary	2.91e-07	5.61e-06
Steel Prod., cold-rolled, semi-finished	Titanium tetrachloride	secondary	2.59e-07	4.99e-06
Natural Gas Prod.	Chromium (VI)	secondary	2.14e-07	4.13e-06
PET Resin Production	Mercury	secondary	1.82e-07	3.50e-06
PET Resin Production	Nickel (+2)	secondary	1.82e-07	3.50e-06
PET Resin Production	Nitrate	secondary	1.82e-07	3.50e-06
Styrene-butadiene Copolymer Prod.	Nickel (+2)	secondary	1.81e-07	3.49e-06
Natural Gas Prod.	Chromium (III)	secondary	1.54e-07	2.96e-06
Aluminum Prod.	Cyanide (-1)	secondary	1.41e-07	2.72e-06
Steel Prod., cold-rolled, semi-finished	Arsenic cmpds	secondary	1.36e-07	2.62e-06

Table M-38. LCD LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Rubidium ion (Rb+)	secondary	1.19e-07	2.29e-06
Steel Prod., cold-rolled, semi-finished	Nitrates/nitrites	secondary	9.51e-08	1.83e-06
Steel Prod., cold-rolled, semi-finished	Selenium	secondary	7.81e-08	1.51e-06
Steel Prod., cold-rolled, semi-finished	Boron (B III)	secondary	3.45e-08	6.65e-07
Natural Gas Prod.	Copper (+1 & +2)	secondary	2.19e-08	4.22e-07
Steel Prod., cold-rolled, semi-finished	Phosphorus pentoxide	secondary	1.53e-08	2.94e-07
Steel Prod., cold-rolled, semi-finished	Hydrazine	secondary	1.13e-08	2.18e-07
Steel Prod., cold-rolled, semi-finished	Morpholine	secondary	9.20e-09	1.77e-07
Aluminum Prod.	Chromium (VI)	secondary	3.43e-09	6.61e-08
Steel Prod., cold-rolled, semi-finished	Hypochlorous acid	secondary	1.72e-09	3.33e-08
Steel Prod., cold-rolled, semi-finished	Cobalt (Co I, Co II, Co III)	secondary	1.54e-09	2.97e-08
Steel Prod., cold-rolled, semi-finished	Dichloromethane	secondary	9.72e-10	1.87e-08
Steel Prod., cold-rolled, semi-finished	Triethylene glycol	secondary	6.72e-10	1.29e-08
Aluminum Prod.	Triethylene glycol	secondary	6.46e-10	1.24e-08
Natural Gas Prod.	Aromatic hydrocarbons	secondary	2.47e-10	4.77e-09
Steel Prod., cold-rolled, semi-finished	Nitrites	secondary	2.36e-10	4.55e-09
Natural Gas Prod.	Barium cmpds	secondary	2.01e-10	3.87e-09
Natural Gas Prod.	Cadmium cmpds	secondary	9.72e-11	1.87e-09
Steel Prod., cold-rolled, semi-finished	Edetic acid (EDTA)	secondary	6.24e-11	1.20e-09
Natural Gas Prod.	Lead cmpds	secondary	3.25e-11	6.26e-10
Natural Gas Prod.	Toluene	secondary	3.02e-11	5.82e-10
Natural Gas Prod.	Nickel cmpds	secondary	3.93e-12	7.58e-11
Natural Gas Prod.	Mercury compounds	secondary	1.77e-12	3.40e-11
Steel Prod., cold-rolled, semi-finished	Chloroform	secondary	1.57e-12	3.03e-11
Steel Prod., cold-rolled, semi-finished	Lithium salts	secondary	1.17e-12	2.25e-11
Natural Gas Prod.	Cyanide (-1)	secondary	1.15e-12	2.22e-11
Steel Prod., cold-rolled, semi-finished	Trichloroethylene	secondary	7.83e-13	1.51e-11
Natural Gas Prod.	Halogenated matter (organic)	secondary	3.29e-13	6.35e-12
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	5.77e-14	1.11e-12
Steel Prod., cold-rolled, semi-finished	Tetrachloroethylene	secondary	4.21e-14	8.13e-13
Steel Prod., cold-rolled, semi-finished	1,1,1-Trichloroethane	secondary	2.91e-14	5.62e-13
Steel Prod., cold-rolled, semi-finished	Hexachloroethane	secondary	1.75e-16	3.38e-15
Total Materials Processing			**6.19e-02**	**1.19e+00**
Manufacturing Life-cycle Stage				
Monitor/module	Phosphorus (yellow or white)	primary	5.06e+00	9.77e+01
Panel components	Phosphorus (yellow or white)	primary	2.92e-02	5.63e-01
Monitor/module	Fluorides (F-)	primary	2.56e-02	4.93e-01
Monitor/module	Copper	primary	2.44e-03	4.70e-02
Monitor/module	Hexane	primary	1.18e-03	2.27e-02
Monitor/module	Zinc (elemental)	primary	9.73e-04	1.88e-02
LCD glass mfg.	Fluorides (F-)	primary	2.72e-04	5.24e-03
LPG Production	Phenol	secondary	2.04e-04	3.93e-03
LPG Production	Aluminum (+3)	secondary	1.18e-04	2.27e-03
Monitor/module	Lead	primary	1.23e-05	2.38e-04
Monitor/module	Chromium	primary	1.06e-05	2.05e-04
Monitor/module	Cyanide (-1)	primary	7.33e-06	1.41e-04
LPG Production	Nitrate	secondary	5.81e-06	1.12e-04
LCD glass mfg.	Lead	primary	4.02e-06	7.75e-05
LPG Production	Fluorides (F-)	secondary	3.27e-06	6.30e-05

Table M-38. LCD LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Monitor/module	Boron	primary	1.61e-06	3.11e-05
Fuel Oil #4 Prod.	Phenol	secondary	1.49e-06	2.88e-05
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	8.64e-07	1.67e-05
LPG Production	Copper (+1 & +2)	secondary	7.43e-07	1.43e-05
Monitor/module	Chromium (VI)	primary	6.39e-07	1.23e-05
Fuel Oil #2 Prod.	Phenol	secondary	5.57e-07	1.07e-05
Fuel Oil #6 Prod.	Phenol	secondary	4.90e-07	9.44e-06
Monitor/module	Antimony	primary	4.64e-07	8.95e-06
Monitor/module	Manganese	primary	4.58e-07	8.83e-06
Monitor/module	Nickel	primary	4.58e-07	8.83e-06
Monitor/module	Polychlorinated biphenyls	primary	4.07e-07	7.85e-06
LCD glass mfg.	Nitrate	primary	3.66e-07	7.06e-06
Fuel Oil #2 Prod.	Aluminum (+3)	secondary	3.22e-07	6.21e-06
Natural Gas Prod.	Zinc (+2)	secondary	3.05e-07	5.89e-06
Fuel Oil #6 Prod.	Aluminum (+3)	secondary	2.83e-07	5.46e-06
Monitor/module	Phenol	primary	2.70e-07	5.21e-06
Monitor/module	Arsenic	primary	2.28e-07	4.40e-06
Monitor/module	Cadmium	primary	2.28e-07	4.40e-06
LPG Production	Zinc (+2)	secondary	2.08e-07	4.01e-06
Monitor/module	Mercury	primary	1.94e-07	3.74e-06
Natural Gas Prod.	Fluorides (F-)	secondary	1.88e-07	3.62e-06
Natural Gas Prod.	Phenol	secondary	1.36e-07	2.63e-06
Natural Gas Prod.	Aluminum (+3)	secondary	7.83e-08	1.51e-06
Monitor/module	Tetrachloroethylene	primary	7.63e-08	1.47e-06
Natural Gas Prod.	Nitrate	secondary	4.74e-08	9.15e-07
Monitor/module	Tin	primary	4.57e-08	8.82e-07
Fuel Oil #4 Prod.	Nitrate	secondary	4.52e-08	8.72e-07
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	3.51e-08	6.77e-07
Monitor/module	1,1,1-Trichloroethane	primary	2.40e-08	4.62e-07
Monitor/module	Trichloroethylene	primary	2.34e-08	4.51e-07
Fuel Oil #6 Prod.	Fluorides (F-)	secondary	1.87e-08	3.61e-07
Fuel Oil #6 Prod.	Nitrate	secondary	1.65e-08	3.19e-07
Fuel Oil #2 Prod.	Nitrate	secondary	1.61e-08	3.11e-07
Fuel Oil #2 Prod.	Fluorides (F-)	secondary	9.97e-09	1.92e-07
LPG Production	Aromatic hydrocarbons	secondary	8.40e-09	1.62e-07
LCD glass mfg.	Nickel	primary	7.60e-09	1.47e-07
LPG Production	Barium cmpds	secondary	6.82e-09	1.32e-07
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	5.44e-09	1.05e-07
LPG Production	Chromium (VI)	secondary	4.87e-09	9.39e-08
Natural Gas Prod.	Chromium (VI)	secondary	4.83e-09	9.32e-08
LCD glass mfg.	Chromium	primary	4.57e-09	8.81e-08
LPG Production	Chromium (III)	secondary	3.49e-09	6.74e-08
Natural Gas Prod.	Chromium (III)	secondary	3.46e-09	6.68e-08
LPG Production	Cadmium cmpds	secondary	3.30e-09	6.37e-08
Fuel Oil #2 Prod.	Copper (+1 & +2)	secondary	2.03e-09	3.91e-08
Fuel Oil #6 Prod.	Copper (+1 & +2)	secondary	1.78e-09	3.44e-08
Fuel Oil #4 Prod.	Zinc (+2)	secondary	1.70e-09	3.28e-08
LPG Production	Lead cmpds	secondary	1.10e-09	2.13e-08
LPG Production	Toluene	secondary	1.03e-09	1.98e-08
Fuel Oil #6 Prod.	Zinc (+2)	secondary	6.70e-10	1.29e-08
Fuel Oil #2 Prod.	Zinc (+2)	secondary	5.84e-10	1.13e-08

Table M-38. LCD LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Copper (+1 & +2)	secondary	4.93e-10	9.51e-09
LPG Production	Nickel cmpds	secondary	1.34e-10	2.58e-09
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	6.15e-11	1.19e-09
LPG Production	Mercury compounds	secondary	6.00e-11	1.16e-09
Fuel Oil #4 Prod.	Barium cmpds	secondary	4.99e-11	9.63e-10
LPG Production	Cyanide (-1)	secondary	3.92e-11	7.56e-10
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	2.42e-11	4.67e-10
Fuel Oil #2 Prod.	Aromatic hydrocarbons	secondary	2.29e-11	4.42e-10
Fuel Oil #4 Prod.	Chromium (VI)	secondary	2.06e-11	3.98e-10
Fuel Oil #6 Prod.	Aromatic hydrocarbons	secondary	2.02e-11	3.89e-10
Fuel Oil #2 Prod.	Barium cmpds	secondary	1.86e-11	3.59e-10
Fuel Oil #6 Prod.	Barium cmpds	secondary	1.64e-11	3.16e-10
Fuel Oil #4 Prod.	Chromium (III)	secondary	1.48e-11	2.85e-10
LPG Production	Halogenated matter (organic)	secondary	1.12e-11	2.16e-10
Fuel Oil #2 Prod.	Cadmium cmpds	secondary	9.02e-12	1.74e-10
Fuel Oil #6 Prod.	Chromium (VI)	secondary	8.55e-12	1.65e-10
Fuel Oil #4 Prod.	Lead cmpds	secondary	8.08e-12	1.56e-10
Fuel Oil #6 Prod.	Cadmium cmpds	secondary	7.93e-12	1.53e-10
Fuel Oil #4 Prod.	Toluene	secondary	7.52e-12	1.45e-10
Fuel Oil #2 Prod.	Chromium (VI)	secondary	6.91e-12	1.33e-10
Fuel Oil #6 Prod.	Chromium (III)	secondary	6.13e-12	1.18e-10
Natural Gas Prod.	Aromatic hydrocarbons	secondary	5.58e-12	1.08e-10
Fuel Oil #2 Prod.	Chromium (III)	secondary	4.96e-12	9.56e-11
Natural Gas Prod.	Barium cmpds	secondary	4.53e-12	8.73e-11
Fuel Oil #2 Prod.	Lead cmpds	secondary	3.01e-12	5.81e-11
Fuel Oil #2 Prod.	Toluene	secondary	2.80e-12	5.40e-11
Fuel Oil #6 Prod.	Lead cmpds	secondary	2.65e-12	5.11e-11
Fuel Oil #6 Prod.	Toluene	secondary	2.46e-12	4.75e-11
Natural Gas Prod.	Cadmium cmpds	secondary	2.19e-12	4.23e-11
Fuel Oil #4 Prod.	Nickel cmpds	secondary	9.78e-13	1.89e-11
Natural Gas Prod.	Lead cmpds	secondary	7.33e-13	1.41e-11
Natural Gas Prod.	Toluene	secondary	6.82e-13	1.31e-11
Fuel Oil #4 Prod.	Mercury compounds	secondary	4.39e-13	8.47e-12
Fuel Oil #2 Prod.	Nickel cmpds	secondary	3.65e-13	7.03e-12
Fuel Oil #6 Prod.	Nickel cmpds	secondary	3.21e-13	6.18e-12
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	2.87e-13	5.54e-12
Fuel Oil #2 Prod.	Mercury compounds	secondary	1.64e-13	3.16e-12
Fuel Oil #6 Prod.	Mercury compounds	secondary	1.44e-13	2.78e-12
Fuel Oil #2 Prod.	Cyanide (-1)	secondary	1.07e-13	2.06e-12
Fuel Oil #6 Prod.	Cyanide (-1)	secondary	9.41e-14	1.81e-12
Natural Gas Prod.	Nickel cmpds	secondary	8.87e-14	1.71e-12
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	8.20e-14	1.58e-12
Natural Gas Prod.	Mercury compounds	secondary	3.98e-14	7.68e-13
Fuel Oil #2 Prod.	Halogenated matter (organic)	secondary	3.06e-14	5.89e-13
Fuel Oil #6 Prod.	Halogenated matter (organic)	secondary	2.69e-14	5.18e-13
Natural Gas Prod.	Cyanide (-1)	secondary	2.60e-14	5.02e-13
Natural Gas Prod.	Halogenated matter (organic)	secondary	7.44e-15	1.43e-13
Total Manufacturing			**5.12e+00**	**9.88e+01**
Use, Maintenance and Repair Life-cycle Stage				

Table M-38. LCD LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
Total Use, Maintenance and Repair			**0.00e+00**	**0.00e+00**
End-of-life Life-cycle Stage				
LCD landfilling	Ammonia	primary	1.86e-05	3.58e-04
LCD landfilling	Silver compounds	primary	1.16e-06	2.23e-05
LCD incineration	Silver compounds	secondary	8.97e-07	1.73e-05
LCD incineration	Cadmium cmpds	secondary	3.51e-08	6.76e-07
LCD landfilling	Cadmium cmpds	primary	3.24e-08	6.24e-07
LCD incineration	Barium cmpds	secondary	2.08e-08	4.02e-07
LCD landfilling	Barium cmpds	primary	1.75e-08	3.38e-07
LPG Production	Phenol	secondary	1.67e-08	3.23e-07
LPG Production	Aluminum (+3)	secondary	9.68e-09	1.87e-07
LCD incineration	Mercury compounds	secondary	8.08e-09	1.56e-07
LCD incineration	Arsenic cmpds	secondary	7.75e-09	1.50e-07
LCD landfilling	Mercury compounds	primary	6.99e-09	1.35e-07
LCD landfilling	Arsenic cmpds	primary	6.59e-09	1.27e-07
LCD incineration	Lead cmpds	secondary	5.11e-09	9.85e-08
LCD landfilling	Lead cmpds	primary	4.73e-09	9.12e-08
LCD incineration	Chromium (VI)	secondary	3.40e-09	6.55e-08
LCD landfilling	Chromium (VI)	primary	2.72e-09	5.25e-08
LCD incineration	Chromium (III)	secondary	2.44e-09	4.70e-08
LCD landfilling	Chromium (III)	primary	1.95e-09	3.77e-08
LCD landfilling	Xylene (mixed isomers)	primary	1.01e-09	1.94e-08
LCD landfilling	Toluene	primary	5.68e-10	1.10e-08
LPG Production	Nitrate	secondary	4.77e-10	9.20e-09
LCD incineration	o-xylene	secondary	4.67e-10	9.01e-09
LCD incineration	Toluene	secondary	4.38e-10	8.45e-09
LPG Production	Fluorides (F-)	secondary	2.68e-10	5.17e-09
LCD landfilling	Ethylbenzene	primary	2.13e-10	4.12e-09
LCD incineration	Ethylbenzene	secondary	1.66e-10	3.19e-09
LPG Production	Copper (+1 & +2)	secondary	6.10e-11	1.18e-09
LCD landfilling	Tetrachloroethylene	primary	3.26e-11	6.28e-10
LCD incineration	Selenium	secondary	3.12e-11	6.02e-10
LCD landfilling	Selenium	primary	2.64e-11	5.09e-10
LCD incineration	Tetrachloroethylene	secondary	2.53e-11	4.87e-10
LCD landfilling	Benzene	primary	2.16e-11	4.17e-10
LPG Production	Zinc (+2)	secondary	1.71e-11	3.29e-10
LCD incineration	Benzene	secondary	1.68e-11	3.23e-10
LCD landfilling	Carbon tetrachloride	primary	1.32e-11	2.55e-10
LCD incineration	Carbon tetrachloride	secondary	1.03e-11	1.98e-10
LCD landfilling	Trichloroethylene	primary	9.99e-12	1.93e-10
LCD incineration	Trichloroethylene	secondary	7.75e-12	1.49e-10
LCD landfilling	Chloroform	primary	5.35e-12	1.03e-10
LCD landfilling	Vinyl chloride	primary	5.34e-12	1.03e-10
LCD incineration	Chloroform	secondary	4.15e-12	8.01e-11
LCD incineration	Vinyl chloride	secondary	4.14e-12	7.99e-11
LCD landfilling	1,2-Dichloroethane	primary	2.81e-12	5.42e-11
LCD incineration	1,2-Dichloroethane	secondary	2.18e-12	4.20e-11
LCD landfilling	Dichloromethane	primary	1.85e-12	3.57e-11
LCD incineration	Dichloromethane	secondary	1.44e-12	2.77e-11
LPG Production	Aromatic hydrocarbons	secondary	6.90e-13	1.33e-11

Table M-38. LCD LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
LPG Production	Barium cmpds	secondary	5.60e-13	1.08e-11
LPG Production	Chromium (VI)	secondary	4.00e-13	7.71e-12
LPG Production	Chromium (III)	secondary	2.87e-13	5.53e-12
LPG Production	Cadmium cmpds	secondary	2.71e-13	5.23e-12
LPG Production	Lead cmpds	secondary	9.06e-14	1.75e-12
LPG Production	Toluene	secondary	8.42e-14	1.62e-12
LPG Production	Nickel cmpds	secondary	1.10e-14	2.11e-13
LPG Production	Mercury compounds	secondary	4.93e-15	9.50e-14
LPG Production	Cyanide (-1)	secondary	3.22e-15	6.20e-14
LPG Production	Halogenated matter (organic)	secondary	9.19e-16	1.77e-14
Natural Gas Prod.	Halogenated matter (organic)	secondary	-1.56e-15	-3.01e-14
Natural Gas Prod.	Cyanide (-1)	secondary	-5.47e-15	-1.05e-13
Natural Gas Prod.	Mercury compounds	secondary	-8.37e-15	-1.61e-13
Natural Gas Prod.	Nickel cmpds	secondary	-1.86e-14	-3.59e-13
LCD incineration	Halogenated matter (organic)	secondary	-2.38e-14	-4.59e-13
LCD incineration	Cyanide (-1)	secondary	-8.33e-14	-1.61e-12
Natural Gas Prod.	Toluene	secondary	-1.43e-13	-2.76e-12
Natural Gas Prod.	Lead cmpds	secondary	-1.54e-13	-2.97e-12
LCD incineration	Nickel cmpds	secondary	-2.84e-13	-5.47e-12
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	-3.78e-13	-7.29e-12
Natural Gas Prod.	Cadmium cmpds	secondary	-4.61e-13	-8.88e-12
Natural Gas Prod.	Barium cmpds	secondary	-9.51e-13	-1.83e-11
Natural Gas Prod.	Aromatic hydrocarbons	secondary	-1.17e-12	-2.26e-11
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	-1.32e-12	-2.55e-11
Fuel Oil #4 Prod.	Mercury compounds	secondary	-2.02e-12	-3.90e-11
Fuel Oil #4 Prod.	Nickel cmpds	secondary	-4.51e-12	-8.69e-11
LCD incineration	Aromatic hydrocarbons	secondary	-1.78e-11	-3.44e-10
Fuel Oil #4 Prod.	Toluene	secondary	-3.46e-11	-6.68e-10
Fuel Oil #4 Prod.	Lead cmpds	secondary	-3.72e-11	-7.18e-10
Fuel Oil #4 Prod.	Chromium (III)	secondary	-6.81e-11	-1.31e-09
Fuel Oil #4 Prod.	Chromium (VI)	secondary	-9.50e-11	-1.83e-09
Natural Gas Prod.	Copper (+1 & +2)	secondary	-1.04e-10	-2.00e-09
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	-1.11e-10	-2.15e-09
Fuel Oil #4 Prod.	Barium cmpds	secondary	-2.30e-10	-4.44e-09
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	-2.83e-10	-5.47e-09
Natural Gas Prod.	Chromium (III)	secondary	-7.28e-10	-1.40e-08
Natural Gas Prod.	Chromium (VI)	secondary	-1.01e-09	-1.96e-08
LCD incineration	Copper (+1 & +2)	secondary	-1.58e-09	-3.04e-08
LCD incineration	Zinc (+2)	secondary	-5.36e-09	-1.03e-07
Fuel Oil #4 Prod.	Zinc (+2)	secondary	-7.83e-09	-1.51e-07
Natural Gas Prod.	Nitrate	secondary	-9.96e-09	-1.92e-07
Natural Gas Prod.	Aluminum (+3)	secondary	-1.65e-08	-3.17e-07
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	-2.51e-08	-4.83e-07
Natural Gas Prod.	Phenol	secondary	-2.86e-08	-5.52e-07
Natural Gas Prod.	Fluorides (F-)	secondary	-3.95e-08	-7.61e-07
Natural Gas Prod.	Zinc (+2)	secondary	-6.41e-08	-1.24e-06
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	-1.62e-07	-3.12e-06
Fuel Oil #4 Prod.	Nitrate	secondary	-2.08e-07	-4.02e-06
LCD incineration	Aluminum (+3)	secondary	-2.51e-07	-4.83e-06

Table M-38. LCD LCIA Results for the Aquatic Toxicity Impact Category

Process Group	Material	LCI Data Type	Aquatic Toxicity (tox-kg)	% of Total
LCD incineration	Phenol	secondary	-4.33e-07	-8.36e-06
LCD incineration	Nitrate	secondary	-2.33e-06	-4.49e-05
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	-3.98e-06	-7.68e-05
Fuel Oil #4 Prod.	Phenol	secondary	-6.88e-06	-1.33e-04
LCD incineration	Fluorides (F-)	secondary	-9.81e-06	-1.89e-04
LCD incineration	Ammonia	secondary	-2.34e-04	-4.51e-03
Total End-of-life			**-2.37e-04**	**-4.58e-03**
Total All Life-cycle Stages			**5.19e+00**	**1.00e+02**

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Materials Processing Life-cycle Stage				
Invar	Sulfur dioxide	secondary	1.65e+02	8.35e+00
Steel Prod., cold-rolled, semi-finished	Sulfur dioxide	secondary	2.54e+01	1.28e+00
Aluminum Prod.	Sulfur dioxide	secondary	1.38e+01	6.99e-01
Polycarbonate Production	Sulfur dioxide	secondary	7.93e+00	4.02e-01
Lead	Sulfur dioxide	secondary	4.57e+00	2.32e-01
ABS Production	Sulfur dioxide	secondary	2.80e+00	1.42e-01
Ferrite mfg.	Sulfur dioxide	secondary	2.35e+00	1.19e-01
Lead	Arsenic	secondary	2.21e+00	1.12e-01
Polystyrene Prod., high-impact	Sulfur dioxide	secondary	1.20e+00	6.07e-02
Aluminum Prod.	Titanium tetrachloride	secondary	7.20e-01	3.65e-02
Steel Prod., cold-rolled, semi-finished	Carbon monoxide	secondary	2.78e-01	1.41e-02
Invar	Titanium tetrachloride	secondary	2.56e-01	1.30e-02
Lead	Titanium tetrachloride	secondary	2.10e-01	1.07e-02
Aluminum Prod.	Manganese cmpds	secondary	1.62e-01	8.20e-03
Invar	Manganese cmpds	secondary	1.50e-01	7.58e-03
Aluminum Prod.	Vanadium	secondary	1.07e-01	5.44e-03
Steel Prod., cold-rolled, semi-finished	PM	secondary	1.05e-01	5.31e-03
Ferrite mfg.	Manganese cmpds	secondary	9.39e-02	4.76e-03
Invar	Vanadium	secondary	7.40e-02	3.75e-03
Invar	Carbon monoxide	secondary	7.04e-02	3.56e-03
Ferrite mfg.	Carbon monoxide	secondary	5.85e-02	2.96e-03
Steel Prod., cold-rolled, semi-finished	Vanadium	secondary	5.15e-02	2.61e-03
Aluminum Prod.	Arsenic cmpds	secondary	4.75e-02	2.41e-03
Lead	Manganese cmpds	secondary	4.60e-02	2.33e-03
Polycarbonate Production	Carbon monoxide	secondary	4.15e-02	2.10e-03
Invar	Arsenic	secondary	3.21e-02	1.62e-03
Ferrite mfg.	Arsenic	secondary	2.90e-02	1.47e-03
Lead	Zinc (elemental)	secondary	2.42e-02	1.23e-03
Ferrite mfg.	Titanium tetrachloride	secondary	2.36e-02	1.20e-03
Invar	Zinc (elemental)	secondary	2.28e-02	1.15e-03
Ferrite mfg.	Zinc (elemental)	secondary	2.21e-02	1.12e-03
Lead	Vanadium	secondary	2.09e-02	1.06e-03
Polycarbonate Production	Methane	secondary	2.03e-02	1.03e-03
ABS Production	Carbon monoxide	secondary	2.01e-02	1.02e-03
Polycarbonate Production	Nitrogen dioxide	secondary	1.94e-02	9.82e-04
Steel Prod., cold-rolled, semi-finished	Fluorides (F-)	secondary	1.91e-02	9.68e-04
Lead	Carbon monoxide	secondary	1.89e-02	9.57e-04
Aluminum Prod.	Carbon monoxide	secondary	1.72e-02	8.74e-04
Invar	Arsenic cmpds	secondary	1.69e-02	8.55e-04
Styrene-butadiene Copolymer Prod.	Carbon monoxide	secondary	1.60e-02	8.12e-04
Steel Prod., cold-rolled, semi-finished	Manganese cmpds	secondary	1.49e-02	7.55e-04
Ferrite mfg.	Vanadium	secondary	1.45e-02	7.35e-04
Steel Prod., cold-rolled, semi-finished	Nitrogen dioxide	secondary	1.40e-02	7.09e-04
Lead	Arsenic cmpds	secondary	1.38e-02	6.99e-04
Steel Prod., cold-rolled, semi-finished	Methane	secondary	1.09e-02	5.52e-04
Aluminum Prod.	Barium cmpds	secondary	1.04e-02	5.29e-04
Aluminum Prod.	PM	secondary	8.90e-03	4.51e-04
Aluminum Prod.	Methane	secondary	8.05e-03	4.08e-04
Aluminum Prod.	Nitrogen dioxide	secondary	7.13e-03	3.61e-04

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Styrene-butadiene Copolymer Prod.	Nitrogen oxides	secondary	6.99e-03	3.54e-04
Styrene-butadiene Copolymer Prod.	Methane	secondary	6.87e-03	3.48e-04
Polycarbonate Production	PM	secondary	6.46e-03	3.27e-04
Aluminum Prod.	Selenium	secondary	6.29e-03	3.19e-04
Invar	Methane	secondary	5.76e-03	2.92e-04
Styrene-butadiene Copolymer Prod.	Sulfur oxides	secondary	5.71e-03	2.89e-04
ABS Production	Methane	secondary	5.08e-03	2.57e-04
Invar	Nitrogen dioxide	secondary	5.07e-03	2.57e-04
ABS Production	Nitrogen dioxide	secondary	4.66e-03	2.36e-04
Steel Prod., cold-rolled, semi-finished	Arsenic	secondary	4.52e-03	2.29e-04
Invar	Barium cmpds	secondary	4.31e-03	2.19e-04
Lead	Nitrogen dioxide	secondary	4.18e-03	2.12e-04
Steel Prod., cold-rolled, semi-finished	Phosphorus (yellow or white)	secondary	4.07e-03	2.06e-04
ABS Production	Hydrochloric acid	secondary	2.93e-03	1.48e-04
Ferrite mfg.	Methane	secondary	2.85e-03	1.45e-04
Invar	PM	secondary	2.76e-03	1.40e-04
Lead	Barium cmpds	secondary	2.71e-03	1.37e-04
Lead	Methane	secondary	2.52e-03	1.28e-04
Invar	Selenium	secondary	2.32e-03	1.18e-04
Polystyrene Prod., high-impact	Carbon monoxide	secondary	2.27e-03	1.15e-04
Steel Prod., cold-rolled, semi-finished	Hydrochloric acid	secondary	2.05e-03	1.04e-04
Ferrite mfg.	Nitrogen dioxide	secondary	2.03e-03	1.03e-04
Invar	Hydrochloric acid	secondary	1.85e-03	9.38e-05
Lead	Selenium	secondary	1.84e-03	9.30e-05
Polystyrene Prod., high-impact	Nitrogen dioxide	secondary	1.81e-03	9.19e-05
Aluminum Prod.	Hydrochloric acid	secondary	1.78e-03	9.04e-05
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	1.76e-03	8.91e-05
Steel Prod., cold-rolled, semi-finished	Barium cmpds	secondary	1.73e-03	8.77e-05
Ferrite mfg.	PM	secondary	1.72e-03	8.72e-05
Polystyrene Prod., high-impact	Methane	secondary	1.66e-03	8.42e-05
Ferrite mfg.	Arsenic cmpds	secondary	1.64e-03	8.30e-05
ABS Production	Formaldehyde	secondary	1.60e-03	8.11e-05
Aluminum Prod.	Aluminum (+3)	secondary	1.59e-03	8.04e-05
Lead	Lead	secondary	1.58e-03	8.01e-05
Steel Prod., cold-rolled, semi-finished	Arsenic cmpds	secondary	1.54e-03	7.78e-05
ABS Production	PM	secondary	1.27e-03	6.44e-05
Aluminum Prod.	Cadmium cmpds	secondary	1.17e-03	5.93e-05
Lead	Hydrochloric acid	secondary	1.07e-03	5.42e-05
Styrene-butadiene Copolymer Prod.	PM	secondary	9.93e-04	5.03e-05
Invar	Copper	secondary	9.89e-04	5.01e-05
Invar	Benzene	secondary	9.17e-04	4.65e-05
Lead	PM	secondary	8.41e-04	4.26e-05
Steel Prod., cold-rolled, semi-finished	Titanium tetrachloride	secondary	8.33e-04	4.22e-05
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	7.99e-04	4.05e-05
Ferrite mfg.	Barium cmpds	secondary	7.81e-04	3.96e-05
Steel Prod., cold-rolled, semi-finished	Nitrous oxide	secondary	7.77e-04	3.94e-05
Ferrite mfg.	Hydrochloric acid	secondary	6.93e-04	3.51e-05
Ferrite mfg.	Benzene	secondary	5.85e-04	2.97e-05
Invar	Aluminum (+3)	secondary	5.70e-04	2.89e-05
Aluminum Prod.	Benzene	secondary	5.69e-04	2.88e-05

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Silicon	secondary	5.06e-04	2.56e-05
Polycarbonate Production	Hydrochloric acid	secondary	4.65e-04	2.36e-05
Lead	Aluminum (+3)	secondary	4.62e-04	2.34e-05
Aluminum Prod.	Barium sulfate	secondary	4.54e-04	2.30e-05
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	4.15e-04	2.10e-05
Steel Prod., cold-rolled, semi-finished	Titanium	secondary	3.26e-04	1.65e-05
Polycarbonate Production	Sulfuric acid	secondary	3.17e-04	1.61e-05
Polystyrene Prod., high-impact	PM	secondary	3.02e-04	1.53e-05
Steel Prod., cold-rolled, semi-finished	Selenium	secondary	3.00e-04	1.52e-05
Lead	Benzene	secondary	2.99e-04	1.51e-05
Invar	Phosphorus (yellow or white)	secondary	2.89e-04	1.46e-05
Ferrite mfg.	Selenium	secondary	2.86e-04	1.45e-05
Ferrite mfg.	Phosphorus (yellow or white)	secondary	2.85e-04	1.44e-05
Steel Prod., cold-rolled, semi-finished	Ethane	secondary	2.46e-04	1.25e-05
ABS Production	Hydrofluoric acid	secondary	2.44e-04	1.23e-05
Polycarbonate Production	Mercury compounds	secondary	2.43e-04	1.23e-05
Aluminum Prod.	Hydrofluoric acid	secondary	2.40e-04	1.22e-05
Aluminum Prod.	Zinc (elemental)	secondary	2.30e-04	1.16e-05
Aluminum Prod.	Titanium	secondary	2.28e-04	1.15e-05
Invar	Silicon	secondary	2.26e-04	1.15e-05
Steel Prod., cold-rolled, semi-finished	Zinc (elemental)	secondary	2.16e-04	1.10e-05
Invar	Titanium	secondary	2.13e-04	1.08e-05
ABS Production	Ammonia	secondary	1.94e-04	9.82e-06
ABS Production	Aromatic hydrocarbons	secondary	1.91e-04	9.65e-06
Steel Prod., cold-rolled, semi-finished	Molybdenum	secondary	1.88e-04	9.51e-06
Aluminum Prod.	Copper (+1 & +2)	secondary	1.80e-04	9.12e-06
Invar	Formaldehyde	secondary	1.60e-04	8.11e-06
Ferrite mfg.	Formaldehyde	secondary	1.56e-04	7.92e-06
Invar	Molybdenum	secondary	1.52e-04	7.70e-06
Ferrite mfg.	Silicon	secondary	1.48e-04	7.52e-06
ABS Production	Sulfuric acid	secondary	1.45e-04	7.37e-06
Styrene-butadiene Copolymer Prod.	Sulfuric acid	secondary	1.42e-04	7.20e-06
Aluminum Prod.	Nitrous oxide	secondary	1.38e-04	7.00e-06
Aluminum Prod.	Perfluoromethane	secondary	1.30e-04	6.57e-06
Invar	Cadmium cmpds	secondary	1.27e-04	6.43e-06
Steel Prod., cold-rolled, semi-finished	Barium	secondary	1.23e-04	6.23e-06
Invar	Nitrates/nitrites	secondary	1.21e-04	6.11e-06
ABS Production	Ethane	secondary	1.19e-04	6.01e-06
Lead	Barium sulfate	secondary	1.15e-04	5.81e-06
ABS Production	Mercury compounds	secondary	1.11e-04	5.65e-06
Aluminum Prod.	Silicon	secondary	1.09e-04	5.54e-06
Styrene-butadiene Copolymer Prod.	Mercury compounds	secondary	1.09e-04	5.52e-06
Steel Prod., cold-rolled, semi-finished	Tin (Sn++, Sn4+)	secondary	1.04e-04	5.28e-06
Steel Prod., cold-rolled, semi-finished	Antimony	secondary	9.51e-05	4.82e-06
Invar	Copper (+1 & +2)	secondary	9.43e-05	4.78e-06
Polycarbonate Production	Fluorides (F-)	secondary	9.16e-05	4.64e-06
Ferrite mfg.	Titanium	secondary	9.12e-05	4.62e-06
Invar	Ethane	secondary	8.26e-05	4.18e-06
Polycarbonate Production	Aromatic hydrocarbons	secondary	8.22e-05	4.16e-06
Ferrite mfg.	Ethane	secondary	8.06e-05	4.09e-06

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Lead	Silicon	secondary	7.13e-05	3.61e-06
Styrene-butadiene Copolymer Prod.	Hydrochloric acid	secondary	6.82e-05	3.46e-06
Styrene-butadiene Copolymer Prod.	Aromatic hydrocarbons	secondary	6.79e-05	3.44e-06
Invar	Nickel	secondary	6.54e-05	3.31e-06
Invar	Barium	secondary	6.53e-05	3.31e-06
Steel Prod., cold-rolled, semi-finished	Silver compounds	secondary	6.17e-05	3.13e-06
Ferrite mfg.	Aluminum (+3)	secondary	5.58e-05	2.82e-06
Ferrite mfg.	Molybdenum	secondary	5.23e-05	2.65e-06
Lead	Copper (+1 & +2)	secondary	5.20e-05	2.64e-06
ABS Production	Aluminum (+3)	secondary	5.08e-05	2.57e-06
Steel Prod., cold-rolled, semi-finished	Nitrates/nitrites	secondary	4.99e-05	2.53e-06
Steel Prod., cold-rolled, semi-finished	Boron	secondary	4.93e-05	2.50e-06
Aluminum Prod.	Nitrate	secondary	4.56e-05	2.31e-06
Steel Prod., cold-rolled, semi-finished	Mercury compounds	secondary	4.52e-05	2.29e-06
Styrene-butadiene Copolymer Prod.	Fluorides (F-)	secondary	4.10e-05	2.08e-06
Aluminum Prod.	Barium	secondary	3.91e-05	1.98e-06
Ferrite mfg.	Barium	secondary	3.73e-05	1.89e-06
Invar	Lead	secondary	3.62e-05	1.83e-06
Ferrite mfg.	Lead	secondary	3.46e-05	1.75e-06
Invar	Barium sulfate	secondary	3.46e-05	1.75e-06
Steel Prod., cold-rolled, semi-finished	Barium sulfate	secondary	3.43e-05	1.74e-06
Ferrite mfg.	Barium sulfate	secondary	3.38e-05	1.71e-06
Invar	Ammonia	secondary	3.16e-05	1.60e-06
Lead	Ethane	secondary	3.16e-05	1.60e-06
Invar	Tin (Sn++, Sn4+)	secondary	3.04e-05	1.54e-06
Polystyrene Prod., high-impact	Aromatic hydrocarbons	secondary	3.02e-05	1.53e-06
ABS Production	Nitrate	secondary	3.01e-05	1.52e-06
Lead	Barium	secondary	2.88e-05	1.46e-06
Lead	Copper	secondary	2.82e-05	1.43e-06
Invar	Boron	secondary	2.79e-05	1.41e-06
Steel Prod., cold-rolled, semi-finished	Cadmium cmpds	secondary	2.70e-05	1.37e-06
Invar	Antimony	secondary	2.69e-05	1.37e-06
Invar	Hydrofluoric acid	secondary	2.69e-05	1.36e-06
Ferrite mfg.	Antimony	secondary	2.63e-05	1.33e-06
Steel Prod., cold-rolled, semi-finished	Aluminum (elemental)	secondary	2.47e-05	1.25e-06
Invar	Zinc (+2)	secondary	2.44e-05	1.23e-06
Polystyrene Prod., high-impact	Hydrochloric acid	secondary	2.42e-05	1.23e-06
Aluminum Prod.	Copper	secondary	2.38e-05	1.21e-06
Steel Prod., cold-rolled, semi-finished	Acetylene	secondary	2.33e-05	1.18e-06
Lead	Nitrous oxide	secondary	2.03e-05	1.03e-06
Aluminum Prod.	Nickel cmpds	secondary	1.91e-05	9.65e-07
Steel Prod., cold-rolled, semi-finished	Hydrofluoric acid	secondary	1.89e-05	9.59e-07
Invar	Silver compounds	secondary	1.86e-05	9.44e-07
Ferrite mfg.	Zinc (+2)	secondary	1.84e-05	9.34e-07
Ferrite mfg.	Silver compounds	secondary	1.82e-05	9.22e-07
Aluminum Prod.	Nickel	secondary	1.78e-05	9.00e-07
Aluminum Prod.	Zinc (+2)	secondary	1.74e-05	8.83e-07
Steel Prod., cold-rolled, semi-finished	Pentane	secondary	1.70e-05	8.59e-07
Steel Prod., cold-rolled, semi-finished	Aluminum (+3)	secondary	1.58e-05	7.98e-07
Aluminum Prod.	Ammonia	secondary	1.55e-05	7.84e-07

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Invar	Aluminum (elemental)	secondary	1.52e-05	7.72e-07
Invar	Nickel cmpds	secondary	1.51e-05	7.66e-07
Ferrite mfg.	Boron	secondary	1.48e-05	7.51e-07
Aluminum Prod.	Aromatic hydrocarbons	secondary	1.41e-05	7.17e-07
Lead	Hydrofluoric acid	secondary	1.36e-05	6.91e-07
Steel Prod., cold-rolled, semi-finished	Hydrogen sulfide	secondary	1.36e-05	6.88e-07
Aluminum Prod.	Nitrites	secondary	1.35e-05	6.85e-07
Steel Prod., cold-rolled, semi-finished	Copper	secondary	1.22e-05	6.19e-07
Lead	Ammonia	secondary	1.19e-05	6.01e-07
Ferrite mfg.	Nitrous oxide	secondary	1.06e-05	5.38e-07
Aluminum Prod.	Aluminum (elemental)	secondary	1.05e-05	5.33e-07
Polycarbonate Production	Copper (+1 & +2)	secondary	1.04e-05	5.25e-07
Ferrite mfg.	Ammonia	secondary	1.03e-05	5.19e-07
ABS Production	Hydrogen sulfide	secondary	1.01e-05	5.13e-07
Aluminum Prod.	Strontium (Sr II)	secondary	1.00e-05	5.06e-07
Lead	Boron	secondary	9.53e-06	4.83e-07
Polycarbonate Production	Phenol	secondary	9.34e-06	4.73e-07
Aluminum Prod.	Fluoride	secondary	9.10e-06	4.61e-07
Lead	Nitrate	secondary	9.00e-06	4.56e-07
Invar	Pentane	secondary	8.97e-06	4.55e-07
Ferrite mfg.	Pentane	secondary	8.76e-06	4.44e-07
Aluminum Prod.	Lead cmpds	secondary	8.72e-06	4.42e-07
Steel Prod., cold-rolled, semi-finished	Copper (+1 & +2)	secondary	8.59e-06	4.35e-07
Invar	Aromatic hydrocarbons	secondary	8.36e-06	4.23e-07
Lead	Aluminum (elemental)	secondary	8.16e-06	4.13e-07
Steel Prod., cold-rolled, semi-finished	Nickel	secondary	8.14e-06	4.13e-07
Aluminum Prod.	Vanadium (V3+, V5+)	secondary	8.14e-06	4.13e-07
Ferrite mfg.	Aluminum (elemental)	secondary	7.77e-06	3.93e-07
Invar	Hydrogen sulfide	secondary	7.26e-06	3.68e-07
Steel Prod., cold-rolled, semi-finished	Aromatic hydrocarbons	secondary	7.17e-06	3.63e-07
Invar	Acetylene	secondary	6.61e-06	3.35e-07
Ferrite mfg.	Acetylene	secondary	6.46e-06	3.27e-07
Ferrite mfg.	Hydrofluoric acid	secondary	6.37e-06	3.23e-07
Ferrite mfg.	Copper (+1 & +2)	secondary	5.96e-06	3.02e-07
Invar	Nitrites	secondary	5.95e-06	3.01e-07
Ferrite mfg.	Cadmium cmpds	secondary	5.94e-06	3.01e-07
Lead	Nickel cmpds	secondary	5.60e-06	2.83e-07
Invar	Strontium (Sr II)	secondary	5.18e-06	2.62e-07
Ferrite mfg.	Hydrogen sulfide	secondary	5.17e-06	2.62e-07
ABS Production	Heptane	secondary	5.02e-06	2.54e-07
Lead	Zinc (+2)	secondary	4.96e-06	2.51e-07
Aluminum Prod.	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	4.94e-06	2.50e-07
ABS Production	Copper (+1 & +2)	secondary	4.75e-06	2.41e-07
Lead	Nickel	secondary	4.72e-06	2.39e-07
Steel Prod., cold-rolled, semi-finished	Strontium (Sr II)	secondary	4.67e-06	2.37e-07
Styrene-butadiene Copolymer Prod.	Copper (+1 & +2)	secondary	4.64e-06	2.35e-07
Ferrite mfg.	Copper	secondary	4.55e-06	2.31e-07
Lead	Fluoride	secondary	4.46e-06	2.26e-07
Steel Prod., cold-rolled, semi-finished	Hexane	secondary	4.43e-06	2.24e-07

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Invar	Fluoride	secondary	4.40e-06	2.23e-07
Ferrite mfg.	Nitrate	secondary	4.04e-06	2.05e-07
Lead	Cadmium	secondary	3.98e-06	2.02e-07
Aluminum Prod.	Hydrogen sulfide	secondary	3.77e-06	1.91e-07
Polycarbonate Production	Ammonia	secondary	3.70e-06	1.87e-07
Polycarbonate Production	Hydrofluoric acid	secondary	3.69e-06	1.87e-07
Steel Prod., cold-rolled, semi-finished	Chromium (VI)	secondary	3.30e-06	1.67e-07
Invar	Vanadium (V3+, V5+)	secondary	3.00e-06	1.52e-07
Invar	Lead cmpds	secondary	2.98e-06	1.51e-07
Lead	Hydrogen sulfide	secondary	2.96e-06	1.50e-07
Styrene-butadiene Copolymer Prod.	Nitrate	secondary	2.90e-06	1.47e-07
Lead	Nitrites	secondary	2.86e-06	1.45e-07
Lead	Lead cmpds	secondary	2.75e-06	1.39e-07
Lead	Vanadium (V3+, V5+)	secondary	2.37e-06	1.20e-07
Ferrite mfg.	Nickel	secondary	2.30e-06	1.16e-07
Ferrite mfg.	Aromatic hydrocarbons	secondary	2.26e-06	1.15e-07
Steel Prod., cold-rolled, semi-finished	Boric acid	secondary	2.17e-06	1.10e-07
Steel Prod., cold-rolled, semi-finished	Bromine	secondary	2.03e-06	1.03e-07
Lead	Strontium (Sr II)	secondary	2.00e-06	1.01e-07
Invar	Methanol	secondary	1.87e-06	9.45e-08
Polycarbonate Production	Halogenated hydrocarbons (unspecified)	secondary	1.85e-06	9.36e-08
Polycarbonate Production	Hydrogen sulfide	secondary	1.85e-06	9.36e-08
Aluminum Prod.	Toluene	secondary	1.81e-06	9.18e-08
Invar	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	1.72e-06	8.73e-08
Steel Prod., cold-rolled, semi-finished	Uranium	secondary	1.68e-06	8.53e-08
Polystyrene Prod., high-impact	Ammonia	secondary	1.62e-06	8.18e-08
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	1.52e-06	7.69e-08
Ferrite mfg.	Strontium (Sr II)	secondary	1.52e-06	7.68e-08
Lead	Mercury	secondary	1.51e-06	7.66e-08
Lead	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	1.49e-06	7.57e-08
Invar	Cobalt (Co I, Co II, Co III)	secondary	1.44e-06	7.31e-08
Aluminum Prod.	Xylene (mixed isomers)	secondary	1.38e-06	6.98e-08
Invar	Hexane	secondary	1.29e-06	6.52e-08
Ferrite mfg.	Hexane	secondary	1.26e-06	6.37e-08
Invar	Boron (B III)	secondary	1.26e-06	6.36e-08
Invar	Benzo[a]pyrene	secondary	1.23e-06	6.23e-08
Steel Prod., cold-rolled, semi-finished	Ethylene	secondary	1.23e-06	6.22e-08
Steel Prod., cold-rolled, semi-finished	Cyanide (-1)	secondary	1.21e-06	6.11e-08
Aluminum Prod.	Lead	secondary	1.20e-06	6.08e-08
Steel Prod., cold-rolled, semi-finished	Methanol	secondary	1.19e-06	6.04e-08
Invar	Cadmium	secondary	1.18e-06	5.97e-08
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	1.12e-06	5.68e-08
Steel Prod., cold-rolled, semi-finished	Lead	secondary	1.10e-06	5.58e-08
Steel Prod., cold-rolled, semi-finished	Naphthalene	secondary	1.10e-06	5.57e-08
Invar	Toluene	secondary	1.10e-06	5.57e-08
Lead	Bromine	secondary	1.08e-06	5.46e-08
Ferrite mfg.	Cadmium	secondary	9.76e-07	4.95e-08
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	9.70e-07	4.91e-08
Steel Prod., cold-rolled, semi-finished	Heptane	secondary	9.33e-07	4.73e-08

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Invar	Chromium (VI)	secondary	9.25e-07	4.69e-08
Polycarbonate Production	Chlorine	secondary	9.23e-07	4.68e-08
Ferrite mfg.	Fluoride	secondary	9.23e-07	4.68e-08
Lead	Cobalt (Co I, Co II, Co III)	secondary	9.18e-07	4.65e-08
Aluminum Prod.	Chromium (VI)	secondary	8.90e-07	4.51e-08
Steel Prod., cold-rolled, semi-finished	Lead cmpds	secondary	8.83e-07	4.47e-08
Lead	Manganese	secondary	8.47e-07	4.29e-08
Styrene-butadiene Copolymer Prod.	Aluminum (+3)	secondary	8.27e-07	4.19e-08
Ferrite mfg.	Nickel cmpds	secondary	7.97e-07	4.04e-08
Lead	Mercury compounds	secondary	7.88e-07	3.99e-08
Invar	Xylene (mixed isomers)	secondary	7.67e-07	3.89e-08
Lead	Boron (B III)	secondary	7.54e-07	3.82e-08
Invar	Bromium (Br)	secondary	7.09e-07	3.59e-08
Ferrite mfg.	Bromine	secondary	6.92e-07	3.50e-08
Aluminum Prod.	Phenol	secondary	6.39e-07	3.24e-08
ABS Production	Chlorine	secondary	6.35e-07	3.22e-08
Invar	Manganese	secondary	6.32e-07	3.20e-08
Invar	Boric acid	secondary	6.13e-07	3.11e-08
Invar	Ethylene	secondary	6.01e-07	3.04e-08
Ferrite mfg.	Boric acid	secondary	5.99e-07	3.03e-08
Steel Prod., cold-rolled, semi-finished	Nickel cmpds	secondary	5.96e-07	3.02e-08
ABS Production	Phenol	secondary	5.88e-07	2.98e-08
Ferrite mfg.	Ethylene	secondary	5.79e-07	2.93e-08
Ferrite mfg.	Toluene	secondary	5.31e-07	2.69e-08
Steel Prod., cold-rolled, semi-finished	Zinc (+2)	secondary	5.30e-07	2.69e-08
Ferrite mfg.	Lead cmpds	secondary	5.19e-07	2.63e-08
ABS Production	Nickel cmpds	secondary	5.04e-07	2.55e-08
Styrene-butadiene Copolymer Prod.	Phenol	secondary	4.92e-07	2.49e-08
Invar	Uranium	secondary	4.81e-07	2.44e-08
Ferrite mfg.	Uranium	secondary	4.69e-07	2.38e-08
Polycarbonate Production	Aluminum (+3)	secondary	4.62e-07	2.34e-08
Polycarbonate Production	Ethanethiol	secondary	4.62e-07	2.34e-08
Polycarbonate Production	Lead	secondary	4.62e-07	2.34e-08
Polycarbonate Production	Mercury	secondary	4.62e-07	2.34e-08
Polycarbonate Production	Nickel (+2)	secondary	4.62e-07	2.34e-08
Polycarbonate Production	Nitrate	secondary	4.62e-07	2.34e-08
Polycarbonate Production	Nitrous oxide	secondary	4.62e-07	2.34e-08
Polycarbonate Production	Zinc (+2)	secondary	4.62e-07	2.34e-08
Invar	Phenol	secondary	4.41e-07	2.23e-08
Aluminum Prod.	Acetic acid	secondary	4.22e-07	2.14e-08
Ferrite mfg.	Chromium (VI)	secondary	4.17e-07	2.11e-08
Styrene-butadiene Copolymer Prod.	Chlorine	secondary	4.14e-07	2.10e-08
Styrene-butadiene Copolymer Prod.	Hydrofluoric acid	secondary	4.14e-07	2.10e-08
Ferrite mfg.	Nitrites	secondary	4.13e-07	2.09e-08
Aluminum Prod.	Cobalt	secondary	4.11e-07	2.08e-08
Steel Prod., cold-rolled, semi-finished	Cobalt	secondary	4.05e-07	2.05e-08
Lead	Chromium (VI)	secondary	3.70e-07	1.88e-08
Steel Prod., cold-rolled, semi-finished	Manganese	secondary	3.60e-07	1.82e-08
Styrene-butadiene Copolymer Prod.	Ammonia	secondary	3.55e-07	1.80e-08
Ferrite mfg.	Xylene (mixed isomers)	secondary	3.50e-07	1.77e-08

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Invar	Acetic acid	secondary	3.50e-07	1.77e-08
Ferrite mfg.	Vanadium (V3+, V5+)	secondary	3.42e-07	1.73e-08
Ferrite mfg.	Methanol	secondary	3.36e-07	1.70e-08
Polystyrene Prod., high-impact	Nitrate	secondary	3.02e-07	1.53e-08
Steel Prod., cold-rolled, semi-finished	Vanadium (V3+, V5+)	secondary	2.97e-07	1.50e-08
Aluminum Prod.	Cadmium	secondary	2.95e-07	1.50e-08
Invar	Cyanide (-1)	secondary	2.89e-07	1.46e-08
Invar	Heptane	secondary	2.83e-07	1.43e-08
Ferrite mfg.	Heptane	secondary	2.76e-07	1.40e-08
Steel Prod., cold-rolled, semi-finished	Boron (B III)	secondary	2.70e-07	1.37e-08
Invar	Acetaldehyde	secondary	2.64e-07	1.34e-08
ABS Production	HALON-1301	secondary	2.56e-07	1.30e-08
Lead	Xylene (mixed isomers)	secondary	2.54e-07	1.29e-08
Aluminum Prod.	Triethylene glycol	secondary	2.42e-07	1.23e-08
Invar	Mercury	secondary	2.12e-07	1.08e-08
ABS Production	Ethanethiol	secondary	2.12e-07	1.07e-08
ABS Production	Fluoride	secondary	2.12e-07	1.07e-08
ABS Production	Halogenated hydrocarbons (unspecified)	secondary	2.12e-07	1.07e-08
ABS Production	Lead	secondary	2.12e-07	1.07e-08
ABS Production	Mercury	secondary	2.12e-07	1.07e-08
ABS Production	Nitrous oxide	secondary	2.12e-07	1.07e-08
ABS Production	Zinc (+2)	secondary	2.12e-07	1.07e-08
Styrene-butadiene Copolymer Prod.	Halogenated hydrocarbons (unspecified)	secondary	2.07e-07	1.05e-08
Styrene-butadiene Copolymer Prod.	Hydrogen sulfide	secondary	2.07e-07	1.05e-08
Styrene-butadiene Copolymer Prod.	Lead	secondary	2.07e-07	1.05e-08
Styrene-butadiene Copolymer Prod.	Mercury	secondary	2.07e-07	1.05e-08
Styrene-butadiene Copolymer Prod.	Nickel (+2)	secondary	2.07e-07	1.05e-08
Styrene-butadiene Copolymer Prod.	Nitrous oxide	secondary	2.07e-07	1.05e-08
Styrene-butadiene Copolymer Prod.	Zinc (+2)	secondary	2.07e-07	1.05e-08
Ferrite mfg.	Cyanide (-1)	secondary	2.05e-07	1.04e-08
Steel Prod., cold-rolled, semi-finished	Acetic acid	secondary	2.05e-07	1.04e-08
Aluminum Prod.	Mercury	secondary	2.02e-07	1.02e-08
Ferrite mfg.	Phenol	secondary	1.95e-07	9.90e-09
Invar	Triethylene glycol	secondary	1.93e-07	9.77e-09
Steel Prod., cold-rolled, semi-finished	Triethylene glycol	secondary	1.92e-07	9.70e-09
Aluminum Prod.	Cyanide (-1)	secondary	1.89e-07	9.60e-09
Ferrite mfg.	Triethylene glycol	secondary	1.88e-07	9.54e-09
Lead	Triethylene glycol	secondary	1.81e-07	9.18e-09
Aluminum Prod.	HALON-1301	secondary	1.80e-07	9.14e-09
Polystyrene Prod., high-impact	Phenol	secondary	1.80e-07	9.11e-09
Steel Prod., cold-rolled, semi-finished	Morpholine	secondary	1.79e-07	9.08e-09
Steel Prod., cold-rolled, semi-finished	Strontium	secondary	1.77e-07	8.98e-09
Steel Prod., cold-rolled, semi-finished	Propylene	secondary	1.77e-07	8.97e-09
Steel Prod., cold-rolled, semi-finished	Cadmium	secondary	1.74e-07	8.83e-09
Lead	Methanol	secondary	1.62e-07	8.23e-09
Ferrite mfg.	Mercury	secondary	1.62e-07	8.18e-09
Steel Prod., cold-rolled, semi-finished	Acetaldehyde	secondary	1.53e-07	7.76e-09
ABS Production	Ethylene	secondary	1.52e-07	7.70e-09
Lead	Phenol	secondary	1.37e-07	6.96e-09
Invar	Ethylbenzene	secondary	1.37e-07	6.92e-09

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Invar	Acetone	secondary	1.36e-07	6.90e-09
Aluminum Prod.	Chromium (III)	secondary	1.31e-07	6.64e-09
Steel Prod., cold-rolled, semi-finished	Rubidium ion (Rb+)	secondary	1.21e-07	6.13e-09
Ferrite mfg.	Cobalt	secondary	1.20e-07	6.09e-09
Ferrite mfg.	Manganese	secondary	1.19e-07	6.01e-09
Steel Prod., cold-rolled, semi-finished	Fluorine	secondary	1.14e-07	5.76e-09
Lead	Cyanide (-1)	secondary	9.76e-08	4.94e-09
Lead	Ethylene	secondary	9.43e-08	4.78e-09
Invar	Strontium	secondary	9.37e-08	4.75e-09
Steel Prod., cold-rolled, semi-finished	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	9.07e-08	4.59e-09
Steel Prod., cold-rolled, semi-finished	Benzo[a]pyrene	secondary	8.92e-08	4.52e-09
Ferrite mfg.	Boron (B III)	secondary	8.91e-08	4.51e-09
Ferrite mfg.	Cobalt (Co I, Co II, Co III)	secondary	8.79e-08	4.45e-09
Ferrite mfg.	Acetic acid	secondary	8.74e-08	4.43e-09
Lead	Toluene	secondary	8.24e-08	4.18e-09
Steel Prod., cold-rolled, semi-finished	Acetone	secondary	7.91e-08	4.01e-09
Invar	HALON-1301	secondary	7.60e-08	3.85e-09
Lead	Cobalt	secondary	7.32e-08	3.71e-09
Lead	Acetic acid	secondary	7.30e-08	3.70e-09
Lead	Aromatic hydrocarbons	secondary	6.79e-08	3.44e-09
Invar	Sulfuric acid	secondary	5.98e-08	3.03e-09
Ferrite mfg.	Sulfuric acid	secondary	5.84e-08	2.96e-09
Invar	Mercury compounds	secondary	5.57e-08	2.82e-09
Ferrite mfg.	Mercury compounds	secondary	5.44e-08	2.76e-09
Steel Prod., cold-rolled, semi-finished	Lanthanum	secondary	5.37e-08	2.72e-09
Steel Prod., cold-rolled, semi-finished	Ethylbenzene	secondary	5.25e-08	2.66e-09
Invar	Morpholine	secondary	5.07e-08	2.57e-09
Invar	Propylene	secondary	5.03e-08	2.55e-09
Ferrite mfg.	Morpholine	secondary	4.95e-08	2.51e-09
Ferrite mfg.	Strontium	secondary	4.94e-08	2.50e-09
Ferrite mfg.	Propylene	secondary	4.91e-08	2.49e-09
Invar	Nitrous oxide	secondary	4.85e-08	2.46e-09
Invar	Chromium (III)	secondary	4.79e-08	2.42e-09
Lead	Ethylbenzene	secondary	4.72e-08	2.39e-09
Steel Prod., cold-rolled, semi-finished	Beryllium	secondary	4.72e-08	2.39e-09
Aluminum Prod.	Strontium	secondary	4.48e-08	2.27e-09
Ferrite mfg.	Acetaldehyde	secondary	4.38e-08	2.22e-09
Lead	Chromium (III)	secondary	3.86e-08	1.96e-09
Invar	Rubidium ion (Rb+)	secondary	3.66e-08	1.85e-09
Ferrite mfg.	Rubidium ion (Rb+)	secondary	3.57e-08	1.81e-09
Lead	Acetaldehyde	secondary	3.39e-08	1.72e-09
Lead	HALON-1301	secondary	3.39e-08	1.72e-09
Steel Prod., cold-rolled, semi-finished	Mercury	secondary	3.26e-08	1.65e-09
Invar	Fluorine	secondary	3.22e-08	1.63e-09
Ferrite mfg.	Fluorine	secondary	3.14e-08	1.59e-09
Steel Prod., cold-rolled, semi-finished	Thorium	secondary	2.88e-08	1.46e-09
Ferrite mfg.	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	2.55e-08	1.29e-09
Steel Prod., cold-rolled, semi-finished	HALON-1301	secondary	2.52e-08	1.28e-09

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Ferrite mfg.	Benzo[a]pyrene	secondary	2.48e-08	1.25e-09
Ferrite mfg.	Acetone	secondary	2.23e-08	1.13e-09
Ferrite mfg.	Ethylbenzene	secondary	1.94e-08	9.82e-10
Lead	Acetone	secondary	1.72e-08	8.70e-10
Steel Prod., cold-rolled, semi-finished	Tin	secondary	1.68e-08	8.49e-10
Steel Prod., cold-rolled, semi-finished	Phosphorus pentoxide	secondary	1.61e-08	8.15e-10
Invar	Lanthanum	secondary	1.53e-08	7.76e-10
Ferrite mfg.	Lanthanum	secondary	1.50e-08	7.58e-10
Invar	Beryllium	secondary	1.34e-08	6.80e-10
Ferrite mfg.	Beryllium	secondary	1.31e-08	6.64e-10
Steel Prod., cold-rolled, semi-finished	Scandium	secondary	1.31e-08	6.62e-10
Steel Prod., cold-rolled, semi-finished	Chlorine	secondary	1.14e-08	5.78e-10
Aluminum Prod.	1,2-Dichlorotetrafluoroethane	secondary	1.04e-08	5.28e-10
Ferrite mfg.	HALON-1301	secondary	9.52e-09	4.82e-10
Steel Prod., cold-rolled, semi-finished	Thallium	secondary	8.89e-09	4.51e-10
Aluminum Prod.	Perfluoroethane	secondary	8.46e-09	4.28e-10
Invar	Thorium	secondary	8.23e-09	4.17e-10
Ferrite mfg.	Thorium	secondary	8.03e-09	4.07e-10
Invar	Hydrogen cyanide	secondary	7.58e-09	3.84e-10
Ferrite mfg.	Hydrogen cyanide	secondary	7.40e-09	3.75e-10
Steel Prod., cold-rolled, semi-finished	Chromium (III)	secondary	5.29e-09	2.68e-10
Steel Prod., cold-rolled, semi-finished	Nitrites	secondary	5.19e-09	2.63e-10
Ferrite mfg.	Chromium (III)	secondary	5.01e-09	2.54e-10
Invar	Tin	secondary	4.77e-09	2.41e-10
Invar	Phosphorus pentoxide	secondary	4.69e-09	2.38e-10
Ferrite mfg.	Tin	secondary	4.65e-09	2.36e-10
Ferrite mfg.	Phosphorus pentoxide	secondary	4.58e-09	2.32e-10
Invar	1,2-Dichlorotetrafluoroethane	secondary	4.31e-09	2.19e-10
Invar	Scandium	secondary	3.74e-09	1.89e-10
Ferrite mfg.	Scandium	secondary	3.65e-09	1.85e-10
Invar	Perfluoromethane	secondary	2.85e-09	1.45e-10
Ferrite mfg.	Perfluoromethane	secondary	2.78e-09	1.41e-10
Invar	Thallium	secondary	2.55e-09	1.29e-10
Ferrite mfg.	Thallium	secondary	2.49e-09	1.26e-10
Invar	Trichlorofluoromethane	secondary	2.06e-09	1.04e-10
Lead	Benzo[a]pyrene	secondary	1.96e-09	9.94e-11
Steel Prod., cold-rolled, semi-finished	Edetic acid (EDTA)	secondary	1.93e-09	9.78e-11
Invar	Hypochlorous acid	secondary	1.77e-09	8.98e-11
Steel Prod., cold-rolled, semi-finished	Hypochlorous acid	secondary	1.76e-09	8.91e-11
Ferrite mfg.	Hypochlorous acid	secondary	1.73e-09	8.76e-11
Steel Prod., cold-rolled, semi-finished	Cobalt (Co I, Co II, Co III)	secondary	1.57e-09	7.96e-11
Invar	Dichloromethane	secondary	1.46e-09	7.39e-11
Steel Prod., cold-rolled, semi-finished	Dichloromethane	secondary	1.45e-09	7.34e-11
Ferrite mfg.	Dichloromethane	secondary	1.42e-09	7.21e-11
Invar	Chlorine	secondary	1.11e-09	5.62e-11
Ferrite mfg.	Chlorine	secondary	1.08e-09	5.49e-11
Ferrite mfg.	Trichlorofluoromethane	secondary	7.65e-10	3.87e-11
Invar	Dichlorodifluoromethane	secondary	6.37e-10	3.23e-11
Invar	Edetic acid (EDTA)	secondary	5.47e-10	2.77e-11
Ferrite mfg.	Edetic acid (EDTA)	secondary	5.34e-10	2.70e-11

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Invar	CFC-13	secondary	5.04e-10	2.55e-11
Steel Prod., cold-rolled, semi-finished	Isopropylpropionate	secondary	2.02e-10	1.02e-11
Ferrite mfg.	Isopropylpropionate	secondary	1.99e-10	1.01e-11
Invar	Halogenated matter (organic)	secondary	1.37e-10	6.95e-12
Ferrite mfg.	Halogenated matter (organic)	secondary	1.34e-10	6.78e-12
Steel Prod., cold-rolled, semi-finished	Lithium salts	secondary	9.91e-11	5.02e-12
Invar	Ethanethiol	secondary	8.71e-11	4.41e-12
Ferrite mfg.	Ethanethiol	secondary	8.50e-11	4.31e-12
Ferrite mfg.	Tin (Sn++, Sn4+)	secondary	7.29e-11	3.69e-12
Invar	Chloroform	secondary	5.44e-11	2.76e-12
Steel Prod., cold-rolled, semi-finished	Chloroform	secondary	5.40e-11	2.73e-12
Ferrite mfg.	Chloroform	secondary	5.31e-11	2.69e-12
Steel Prod., cold-rolled, semi-finished	Zirconium	secondary	4.66e-11	2.36e-12
Steel Prod., cold-rolled, semi-finished	Perfluoromethane	secondary	4.49e-11	2.28e-12
ABS Production	HCFC-22	secondary	3.47e-11	1.76e-12
Invar	Lithium salts	secondary	2.81e-11	1.42e-12
Ferrite mfg.	Lithium salts	secondary	2.74e-11	1.39e-12
Lead	Acrolein	secondary	2.38e-11	1.21e-12
Invar	Zirconium	secondary	1.34e-11	6.77e-13
Ferrite mfg.	Zirconium	secondary	1.30e-11	6.61e-13
Lead	Benzaldehyde	secondary	1.04e-12	5.25e-14
Invar	Trichloroethylene	secondary	7.82e-13	3.96e-14
Steel Prod., cold-rolled, semi-finished	Trichloroethylene	secondary	7.75e-13	3.93e-14
Ferrite mfg.	Trichloroethylene	secondary	7.63e-13	3.87e-14
Invar	HFC-125	secondary	6.44e-13	3.26e-14
Ferrite mfg.	HFC-125	secondary	6.29e-13	3.19e-14
Invar	Propionaldehyde	secondary	5.32e-14	2.69e-15
Steel Prod., cold-rolled, semi-finished	Propionaldehyde	secondary	5.32e-14	2.69e-15
Ferrite mfg.	Propionaldehyde	secondary	5.19e-14	2.63e-15
Invar	Pentachlorobenzene	secondary	2.77e-14	1.40e-15
Steel Prod., cold-rolled, semi-finished	Tetrachloroethylene	secondary	2.19e-14	1.11e-15
Invar	Tetrachloroethylene	secondary	2.16e-14	1.09e-15
Ferrite mfg.	Tetrachloroethylene	secondary	2.11e-14	1.07e-15
Invar	Acrolein	secondary	9.90e-15	5.01e-16
Steel Prod., cold-rolled, semi-finished	Benzaldehyde	secondary	4.72e-15	2.39e-16
Invar	Benzaldehyde	secondary	4.69e-15	2.38e-16
Ferrite mfg.	Benzaldehyde	secondary	4.57e-15	2.32e-16
Invar	1,1,1-Trichloroethane	secondary	3.25e-15	1.65e-16
Steel Prod., cold-rolled, semi-finished	1,1,1-Trichloroethane	secondary	3.21e-15	1.63e-16
Ferrite mfg.	1,1,1-Trichloroethane	secondary	3.16e-15	1.60e-16
Invar	Perfluoroethane	secondary	3.14e-15	1.59e-16
Invar	Pentachlorophenol	secondary	1.24e-15	6.28e-17
Ferrite mfg.	1,2-Dichlorotetrafluoroethane	secondary	3.19e-16	1.61e-17
Invar	Hexachloroethane	secondary	1.24e-16	6.27e-18
Steel Prod., cold-rolled, semi-finished	Hexachloroethane	secondary	1.23e-16	6.23e-18
Ferrite mfg.	Hexachloroethane	secondary	1.21e-16	6.12e-18
Ferrite mfg.	Dichlorodifluoromethane	secondary	4.72e-17	2.39e-18
Ferrite mfg.	CFC-13	secondary	3.74e-17	1.89e-18
Invar	HCFC-22	secondary	8.74e-19	4.43e-20
Ferrite mfg.	HCFC-22	secondary	8.54e-19	4.32e-20

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Total Materials Processing			**2.28e+02**	**1.16e+01**
Manufacturing Life-cycle Stage				
Japanese Electric Grid	Sulfur dioxide	model/secondary	5.69e+01	2.88e+00
US electric grid	Sulfur dioxide	model/secondary	2.63e+01	1.33e+00
LPG Production	Carbon monoxide	secondary	5.34e+00	2.71e-01
LPG Production	Vanadium	secondary	1.05e+00	5.30e-02
LPG Production	Benzene	secondary	8.57e-01	4.34e-02
LPG Production	Methane	secondary	8.39e-01	4.25e-02
LPG Production	Sulfur oxides	secondary	8.01e-01	4.06e-02
Glass/frit	Fluorides (F-)	primary	5.82e-01	2.95e-02
LPG Production	Nitrogen oxides	secondary	5.73e-01	2.90e-02
CRT tube mfg.	Carbon monoxide	primary	2.12e-01	1.07e-02
LPG Production	Arsenic	secondary	2.06e-01	1.05e-02
LPG Production	Formaldehyde	secondary	1.34e-01	6.79e-03
LPG Production	PM	secondary	1.29e-01	6.53e-03
Natural Gas Prod.	Benzene	secondary	7.57e-02	3.83e-03
Natural Gas Prod.	Carbon monoxide	secondary	6.36e-02	3.22e-03
Natural Gas Prod.	Methane	secondary	5.02e-02	2.54e-03
Glass/frit	Nitrogen oxides	primary	4.41e-02	2.24e-03
Japanese Electric Grid	Nitrogen oxides	model/secondary	4.07e-02	2.06e-03
CRT tube mfg.	Phosphorus (yellow or white)	primary	4.00e-02	2.03e-03
LPG Production	Hydrochloric acid	secondary	3.68e-02	1.86e-03
Japanese Electric Grid	Carbon monoxide	model/secondary	3.50e-02	1.77e-03
Fuel Oil #6 Prod.	Carbon monoxide	secondary	2.62e-02	1.33e-03
Japanese Electric Grid	Vanadium	model/secondary	2.27e-02	1.15e-03
US electric grid	Nitrogen oxides	model/secondary	1.88e-02	9.52e-04
LPG Production	Nitrous oxide	secondary	1.62e-02	8.22e-04
US electric grid	Carbon monoxide	model/secondary	1.61e-02	8.17e-04
Fuel Oil #2 Prod.	Carbon monoxide	secondary	1.56e-02	7.89e-04
Fuel Oil #6 Prod.	Vanadium	secondary	1.08e-02	5.45e-04
Japanese Electric Grid	Arsenic	model/secondary	1.04e-02	5.28e-04
US electric grid	Methane	model/secondary	1.03e-02	5.21e-04
CRT tube mfg.	Sulfur oxides	primary	9.96e-03	5.05e-04
LPG Production	Phosphorus (yellow or white)	secondary	9.81e-03	4.97e-04
Natural Gas Prod.	Nitrogen oxides	secondary	9.32e-03	4.72e-04
US electric grid	Arsenic	model/secondary	8.91e-03	4.51e-04
US electric grid	Hydrochloric acid	model/secondary	7.87e-03	3.99e-04
LPG Production	Fluorides (F-)	secondary	7.50e-03	3.80e-04
LPG Production	Selenium	secondary	7.41e-03	3.76e-04
Japanese Electric Grid	Hydrochloric acid	model/secondary	6.28e-03	3.18e-04
Fuel Oil #6 Prod.	Methane	secondary	5.89e-03	2.98e-04
Glass/frit	Fluorides (F-)	primary	5.82e-03	2.95e-04
Fuel Oil #6 Prod.	Sulfur oxides	secondary	5.47e-03	2.77e-04
Fuel Oil #6 Prod.	Benzene	secondary	4.90e-03	2.48e-04
PWB Mfg.	Formaldehyde	model/secondary	4.44e-03	2.25e-04
Fuel Oil #6 Prod.	Nitrogen oxides	secondary	4.09e-03	2.07e-04
LPG Production	Ammonia	secondary	3.74e-03	1.89e-04
CRT tube mfg.	Fluoride	primary	3.45e-03	1.75e-04
Fuel Oil #2 Prod.	Vanadium	secondary	3.45e-03	1.75e-04
LPG Production	Hydrogen sulfide	secondary	3.07e-03	1.55e-04

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
CRT tube mfg.	Dimethyl Formamide	primary	3.03e-03	1.54e-04
Fuel Oil #2 Prod.	Methane	secondary	2.57e-03	1.30e-04
Fuel Oil #2 Prod.	Benzene	secondary	2.55e-03	1.29e-04
Fuel Oil #2 Prod.	Sulfur oxides	secondary	2.44e-03	1.23e-04
CRT tube mfg.	Nitrogen oxides	primary	2.17e-03	1.10e-04
Japanese Electric Grid	PM-10	model/secondary	2.00e-03	1.01e-04
Glass/frit	Carbon monoxide	primary	2.00e-03	1.01e-04
Fuel Oil #2 Prod.	Nitrogen oxides	secondary	1.76e-03	8.90e-05
Fuel Oil #6 Prod.	Arsenic	secondary	1.72e-03	8.74e-05
CRT tube mfg.	Zinc (elemental)	primary	1.65e-03	8.35e-05
LPG Production	Molybdenum	secondary	1.65e-03	8.34e-05
US electric grid	Selenium	model/secondary	1.48e-03	7.50e-05
Fuel Oil #4 Prod.	Carbon monoxide	secondary	1.40e-03	7.11e-05
Fuel Oil #6 Prod.	Formaldehyde	secondary	1.37e-03	6.93e-05
Japanese Electric Grid	Fluorides (F-)	model/secondary	1.31e-03	6.63e-05
Japanese Electric Grid	Selenium	model/secondary	1.27e-03	6.46e-05
LPG Production	Zinc (elemental)	secondary	1.20e-03	6.08e-05
Japanese Electric Grid	Formaldehyde	model/secondary	1.17e-03	5.92e-05
US electric grid	Vanadium	model/secondary	1.11e-03	5.64e-05
LPG Production	Hydrofluoric acid	secondary	1.00e-03	5.08e-05
Fuel Oil #6 Prod.	PM	secondary	9.24e-04	4.68e-05
US electric grid	PM-10	model/secondary	9.22e-04	4.67e-05
LPG Production	Ethane	secondary	7.76e-04	3.93e-05
LPG Production	Phenol	secondary	7.15e-04	3.62e-05
Fuel Oil #2 Prod.	Arsenic	secondary	6.52e-04	3.30e-05
LPG Production	Pentane	secondary	6.51e-04	3.30e-05
CRT tube mfg.	Toluene	primary	6.41e-04	3.25e-05
Japanese Electric Grid	Zinc (elemental)	model/secondary	6.13e-04	3.11e-05
Glass/frit	Nitrogen oxides	primary	5.33e-04	2.70e-05
LPG Production	Hexane	secondary	4.51e-04	2.28e-05
Fuel Oil #2 Prod.	Formaldehyde	secondary	4.41e-04	2.23e-05
Natural Gas Prod.	PM	secondary	4.14e-04	2.10e-05
Fuel Oil #4 Prod.	Vanadium	secondary	4.03e-04	2.04e-05
Fuel Oil #2 Prod.	PM	secondary	3.96e-04	2.01e-05
Japanese Electric Grid	Antimony	model/secondary	3.23e-04	1.64e-05
Natural Gas Prod.	Arsenic	secondary	3.15e-04	1.59e-05
Fuel Oil #6 Prod.	Hydrochloric acid	secondary	2.97e-04	1.50e-05
LPG Production	Nickel	secondary	2.90e-04	1.47e-05
Natural Gas Prod.	Sulfur oxides	secondary	2.76e-04	1.40e-05
Natural Gas Prod.	Ammonia	secondary	2.69e-04	1.36e-05
Fuel Oil #4 Prod.	Methane	secondary	2.61e-04	1.32e-05
Fuel Oil #4 Prod.	Sulfur oxides	secondary	2.45e-04	1.24e-05
Fuel Oil #4 Prod.	Benzene	secondary	2.41e-04	1.22e-05
LPG Production	PM-10	secondary	2.25e-04	1.14e-05
US electric grid	Hydrofluoric acid	model/secondary	2.15e-04	1.09e-05
LPG Production	Antimony	secondary	2.14e-04	1.08e-05
CRT tube mfg.	Nickel	primary	1.89e-04	9.56e-06
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	1.79e-04	9.09e-06
Japanese Electric Grid	Hydrofluoric acid	model/secondary	1.71e-04	8.69e-06
US electric grid	Formaldehyde	model/secondary	1.55e-04	7.84e-06

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #6 Prod.	Nitrous oxide	secondary	1.45e-04	7.35e-06
LPG Production	Aluminum (+3)	secondary	1.42e-04	7.17e-06
Japanese Electric Grid	Molybdenum	model/secondary	1.31e-04	6.66e-06
Fuel Oil #2 Prod.	Hydrochloric acid	secondary	1.15e-04	5.85e-06
Japanese Electric Grid	Nitrous oxide	model/secondary	1.12e-04	5.66e-06
US electric grid	Benzene	model/secondary	1.11e-04	5.64e-06
Glass/frit	PM	primary	1.09e-04	5.53e-06
CRT tube mfg.	Molybdenum	primary	1.02e-04	5.18e-06
LPG Production	Chromium (VI)	secondary	1.01e-04	5.11e-06
Fuel Oil #6 Prod.	Phosphorus (yellow or white)	secondary	9.77e-05	4.95e-06
Japanese Electric Grid	Benzene	model/secondary	9.10e-05	4.61e-06
Japanese Electric Grid	Methane	model/secondary	8.13e-05	4.12e-06
Fuel Oil #4 Prod.	Arsenic	secondary	7.04e-05	3.57e-06
Natural Gas Prod.	Vanadium	secondary	6.96e-05	3.53e-06
Natural Gas Prod.	Hydrochloric acid	secondary	6.39e-05	3.24e-06
US electric grid	Phosphorus (yellow or white)	model/secondary	6.27e-05	3.18e-06
Fuel Oil #6 Prod.	Selenium	secondary	6.07e-05	3.07e-06
LPG Production	Nitrate	secondary	6.06e-05	3.07e-06
Fuel Oil #6 Prod.	Fluorides (F-)	secondary	5.83e-05	2.96e-06
Glass/frit	Carbon monoxide	primary	5.59e-05	2.83e-06
US electric grid	Nitrous oxide	model/secondary	5.42e-05	2.75e-06
Fuel Oil #2 Prod.	Nitrous oxide	secondary	5.19e-05	2.63e-06
Fuel Oil #4 Prod.	Formaldehyde	secondary	5.14e-05	2.60e-06
Glass/frit	Sulfur oxides	primary	5.08e-05	2.58e-06
Glass/frit	Lead	primary	4.37e-05	2.21e-06
CRT tube mfg.	Copper	primary	4.05e-05	2.05e-06
Fuel Oil #4 Prod.	PM	secondary	4.05e-05	2.05e-06
Japanese Electric Grid	Nickel	model/secondary	3.51e-05	1.78e-06
LPG Production	Copper	secondary	3.49e-05	1.77e-06
LPG Production	2-Chloroacetophenone	secondary	3.22e-05	1.63e-06
Fuel Oil #2 Prod.	Phosphorus (yellow or white)	secondary	3.21e-05	1.63e-06
LPG Production	Dimethylbenzanthracene	secondary	3.19e-05	1.62e-06
LPG Production	Bromomethane	secondary	3.18e-05	1.61e-06
Fuel Oil #6 Prod.	Hydrogen sulfide	secondary	3.18e-05	1.61e-06
Glass/frit	Nitrates/nitrites	primary	2.94e-05	1.49e-06
Japanese Electric Grid	Barium	model/secondary	2.94e-05	1.49e-06
US electric grid	Zinc (elemental)	model/secondary	2.89e-05	1.47e-06
Natural Gas Prod.	Formaldehyde	secondary	2.77e-05	1.40e-06
LPG Production	Naphthalene	secondary	2.58e-05	1.31e-06
CRT tube mfg.	Xylene (mixed isomers)	primary	2.55e-05	1.29e-06
US electric grid	Antimony	model/secondary	2.37e-05	1.20e-06
Fuel Oil #2 Prod.	Fluorides (F-)	secondary	2.34e-05	1.18e-06
Fuel Oil #2 Prod.	Selenium	secondary	2.33e-05	1.18e-06
LPG Production	Manganese	secondary	2.23e-05	1.13e-06
Fuel Oil #6 Prod.	Ammonia	secondary	2.01e-05	1.02e-06
LPG Production	Barium	secondary	1.86e-05	9.44e-07
LPG Production	Silicon	secondary	1.69e-05	8.57e-07
LPG Production	Cyanide (-1)	secondary	1.67e-05	8.47e-07
Japanese Electric Grid	Naphthalene	model/secondary	1.63e-05	8.28e-07
LPG Production	Barium cmpds	secondary	1.59e-05	8.04e-07
Fuel Oil #6 Prod.	Molybdenum	secondary	1.56e-05	7.89e-07

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Fluorides (F-)	secondary	1.35e-05	6.85e-07
LPG Production	Lead	secondary	1.24e-05	6.26e-07
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	1.23e-05	6.24e-07
Natural Gas Prod.	Selenium	secondary	1.21e-05	6.15e-07
Natural Gas Prod.	Nitrous oxide	secondary	1.15e-05	5.85e-07
Fuel Oil #2 Prod.	Ammonia	secondary	1.10e-05	5.58e-07
Fuel Oil #2 Prod.	Hydrogen sulfide	secondary	1.01e-05	5.12e-07
Natural Gas Prod.	Zinc (elemental)	secondary	8.50e-06	4.31e-07
Fuel Oil #6 Prod.	Hydrofluoric acid	secondary	8.10e-06	4.10e-07
US electric grid	Molybdenum	model/secondary	7.92e-06	4.01e-07
Japanese Electric Grid	Copper	model/secondary	7.14e-06	3.62e-07
Natural Gas Prod.	Ethane	secondary	6.99e-06	3.54e-07
US electric grid	2-Chloroacetophenone	model/secondary	6.88e-06	3.49e-07
US electric grid	Bromomethane	model/secondary	6.81e-06	3.45e-07
Fuel Oil #6 Prod.	Zinc (elemental)	secondary	6.59e-06	3.34e-07
LPG Production	Carbon disulfide	secondary	5.98e-06	3.03e-07
Natural Gas Prod.	Pentane	secondary	5.86e-06	2.97e-07
Fuel Oil #4 Prod.	Nitrous oxide	secondary	5.75e-06	2.91e-07
Japanese Electric Grid	2-Chloroacetophenone	model/secondary	5.50e-06	2.79e-07
Japanese Electric Grid	Bromomethane	model/secondary	5.44e-06	2.76e-07
Fuel Oil #2 Prod.	Molybdenum	secondary	5.33e-06	2.70e-07
LPG Production	Benzyl chloride	secondary	4.68e-06	2.37e-07
Fuel Oil #6 Prod.	Ethane	secondary	4.43e-06	2.25e-07
Natural Gas Prod.	Hexane	secondary	4.06e-06	2.06e-07
LPG Production	Aluminum (elemental)	secondary	3.87e-06	1.96e-07
Fuel Oil #6 Prod.	Pentane	secondary	3.72e-06	1.88e-07
Fuel Oil #4 Prod.	Phosphorus (yellow or white)	secondary	3.70e-06	1.88e-07
LPG Production	Chloroform	secondary	3.64e-06	1.84e-07
CRT tube mfg.	Manganese	primary	3.60e-06	1.83e-07
US electric grid	Cyanide (-1)	model/secondary	3.58e-06	1.81e-07
Fuel Oil #2 Prod.	Zinc (elemental)	secondary	3.54e-06	1.80e-07
Fuel Oil #2 Prod.	Hydrofluoric acid	secondary	3.15e-06	1.60e-07
CRT tube mfg.	Lead	primary	3.01e-06	1.53e-07
Japanese Electric Grid	Cyanide (-1)	model/secondary	2.86e-06	1.45e-07
Fuel Oil #6 Prod.	Nickel	secondary	2.81e-06	1.42e-07
US electric grid	2,3,7,8-TCDD	model/secondary	2.71e-06	1.37e-07
US electric grid	Nickel	model/secondary	2.60e-06	1.32e-07
Fuel Oil #6 Prod.	Hexane	secondary	2.58e-06	1.31e-07
LPG Production	Cobalt	secondary	2.51e-06	1.27e-07
Fuel Oil #4 Prod.	Selenium	secondary	2.50e-06	1.27e-07
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	2.46e-06	1.25e-07
Fuel Oil #6 Prod.	Phenol	secondary	2.42e-06	1.23e-07
Fuel Oil #6 Prod.	PM-10	secondary	2.33e-06	1.18e-07
Natural Gas Prod.	Molybdenum	secondary	2.31e-06	1.17e-07
Fuel Oil #2 Prod.	Ethane	secondary	2.30e-06	1.17e-07
Japanese Electric Grid	2,3,7,8-TCDD	model/secondary	2.22e-06	1.13e-07
US electric grid	Naphthalene	model/secondary	2.16e-06	1.09e-07
Fuel Oil #2 Prod.	Phenol	secondary	2.01e-06	1.02e-07
LPG Production	Acrolein	secondary	1.94e-06	9.83e-08
Fuel Oil #2 Prod.	Pentane	secondary	1.93e-06	9.79e-08

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	Barium	model/secondary	1.86e-06	9.42e-08
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	1.77e-06	8.96e-08
Natural Gas Prod.	Hydrofluoric acid	secondary	1.74e-06	8.83e-08
LPG Production	Methyl chloride	secondary	1.57e-06	7.96e-08
LPG Production	Beryllium	secondary	1.40e-06	7.11e-08
Fuel Oil #2 Prod.	Hexane	secondary	1.34e-06	6.79e-08
US electric grid	Carbon disulfide	model/secondary	1.28e-06	6.48e-08
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	1.19e-06	6.00e-08
Fuel Oil #6 Prod.	Antimony	secondary	1.18e-06	6.00e-08
Japanese Electric Grid	Cobalt	model/secondary	1.18e-06	5.99e-08
LPG Production	Methyl hydrazine	secondary	1.14e-06	5.76e-08
Fuel Oil #4 Prod.	Ammonia	secondary	1.02e-06	5.18e-08
Japanese Electric Grid	Carbon disulfide	model/secondary	1.02e-06	5.17e-08
US electric grid	Benzyl chloride	model/secondary	1.00e-06	5.08e-08
Fuel Oil #2 Prod.	Nickel	secondary	9.44e-07	4.78e-08
LPG Production	Acetaldehyde	secondary	8.73e-07	4.42e-08
LPG Production	Propionaldehyde	secondary	8.73e-07	4.42e-08
LPG Production	Mercury	secondary	8.69e-07	4.40e-08
LPG Production	Cadmium	secondary	8.10e-07	4.10e-08
Japanese Electric Grid	Benzyl chloride	model/secondary	8.00e-07	4.05e-08
US electric grid	Chloroform	model/secondary	7.79e-07	3.95e-08
Fuel Oil #2 Prod.	PM-10	secondary	7.42e-07	3.76e-08
US electric grid	Manganese	model/secondary	7.28e-07	3.69e-08
LPG Production	Cadmium cmpds	secondary	6.94e-07	3.52e-08
LPG Production	Di(2-ethylhexyl)phthalate	secondary	6.71e-07	3.40e-08
Glass/frit	PM	primary	6.67e-07	3.38e-08
Japanese Electric Grid	Chromium (VI)	model/secondary	6.39e-07	3.24e-08
Fuel Oil #2 Prod.	Antimony	secondary	6.32e-07	3.20e-08
LPG Production	Toluene	secondary	6.23e-07	3.16e-08
Japanese Electric Grid	Chloroform	model/secondary	6.22e-07	3.15e-08
CRT tube mfg.	Cyanide (-1)	primary	6.06e-07	3.07e-08
Fuel Oil #4 Prod.	Molybdenum	secondary	6.03e-07	3.05e-08
Glass/frit	Zinc (elemental)	primary	5.55e-07	2.81e-08
US electric grid	Chromium (VI)	model/secondary	5.48e-07	2.78e-08
Fuel Oil #6 Prod.	Aluminum (+3)	secondary	4.79e-07	2.43e-08
Natural Gas Prod.	Antimony	secondary	4.44e-07	2.25e-08
US electric grid	Acrolein	model/secondary	4.15e-07	2.10e-08
Fuel Oil #6 Prod.	Chromium (VI)	secondary	4.09e-07	2.07e-08
Fuel Oil #2 Prod.	Aluminum (+3)	secondary	3.97e-07	2.01e-08
LPG Production	1,4-Dichlorobenzene	secondary	3.57e-07	1.81e-08
US electric grid	Copper	model/secondary	3.57e-07	1.81e-08
US electric grid	Methyl chloride	model/secondary	3.36e-07	1.70e-08
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	3.36e-07	1.70e-08
Japanese Electric Grid	Acrolein	model/secondary	3.31e-07	1.68e-08
Fuel Oil #4 Prod.	Zinc (elemental)	secondary	3.31e-07	1.68e-08
LPG Production	Dimethyl sulfate	secondary	3.21e-07	1.63e-08
Fuel Oil #6 Prod.	Copper	secondary	3.17e-07	1.61e-08
US electric grid	Fluoride	model/secondary	3.12e-07	1.58e-08
LPG Production	Isophorone	secondary	3.08e-07	1.56e-08
Natural Gas Prod.	Dimethylbenzanthracene	secondary	2.87e-07	1.46e-08

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Japanese Electric Grid	Methyl chloride	model/secondary	2.69e-07	1.36e-08
Fuel Oil #6 Prod.	2-Chloroacetophenone	secondary	2.60e-07	1.32e-08
Fuel Oil #6 Prod.	Bromomethane	secondary	2.57e-07	1.30e-08
LPG Production	Methyl ethyl ketone	secondary	2.48e-07	1.26e-08
LPG Production	Tetrachloroethylene	secondary	2.45e-07	1.24e-08
US electric grid	Methyl hydrazine	model/secondary	2.43e-07	1.23e-08
Fuel Oil #6 Prod.	Nitrate	secondary	2.43e-07	1.23e-08
Japanese Electric Grid	Toluene	model/secondary	2.39e-07	1.21e-08
Glass/frit	Chromium	primary	2.20e-07	1.12e-08
Fuel Oil #4 Prod.	Ethane	secondary	2.18e-07	1.10e-08
LPG Production	Methyl methacrylate	secondary	2.12e-07	1.08e-08
US electric grid	Lead	model/secondary	2.04e-07	1.03e-08
Glass/frit	Nickel	primary	1.95e-07	9.89e-09
Japanese Electric Grid	Methyl hydrazine	model/secondary	1.94e-07	9.84e-09
US electric grid	Cobalt	model/secondary	1.94e-07	9.83e-09
US electric grid	Acetaldehyde	model/secondary	1.87e-07	9.47e-09
US electric grid	Propionaldehyde	model/secondary	1.87e-07	9.47e-09
Fuel Oil #4 Prod.	Pentane	secondary	1.83e-07	9.26e-09
Fuel Oil #6 Prod.	Dimethylbenzanthracene	secondary	1.82e-07	9.24e-09
Fuel Oil #6 Prod.	Manganese	secondary	1.79e-07	9.07e-09
LPG Production	1,2-Dichloroethane	secondary	1.77e-07	8.96e-09
Fuel Oil #6 Prod.	Silicon	secondary	1.75e-07	8.88e-09
LPG Production	Bromoform	secondary	1.73e-07	8.79e-09
Fuel Oil #2 Prod.	Nitrate	secondary	1.73e-07	8.75e-09
LPG Production	Chromium (III)	secondary	1.72e-07	8.70e-09
LPG Production	Dichloromethane	secondary	1.67e-07	8.48e-09
Fuel Oil #4 Prod.	Phenol	secondary	1.63e-07	8.26e-09
Fuel Oil #2 Prod.	Chromium (VI)	secondary	1.58e-07	8.02e-09
Fuel Oil #6 Prod.	Naphthalene	secondary	1.56e-07	7.91e-09
Japanese Electric Grid	Acetaldehyde	model/secondary	1.49e-07	7.56e-09
Japanese Electric Grid	Propionaldehyde	model/secondary	1.49e-07	7.56e-09
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	1.44e-07	7.27e-09
Japanese Electric Grid	Cadmium	model/secondary	1.41e-07	7.14e-09
LPG Production	Chlorobenzene	secondary	1.40e-07	7.10e-09
LPG Production	Aromatic hydrocarbons	secondary	1.40e-07	7.09e-09
Fuel Oil #6 Prod.	Cyanide (-1)	secondary	1.35e-07	6.84e-09
LPG Production	Copper (+1 & +2)	secondary	1.31e-07	6.64e-09
Natural Gas Prod.	Naphthalene	secondary	1.30e-07	6.59e-09
Fuel Oil #4 Prod.	Hexane	secondary	1.27e-07	6.42e-09
Natural Gas Prod.	Nickel	secondary	1.23e-07	6.22e-09
US electric grid	Mercury	model/secondary	1.20e-07	6.07e-09
Japanese Electric Grid	Mercury	model/secondary	1.18e-07	5.98e-09
Japanese Electric Grid	Di(2-ethylhexyl)phthalate	model/secondary	1.15e-07	5.81e-09
Fuel Oil #2 Prod.	Copper	secondary	1.12e-07	5.67e-09
LPG Production	2,4-Dinitrotoluene	secondary	1.11e-07	5.65e-09
Fuel Oil #4 Prod.	Nickel	secondary	1.08e-07	5.46e-09
Fuel Oil #2 Prod.	2-Chloroacetophenone	secondary	1.01e-07	5.11e-09
Fuel Oil #6 Prod.	Lead	secondary	9.99e-08	5.06e-09
Fuel Oil #2 Prod.	Bromomethane	secondary	9.99e-08	5.06e-09
Fuel Oil #6 Prod.	Barium	secondary	9.97e-08	5.05e-09

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	Hexane	model/secondary	9.59e-08	4.86e-09
Fuel Oil #2 Prod.	Dimethylbenzanthracene	secondary	9.48e-08	4.80e-09
Natural Gas Prod.	Chromium (VI)	secondary	9.46e-08	4.79e-09
Fuel Oil #4 Prod.	PM-10	secondary	8.70e-08	4.41e-09
Fuel Oil #2 Prod.	Naphthalene	secondary	7.72e-08	3.91e-09
US electric grid	Cadmium	model/secondary	7.69e-08	3.90e-09
Japanese Electric Grid	Hexane	model/secondary	7.66e-08	3.88e-09
Fuel Oil #2 Prod.	Manganese	secondary	7.00e-08	3.54e-09
US electric grid	Dimethyl sulfate	model/secondary	6.87e-08	3.48e-09
LPG Production	o-xylene	secondary	6.86e-08	3.48e-09
US electric grid	Toluene	model/secondary	6.78e-08	3.44e-09
Natural Gas Prod.	Hydrogen sulfide	secondary	6.73e-08	3.41e-09
US electric grid	Isophorone	model/secondary	6.59e-08	3.34e-09
Fuel Oil #4 Prod.	Antimony	secondary	5.92e-08	3.00e-09
Natural Gas Prod.	Barium	secondary	5.90e-08	2.99e-09
Fuel Oil #2 Prod.	Silicon	secondary	5.58e-08	2.83e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	5.58e-08	2.83e-09
LPG Production	Ethylbenzene	secondary	5.56e-08	2.82e-09
Natural Gas Prod.	Bromomethane	secondary	5.52e-08	2.80e-09
Fuel Oil #2 Prod.	Barium	secondary	5.49e-08	2.78e-09
Japanese Electric Grid	Dimethyl sulfate	model/secondary	5.49e-08	2.78e-09
Fuel Oil #6 Prod.	Barium cmpds	secondary	5.37e-08	2.72e-09
US electric grid	Methyl ethyl ketone	model/secondary	5.32e-08	2.69e-09
Glass/frit	Barium	primary	5.29e-08	2.68e-09
Natural Gas Prod.	Copper	secondary	5.28e-08	2.67e-09
Japanese Electric Grid	Isophorone	model/secondary	5.26e-08	2.66e-09
Fuel Oil #2 Prod.	Cyanide (-1)	secondary	5.25e-08	2.66e-09
US electric grid	Tetrachloroethylene	model/secondary	5.23e-08	2.65e-09
Fuel Oil #6 Prod.	Carbon disulfide	secondary	4.82e-08	2.44e-09
US electric grid	Methyl methacrylate	model/secondary	4.54e-08	2.30e-09
Fuel Oil #2 Prod.	Barium cmpds	secondary	4.45e-08	2.26e-09
Japanese Electric Grid	Methyl ethyl ketone	model/secondary	4.24e-08	2.15e-09
Japanese Electric Grid	Tetrachloroethylene	model/secondary	4.18e-08	2.12e-09
Fuel Oil #6 Prod.	Aluminum (elemental)	secondary	4.01e-08	2.03e-09
Natural Gas Prod.	Manganese	secondary	3.95e-08	2.00e-09
Fuel Oil #2 Prod.	Lead	secondary	3.88e-08	1.97e-09
US electric grid	1,2-Dichloroethane	model/secondary	3.79e-08	1.92e-09
Fuel Oil #6 Prod.	Benzyl chloride	secondary	3.78e-08	1.91e-09
US electric grid	Bromoform	model/secondary	3.71e-08	1.88e-09
Japanese Electric Grid	Methyl methacrylate	model/secondary	3.63e-08	1.84e-09
US electric grid	Dichloromethane	model/secondary	3.58e-08	1.82e-09
Japanese Electric Grid	Beryllium	model/secondary	3.23e-08	1.64e-09
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	3.23e-08	1.64e-09
US electric grid	Beryllium	model/secondary	3.05e-08	1.54e-09
Japanese Electric Grid	1,2-Dichloroethane	model/secondary	3.02e-08	1.53e-09
US electric grid	Chlorobenzene	model/secondary	3.00e-08	1.52e-09
Japanese Electric Grid	Bromoform	model/secondary	2.96e-08	1.50e-09
Fuel Oil #6 Prod.	Chloroform	secondary	2.94e-08	1.49e-09
Natural Gas Prod.	Cyanide (-1)	secondary	2.90e-08	1.47e-09
Japanese Electric Grid	Dichloromethane	model/secondary	2.86e-08	1.45e-09

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Methyl tert-butyl ether	secondary	2.79e-08	1.41e-09
Japanese Electric Grid	Chlorobenzene	model/secondary	2.39e-08	1.21e-09
US electric grid	2,4-Dinitrotoluene	model/secondary	2.38e-08	1.21e-09
LPG Production	Phenanthrene	secondary	2.27e-08	1.15e-09
Natural Gas Prod.	Lead	secondary	2.17e-08	1.10e-09
Fuel Oil #6 Prod.	Cobalt	secondary	2.12e-08	1.08e-09
LPG Production	Styrene	secondary	2.03e-08	1.03e-09
LPG Production	Vinyl acetate	secondary	1.98e-08	1.01e-09
Japanese Electric Grid	2,4-Dinitrotoluene	model/secondary	1.90e-08	9.62e-10
Fuel Oil #2 Prod.	Carbon disulfide	secondary	1.87e-08	9.50e-10
LPG Production	3-Methylcholanthrene	secondary	1.87e-08	9.49e-10
Fuel Oil #4 Prod.	Chromium (VI)	secondary	1.69e-08	8.56e-10
Fuel Oil #6 Prod.	Acrolein	secondary	1.57e-08	7.93e-10
Natural Gas Prod.	Nitrate	secondary	1.50e-08	7.62e-10
Fuel Oil #2 Prod.	Benzyl chloride	secondary	1.47e-08	7.44e-10
Fuel Oil #4 Prod.	Nitrate	secondary	1.47e-08	7.43e-10
Natural Gas Prod.	Phenol	secondary	1.46e-08	7.39e-10
Glass/frit	Copper	primary	1.42e-08	7.20e-10
Japanese Electric Grid	Cumene hydroperoxide	model/secondary	1.34e-08	6.80e-10
Fuel Oil #2 Prod.	Aluminum (elemental)	secondary	1.28e-08	6.47e-10
Fuel Oil #6 Prod.	Methyl chloride	secondary	1.27e-08	6.42e-10
Fuel Oil #4 Prod.	Copper	secondary	1.25e-08	6.32e-10
US electric grid	Ethylbenzene	model/secondary	1.18e-08	5.99e-10
LPG Production	Zinc (+2)	secondary	1.17e-08	5.94e-10
Fuel Oil #2 Prod.	Chloroform	secondary	1.14e-08	5.79e-10
Fuel Oil #6 Prod.	Beryllium	secondary	1.12e-08	5.67e-10
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	1.08e-08	5.45e-10
Fuel Oil #4 Prod.	Bromomethane	secondary	1.07e-08	5.40e-10
Japanese Electric Grid	Ethylbenzene	model/secondary	1.04e-08	5.26e-10
Natural Gas Prod.	Carbon disulfide	secondary	1.04e-08	5.25e-10
Fuel Oil #6 Prod.	Methyl hydrazine	secondary	9.18e-09	4.65e-10
Fuel Oil #4 Prod.	Dimethylbenzanthracene	secondary	8.97e-09	4.54e-10
Natural Gas Prod.	Toluene	secondary	8.63e-09	4.37e-10
Natural Gas Prod.	Benzyl chloride	secondary	8.12e-09	4.12e-10
LPG Production	Ethylene dibromide	secondary	8.03e-09	4.07e-10
Fuel Oil #2 Prod.	Cobalt	secondary	7.95e-09	4.03e-10
LPG Production	1,1,1-Trichloroethane	secondary	7.57e-09	3.83e-10
Fuel Oil #4 Prod.	Naphthalene	secondary	7.45e-09	3.77e-10
Fuel Oil #4 Prod.	Manganese	secondary	7.44e-09	3.77e-10
Fuel Oil #6 Prod.	Acetaldehyde	secondary	7.05e-09	3.57e-10
Fuel Oil #6 Prod.	Propionaldehyde	secondary	7.05e-09	3.57e-10
Fuel Oil #6 Prod.	Mercury	secondary	6.94e-09	3.52e-10
Fuel Oil #4 Prod.	Silicon	secondary	6.54e-09	3.31e-10
Fuel Oil #6 Prod.	Cadmium	secondary	6.36e-09	3.22e-10
Natural Gas Prod.	Chloroform	secondary	6.32e-09	3.20e-10
Fuel Oil #2 Prod.	Acrolein	secondary	6.09e-09	3.08e-10
LPG Production	2-Methylnaphthalene	secondary	6.01e-09	3.04e-10
US electric grid	Methyl tert-butyl ether	model/secondary	5.96e-09	3.02e-10
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	5.60e-09	2.83e-10
Fuel Oil #6 Prod.	Di(2-ethylhexyl)phthalate	secondary	5.41e-09	2.74e-10

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Ethyl Chloride	secondary	5.36e-09	2.72e-10
LPG Production	Chlorine	secondary	5.32e-09	2.70e-10
Japanese Electric Grid	Phenanthrene	model/secondary	5.21e-09	2.64e-10
Fuel Oil #4 Prod.	Barium	secondary	5.08e-09	2.58e-10
Natural Gas Prod.	PM-10	secondary	4.94e-09	2.50e-10
Fuel Oil #2 Prod.	Methyl chloride	secondary	4.93e-09	2.50e-10
Japanese Electric Grid	Methyl tert-butyl ether	model/secondary	4.75e-09	2.40e-10
Natural Gas Prod.	o-xylene	secondary	4.60e-09	2.33e-10
US electric grid	Phenol	model/secondary	4.54e-09	2.30e-10
LPG Production	Cumene	secondary	4.54e-09	2.30e-10
Japanese Electric Grid	Chromium (III)	model/secondary	4.48e-09	2.27e-10
Fuel Oil #2 Prod.	Beryllium	secondary	4.40e-09	2.23e-10
US electric grid	Styrene	model/secondary	4.35e-09	2.20e-10
US electric grid	Vinyl acetate	model/secondary	4.25e-09	2.15e-10
Fuel Oil #6 Prod.	Toluene	secondary	4.19e-09	2.12e-10
Fuel Oil #4 Prod.	Lead	secondary	4.14e-09	2.10e-10
US electric grid	Phenanthrene	model/secondary	4.00e-09	2.03e-10
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	3.66e-09	1.85e-10
Japanese Electric Grid	Phenol	model/secondary	3.63e-09	1.84e-10
Fuel Oil #4 Prod.	Barium cmpds	secondary	3.62e-09	1.83e-10
Fuel Oil #2 Prod.	Methyl hydrazine	secondary	3.57e-09	1.81e-10
US electric grid	Xylene (mixed isomers)	model/secondary	3.52e-09	1.78e-10
Japanese Electric Grid	Styrene	model/secondary	3.47e-09	1.76e-10
Japanese Electric Grid	Vinyl acetate	model/secondary	3.38e-09	1.71e-10
Natural Gas Prod.	Acrolein	secondary	3.37e-09	1.71e-10
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	3.22e-09	1.63e-10
US electric grid	Chromium (III)	model/secondary	3.15e-09	1.59e-10
Natural Gas Prod.	Aluminum (+3)	secondary	2.86e-09	1.45e-10
LPG Production	Acetophenone	secondary	2.82e-09	1.43e-10
Japanese Electric Grid	Xylene (mixed isomers)	model/secondary	2.81e-09	1.42e-10
Natural Gas Prod.	Beryllium	secondary	2.80e-09	1.42e-10
Fuel Oil #2 Prod.	Acetaldehyde	secondary	2.74e-09	1.39e-10
Fuel Oil #2 Prod.	Propionaldehyde	secondary	2.74e-09	1.39e-10
Natural Gas Prod.	Methyl chloride	secondary	2.73e-09	1.38e-10
Fuel Oil #2 Prod.	Mercury	secondary	2.72e-09	1.38e-10
LPG Production	Biphenyl	secondary	2.71e-09	1.37e-10
Natural Gas Prod.	Cobalt	secondary	2.64e-09	1.34e-10
Fuel Oil #6 Prod.	Dimethyl sulfate	secondary	2.59e-09	1.31e-10
Fuel Oil #2 Prod.	Cadmium	secondary	2.53e-09	1.28e-10
Fuel Oil #6 Prod.	Isophorone	secondary	2.48e-09	1.26e-10
Fuel Oil #6 Prod.	Cadmium cmpds	secondary	2.35e-09	1.19e-10
LPG Production	Acenaphthylene	secondary	2.14e-09	1.08e-10
Fuel Oil #2 Prod.	Di(2-ethylhexyl)phthalate	secondary	2.11e-09	1.07e-10
Fuel Oil #6 Prod.	1,4-Dichlorobenzene	secondary	2.04e-09	1.03e-10
Fuel Oil #6 Prod.	Methyl ethyl ketone	secondary	2.00e-09	1.02e-10
Fuel Oil #4 Prod.	Carbon disulfide	secondary	2.00e-09	1.01e-10
Fuel Oil #6 Prod.	Tetrachloroethylene	secondary	1.97e-09	1.00e-10
Natural Gas Prod.	Methyl hydrazine	secondary	1.97e-09	1.00e-10
Fuel Oil #2 Prod.	Cadmium cmpds	secondary	1.95e-09	9.87e-11
Fuel Oil #2 Prod.	Toluene	secondary	1.90e-09	9.61e-11

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Mercury	secondary	1.88e-09	9.54e-11
LPG Production	Acenaphthene	secondary	1.78e-09	9.03e-11
US electric grid	1,1,1-Trichloroethane	model/secondary	1.73e-09	8.77e-11
US electric grid	Ethylene dibromide	model/secondary	1.72e-09	8.70e-11
Fuel Oil #6 Prod.	Methyl methacrylate	secondary	1.71e-09	8.68e-11
Fuel Oil #4 Prod.	Benzyl chloride	secondary	1.57e-09	7.94e-11
Natural Gas Prod.	Acetaldehyde	secondary	1.51e-09	7.67e-11
Natural Gas Prod.	Propionaldehyde	secondary	1.51e-09	7.67e-11
Fuel Oil #4 Prod.	Aluminum (elemental)	secondary	1.50e-09	7.58e-11
Japanese Electric Grid	Acenaphthene	model/secondary	1.47e-09	7.44e-11
Fuel Oil #6 Prod.	1,2-Dichloroethane	secondary	1.43e-09	7.23e-11
Natural Gas Prod.	Cadmium	secondary	1.40e-09	7.11e-11
Fuel Oil #6 Prod.	Bromoform	secondary	1.40e-09	7.09e-11
LPG Production	Nickel cmpds	secondary	1.39e-09	7.04e-11
Japanese Electric Grid	Ethylene dibromide	model/secondary	1.37e-09	6.95e-11
Fuel Oil #6 Prod.	Dichloromethane	secondary	1.35e-09	6.85e-11
Japanese Electric Grid	o-xylene	model/secondary	1.28e-09	6.50e-11
Glass/frit	Nickel	primary	1.27e-09	6.43e-11
LPG Production	Benzo[a]anthracene	secondary	1.25e-09	6.32e-11
Fuel Oil #4 Prod.	Chloroform	secondary	1.22e-09	6.17e-11
LPG Production	Chrysene	secondary	1.20e-09	6.07e-11
LPG Production	Lead cmpds	secondary	1.17e-09	5.91e-11
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	1.16e-09	5.90e-11
US electric grid	Ethyl Chloride	model/secondary	1.15e-09	5.81e-11
Fuel Oil #6 Prod.	Chlorobenzene	secondary	1.13e-09	5.73e-11
Fuel Oil #2 Prod.	1,4-Dichlorobenzene	secondary	1.06e-09	5.38e-11
Fuel Oil #2 Prod.	Dimethyl sulfate	secondary	1.01e-09	5.10e-11
US electric grid	Cumene	model/secondary	9.71e-10	4.92e-11
Fuel Oil #2 Prod.	Isophorone	secondary	9.66e-10	4.89e-11
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	9.29e-10	4.70e-11
Japanese Electric Grid	Ethyl Chloride	model/secondary	9.16e-10	4.64e-11
Fuel Oil #6 Prod.	2,4-Dinitrotoluene	secondary	8.99e-10	4.56e-11
Fuel Oil #4 Prod.	Cobalt	secondary	8.62e-10	4.37e-11
Japanese Electric Grid	Benzo[a]anthracene	model/secondary	8.00e-10	4.05e-11
Fuel Oil #2 Prod.	Methyl ethyl ketone	secondary	7.79e-10	3.95e-11
Fuel Oil #2 Prod.	Tetrachloroethylene	secondary	7.67e-10	3.89e-11
LPG Production	Benzo[b,j,k]fluoranthene	secondary	7.36e-10	3.73e-11
LPG Production	Mercury compounds	secondary	7.07e-10	3.58e-11
Fuel Oil #6 Prod.	Chromium (III)	secondary	6.96e-10	3.52e-11
LPG Production	Benzo[a]pyrene	secondary	6.83e-10	3.46e-11
Fuel Oil #2 Prod.	Methyl methacrylate	secondary	6.66e-10	3.37e-11
LPG Production	Fluorene	secondary	6.60e-10	3.35e-11
Fuel Oil #4 Prod.	Acrolein	secondary	6.49e-10	3.29e-11
US electric grid	Acetophenone	model/secondary	6.04e-10	3.06e-11
US electric grid	Biphenyl	model/secondary	5.79e-10	2.93e-11
LPG Production	Pyrene	secondary	5.71e-10	2.89e-11
Natural Gas Prod.	Dimethyl sulfate	secondary	5.57e-10	2.82e-11
Fuel Oil #2 Prod.	1,2-Dichloroethane	secondary	5.55e-10	2.81e-11
LPG Production	Benzo[g,h,i]perylene	secondary	5.55e-10	2.81e-11
Fuel Oil #2 Prod.	Bromoform	secondary	5.44e-10	2.76e-11

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Fluoranthene	secondary	5.39e-10	2.73e-11
Japanese Electric Grid	Chrysene	model/secondary	5.35e-10	2.71e-11
Natural Gas Prod.	Isophorone	secondary	5.34e-10	2.71e-11
Fuel Oil #4 Prod.	Methyl chloride	secondary	5.26e-10	2.66e-11
Fuel Oil #2 Prod.	Dichloromethane	secondary	5.25e-10	2.66e-11
Natural Gas Prod.	Zinc (+2)	secondary	5.24e-10	2.66e-11
LPG Production	HALON-1301	secondary	5.08e-10	2.57e-11
LPG Production	Benzo[b]fluoranthene	secondary	4.99e-10	2.53e-11
Japanese Electric Grid	Acetophenone	model/secondary	4.82e-10	2.44e-11
Fuel Oil #6 Prod.	Aromatic hydrocarbons	secondary	4.74e-10	2.40e-11
Natural Gas Prod.	Chlorine	secondary	4.73e-10	2.40e-11
Fuel Oil #4 Prod.	Beryllium	secondary	4.67e-10	2.36e-11
Glass/frit	Chromium	primary	4.67e-10	2.36e-11
Glass/frit	Manganese	primary	4.67e-10	2.36e-11
Japanese Electric Grid	Biphenyl	model/secondary	4.62e-10	2.34e-11
Japanese Electric Grid	Indeno(1,2,3-cd)pyrene	model/secondary	4.48e-10	2.27e-11
Fuel Oil #6 Prod.	Ethylbenzene	secondary	4.47e-10	2.26e-11
Fuel Oil #6 Prod.	Copper (+1 & +2)	secondary	4.43e-10	2.25e-11
Fuel Oil #2 Prod.	Chlorobenzene	secondary	4.40e-10	2.23e-11
Natural Gas Prod.	Methyl ethyl ketone	secondary	4.31e-10	2.18e-11
Japanese Electric Grid	Benzo[g,h,i]perylene	model/secondary	4.30e-10	2.18e-11
Fuel Oil #6 Prod.	o-xylene	secondary	4.29e-10	2.17e-11
Natural Gas Prod.	Tetrachloroethylene	secondary	4.24e-10	2.15e-11
Fuel Oil #2 Prod.	Aromatic hydrocarbons	secondary	3.93e-10	1.99e-11
Japanese Electric Grid	Benzo[b,j,k]fluoranthene	model/secondary	3.89e-10	1.97e-11
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	3.81e-10	1.93e-11
Natural Gas Prod.	Silicon	secondary	3.71e-10	1.88e-11
Natural Gas Prod.	Methyl methacrylate	secondary	3.68e-10	1.87e-11
Fuel Oil #2 Prod.	Copper (+1 & +2)	secondary	3.68e-10	1.86e-11
US electric grid	Acenaphthylene	model/secondary	3.60e-10	1.82e-11
LPG Production	Dibenzo[a,h]anthracene	secondary	3.55e-10	1.80e-11
Fuel Oil #2 Prod.	2,4-Dinitrotoluene	secondary	3.50e-10	1.77e-11
Japanese Electric Grid	Acenaphthylene	model/secondary	3.29e-10	1.67e-11
Natural Gas Prod.	Barium cmpds	secondary	3.21e-10	1.63e-11
Glass/frit	Lead	primary	3.20e-10	1.62e-11
US electric grid	Acenaphthene	model/secondary	3.08e-10	1.56e-11
Natural Gas Prod.	1,2-Dichloroethane	secondary	3.07e-10	1.55e-11
Natural Gas Prod.	Bromoform	secondary	3.01e-10	1.52e-11
Japanese Electric Grid	Dibenzo[a,h]anthracene	model/secondary	2.96e-10	1.50e-11
Fuel Oil #4 Prod.	Acetaldehyde	secondary	2.92e-10	1.48e-11
Fuel Oil #4 Prod.	Propionaldehyde	secondary	2.92e-10	1.48e-11
Natural Gas Prod.	Dichloromethane	secondary	2.90e-10	1.47e-11
Fuel Oil #4 Prod.	Mercury	secondary	2.89e-10	1.46e-11
Fuel Oil #2 Prod.	Chromium (III)	secondary	2.70e-10	1.37e-11
Fuel Oil #4 Prod.	Cadmium	secondary	2.67e-10	1.35e-11
Natural Gas Prod.	Chlorobenzene	secondary	2.43e-10	1.23e-11
Japanese Electric Grid	2-Methylnaphthalene	model/secondary	2.38e-10	1.20e-11
Fuel Oil #6 Prod.	Methyl tert-butyl ether	secondary	2.25e-10	1.14e-11
Fuel Oil #4 Prod.	Di(2-ethylhexyl)phthalate	secondary	2.25e-10	1.14e-11
Fuel Oil #2 Prod.	o-xylene	secondary	2.06e-10	1.05e-11

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Japanese Electric Grid	Pyrene	model/secondary	2.00e-10	1.01e-11
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	1.93e-10	9.80e-12
Fuel Oil #4 Prod.	Toluene	secondary	1.90e-10	9.60e-12
Fuel Oil #2 Prod.	Ethylbenzene	secondary	1.74e-10	8.83e-12
Japanese Electric Grid	Fluorene	model/secondary	1.74e-10	8.82e-12
Fuel Oil #6 Prod.	Phenanthrene	secondary	1.71e-10	8.68e-12
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	1.70e-10	8.60e-12
Natural Gas Prod.	3-Methylcholanthrene	secondary	1.69e-10	8.55e-12
Japanese Electric Grid	Fluoranthene	model/secondary	1.66e-10	8.43e-12
Fuel Oil #6 Prod.	Styrene	secondary	1.64e-10	8.31e-12
US electric grid	Chrysene	model/secondary	1.63e-10	8.26e-12
Natural Gas Prod.	Chromium (III)	secondary	1.61e-10	8.16e-12
Fuel Oil #6 Prod.	Vinyl acetate	secondary	1.60e-10	8.11e-12
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	1.58e-10	8.02e-12
US electric grid	Benzo[a]anthracene	model/secondary	1.48e-10	7.50e-12
LPG Production	5-Methyl chrysene	secondary	1.47e-10	7.46e-12
Glass/frit	Cobalt	primary	1.43e-10	7.26e-12
US electric grid	Fluorene	model/secondary	1.28e-10	6.46e-12
LPG Production	Halogenated matter (organic)	secondary	1.17e-10	5.91e-12
Fuel Oil #4 Prod.	Dimethyl sulfate	secondary	1.07e-10	5.44e-12
Fuel Oil #6 Prod.	3-Methylcholanthrene	secondary	1.07e-10	5.43e-12
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	1.05e-10	5.33e-12
Fuel Oil #4 Prod.	Isophorone	secondary	1.03e-10	5.22e-12
US electric grid	Fluoranthene	model/secondary	1.02e-10	5.17e-12
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	1.00e-10	5.09e-12
Natural Gas Prod.	Ethylbenzene	secondary	9.66e-11	4.89e-12
Fuel Oil #2 Prod.	Methyl tert-butyl ether	secondary	8.74e-11	4.43e-12
Natural Gas Prod.	Aluminum (elemental)	secondary	8.50e-11	4.30e-12
US electric grid	Pyrene	model/secondary	8.43e-11	4.27e-12
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	8.31e-11	4.21e-12
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	8.18e-11	4.14e-12
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	7.10e-11	3.60e-12
Natural Gas Prod.	Phenanthrene	secondary	7.05e-11	3.57e-12
Fuel Oil #2 Prod.	Phenanthrene	secondary	7.03e-11	3.56e-12
Fuel Oil #6 Prod.	Ethylene dibromide	secondary	6.48e-11	3.28e-12
Fuel Oil #2 Prod.	Styrene	secondary	6.38e-11	3.23e-12
Fuel Oil #2 Prod.	Vinyl acetate	secondary	6.23e-11	3.15e-12
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	6.11e-11	3.09e-12
US electric grid	o-xylene	model/secondary	6.06e-11	3.07e-12
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	5.92e-11	3.00e-12
Fuel Oil #4 Prod.	Bromoform	secondary	5.80e-11	2.94e-12
US electric grid	Benzo[g,h,i]perylene	model/secondary	5.75e-11	2.91e-12
Fuel Oil #4 Prod.	Dichloromethane	secondary	5.60e-11	2.84e-12
Fuel Oil #2 Prod.	3-Methylcholanthrene	secondary	5.57e-11	2.82e-12
US electric grid	Benzo[a]pyrene	model/secondary	5.44e-11	2.76e-12
Natural Gas Prod.	2-Methylnaphthalene	secondary	5.41e-11	2.74e-12
Fuel Oil #6 Prod.	Zinc (+2)	secondary	5.33e-11	2.70e-12
Natural Gas Prod.	Methyl tert-butyl ether	secondary	4.83e-11	2.45e-12
Fuel Oil #4 Prod.	Chlorobenzene	secondary	4.69e-11	2.37e-12
Japanese Electric Grid	Benzo[a]pyrene	model/secondary	4.35e-11	2.20e-12

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #6 Prod.	Ethyl Chloride	secondary	4.33e-11	2.19e-12
US electric grid	2-Methylnaphthalene	model/secondary	4.26e-11	2.16e-12
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	3.73e-11	1.89e-12
Fuel Oil #6 Prod.	Cumene	secondary	3.66e-11	1.85e-12
Natural Gas Prod.	Styrene	secondary	3.53e-11	1.79e-12
Natural Gas Prod.	Vinyl acetate	secondary	3.44e-11	1.74e-12
Fuel Oil #6 Prod.	2-Methylnaphthalene	secondary	3.43e-11	1.74e-12
Fuel Oil #2 Prod.	Zinc (+2)	secondary	3.39e-11	1.72e-12
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	3.19e-11	1.62e-12
US electric grid	5-Methyl chrysene	model/secondary	3.15e-11	1.60e-12
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	2.99e-11	1.51e-12
Fuel Oil #6 Prod.	Chlorine	secondary	2.96e-11	1.50e-12
Fuel Oil #4 Prod.	Chromium (III)	secondary	2.88e-11	1.46e-12
Fuel Oil #2 Prod.	Ethylene dibromide	secondary	2.52e-11	1.28e-12
Japanese Electric Grid	5-Methyl chrysene	model/secondary	2.51e-11	1.27e-12
LPG Production	Anthracene	secondary	2.48e-11	1.26e-12
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	2.37e-11	1.20e-12
Fuel Oil #6 Prod.	Acetophenone	secondary	2.28e-11	1.15e-12
Fuel Oil #6 Prod.	Biphenyl	secondary	2.18e-11	1.11e-12
Fuel Oil #4 Prod.	o-xylene	secondary	2.01e-11	1.02e-12
Fuel Oil #4 Prod.	Ethylbenzene	secondary	1.86e-11	9.40e-13
Fuel Oil #2 Prod.	2-Methylnaphthalene	secondary	1.78e-11	9.04e-13
Fuel Oil #2 Prod.	Ethyl Chloride	secondary	1.68e-11	8.52e-13
Fuel Oil #6 Prod.	Acenaphthylene	secondary	1.61e-11	8.17e-13
Fuel Oil #2 Prod.	Chlorine	secondary	1.56e-11	7.90e-13
Fuel Oil #2 Prod.	Cumene	secondary	1.42e-11	7.21e-13
Natural Gas Prod.	Cadmium cmpds	secondary	1.40e-11	7.11e-13
US electric grid	Dibenzo[a,h]anthracene	model/secondary	1.40e-11	7.07e-13
Natural Gas Prod.	Ethylene dibromide	secondary	1.39e-11	7.06e-13
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	1.31e-11	6.65e-13
Fuel Oil #6 Prod.	Acenaphthene	secondary	1.19e-11	6.01e-13
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	9.32e-12	4.72e-13
Natural Gas Prod.	Ethyl Chloride	secondary	9.30e-12	4.71e-13
Fuel Oil #2 Prod.	Acetophenone	secondary	8.86e-12	4.49e-13
Fuel Oil #2 Prod.	Biphenyl	secondary	8.49e-12	4.30e-13
Fuel Oil #6 Prod.	Chrysene	secondary	8.24e-12	4.18e-13
Natural Gas Prod.	Cumene	secondary	7.87e-12	3.99e-13
Fuel Oil #6 Prod.	Benzo[a]anthracene	secondary	7.80e-12	3.95e-13
Fuel Oil #4 Prod.	Phenanthrene	secondary	7.32e-12	3.71e-13
Natural Gas Prod.	Acenaphthylene	secondary	7.00e-12	3.54e-13
Fuel Oil #4 Prod.	Styrene	secondary	6.80e-12	3.45e-13
Fuel Oil #4 Prod.	Vinyl acetate	secondary	6.64e-12	3.36e-13
Fuel Oil #2 Prod.	Acenaphthylene	secondary	6.63e-12	3.36e-13
Fuel Oil #6 Prod.	Indeno(1,2,3-cd)pyrene	secondary	6.11e-12	3.09e-13
Fuel Oil #6 Prod.	Benzo[b,j,k]fluoranthene	secondary	5.94e-12	3.01e-13
Natural Gas Prod.	Benzo[a]anthracene	secondary	5.61e-12	2.84e-13
Japanese Electric Grid	Anthracene	model/secondary	5.42e-12	2.75e-13
Fuel Oil #2 Prod.	Acenaphthene	secondary	5.41e-12	2.74e-13
Natural Gas Prod.	Chrysene	secondary	5.40e-12	2.74e-13
Fuel Oil #4 Prod.	3-Methylcholanthrene	secondary	5.27e-12	2.67e-13

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #6 Prod.	Fluorene	secondary	5.11e-12	2.59e-13
Fuel Oil #6 Prod.	Benzo[a]pyrene	secondary	5.10e-12	2.58e-13
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	4.93e-12	2.50e-13
Natural Gas Prod.	Acetophenone	secondary	4.90e-12	2.48e-13
Fuel Oil #6 Prod.	Nickel cmpds	secondary	4.70e-12	2.38e-13
Natural Gas Prod.	Biphenyl	secondary	4.70e-12	2.38e-13
Natural Gas Prod.	Acenaphthene	secondary	4.50e-12	2.28e-13
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	4.17e-12	2.11e-13
Fuel Oil #6 Prod.	Fluoranthene	secondary	4.11e-12	2.08e-13
Fuel Oil #6 Prod.	Pyrene	secondary	4.04e-12	2.05e-13
Fuel Oil #6 Prod.	Lead cmpds	secondary	3.95e-12	2.00e-13
Fuel Oil #2 Prod.	Nickel cmpds	secondary	3.90e-12	1.97e-13
Fuel Oil #2 Prod.	Benzo[a]anthracene	secondary	3.76e-12	1.90e-13
US electric grid	Anthracene	model/secondary	3.70e-12	1.87e-13
Fuel Oil #2 Prod.	Chrysene	secondary	3.66e-12	1.85e-13
Fuel Oil #6 Prod.	Benzo[g,h,i]perylene	secondary	3.43e-12	1.74e-13
Fuel Oil #2 Prod.	Lead cmpds	secondary	3.27e-12	1.66e-13
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	3.19e-12	1.62e-13
Natural Gas Prod.	Benzo[a]pyrene	secondary	3.15e-12	1.59e-13
Fuel Oil #4 Prod.	Zinc (+2)	secondary	2.98e-12	1.51e-13
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	2.83e-12	1.44e-13
Natural Gas Prod.	Aromatic hydrocarbons	secondary	2.83e-12	1.43e-13
Fuel Oil #2 Prod.	Indeno(1,2,3-cd)pyrene	secondary	2.82e-12	1.43e-13
Fuel Oil #6 Prod.	Benzo[b]fluoranthene	secondary	2.74e-12	1.39e-13
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	2.69e-12	1.36e-13
Natural Gas Prod.	Copper (+1 & +2)	secondary	2.65e-12	1.34e-13
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	2.53e-12	1.28e-13
Natural Gas Prod.	Pyrene	secondary	2.45e-12	1.24e-13
Fuel Oil #6 Prod.	Mercury compounds	secondary	2.39e-12	1.21e-13
Fuel Oil #2 Prod.	Benzo[b,j,k]fluoranthene	secondary	2.31e-12	1.17e-13
Fuel Oil #2 Prod.	Benzo[a]pyrene	secondary	2.11e-12	1.07e-13
Fuel Oil #2 Prod.	Fluorene	secondary	2.06e-12	1.04e-13
Fuel Oil #2 Prod.	Mercury compounds	secondary	1.98e-12	1.00e-13
Fuel Oil #6 Prod.	Dibenzo[a,h]anthracene	secondary	1.90e-12	9.65e-14
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	1.79e-12	9.09e-14
Fuel Oil #2 Prod.	Pyrene	secondary	1.75e-12	8.87e-14
Fuel Oil #6 Prod.	HALON-1301	secondary	1.72e-12	8.70e-14
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	1.69e-12	8.55e-14
Fuel Oil #2 Prod.	Fluoranthene	secondary	1.67e-12	8.48e-14
Fuel Oil #2 Prod.	Benzo[g,h,i]perylene	secondary	1.67e-12	8.44e-14
Natural Gas Prod.	Fluorene	secondary	1.64e-12	8.30e-14
Fuel Oil #4 Prod.	Cumene	secondary	1.52e-12	7.69e-14
Fuel Oil #2 Prod.	Benzo[b]fluoranthene	secondary	1.47e-12	7.47e-14
Fuel Oil #4 Prod.	Chlorine	secondary	1.47e-12	7.44e-14
Natural Gas Prod.	Fluoranthene	secondary	1.46e-12	7.42e-14
Fuel Oil #2 Prod.	HALON-1301	secondary	1.42e-12	7.22e-14
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	1.28e-12	6.47e-14
Fuel Oil #6 Prod.	5-Methyl chrysene	secondary	1.19e-12	6.02e-14
Fuel Oil #2 Prod.	Dibenzo[a,h]anthracene	secondary	1.05e-12	5.30e-14
Fuel Oil #4 Prod.	Acetophenone	secondary	9.45e-13	4.78e-14

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Biphenyl	secondary	9.06e-13	4.59e-14
Fuel Oil #4 Prod.	Acenaphthylene	secondary	6.90e-13	3.50e-14
Fuel Oil #4 Prod.	Acenaphthene	secondary	5.39e-13	2.73e-14
Fuel Oil #2 Prod.	5-Methyl chrysene	secondary	4.62e-13	2.34e-14
Fuel Oil #6 Prod.	Halogenated matter (organic)	secondary	3.95e-13	2.00e-14
Fuel Oil #4 Prod.	Chrysene	secondary	3.68e-13	1.87e-14
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	3.66e-13	1.85e-14
Fuel Oil #2 Prod.	Halogenated matter (organic)	secondary	3.27e-13	1.66e-14
Fuel Oil #4 Prod.	Nickel cmpds	secondary	3.17e-13	1.60e-14
LPG Production	Halogenated hydrocarbons (unspecified)	secondary	2.92e-13	1.48e-14
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	2.79e-13	1.41e-14
Fuel Oil #4 Prod.	Lead cmpds	secondary	2.66e-13	1.35e-14
Natural Gas Prod.	5-Methyl chrysene	secondary	2.55e-13	1.29e-14
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	2.46e-13	1.25e-14
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	2.19e-13	1.11e-14
Fuel Oil #4 Prod.	Fluorene	secondary	2.16e-13	1.09e-14
Fuel Oil #6 Prod.	Anthracene	secondary	1.79e-13	9.07e-15
Fuel Oil #4 Prod.	Pyrene	secondary	1.78e-13	9.02e-15
Fuel Oil #4 Prod.	Fluoranthene	secondary	1.75e-13	8.86e-15
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	1.62e-13	8.20e-15
Fuel Oil #4 Prod.	Mercury compounds	secondary	1.61e-13	8.16e-15
Fuel Oil #4 Prod.	Benzo[b]fluoranthene	secondary	1.38e-13	6.98e-15
Fuel Oil #4 Prod.	HALON-1301	secondary	1.16e-13	5.86e-15
Fuel Oil #4 Prod.	Dibenzo[a,h]anthracene	secondary	9.69e-14	4.91e-15
Natural Gas Prod.	Anthracene	secondary	9.56e-14	4.84e-15
Fuel Oil #2 Prod.	Anthracene	secondary	7.64e-14	3.87e-15
US electric grid	2,3,7,8-TCDF	model/secondary	7.30e-14	3.70e-15
Japanese Electric Grid	2,3,7,8-TCDF	model/secondary	5.84e-14	2.96e-15
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	4.92e-14	2.49e-15
Natural Gas Prod.	Nickel cmpds	secondary	2.81e-14	1.42e-15
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	2.66e-14	1.35e-15
Natural Gas Prod.	Lead cmpds	secondary	2.36e-14	1.19e-15
Natural Gas Prod.	Mercury compounds	secondary	1.43e-14	7.24e-16
Natural Gas Prod.	HALON-1301	secondary	1.03e-14	5.20e-16
Fuel Oil #4 Prod.	Anthracene	secondary	7.82e-15	3.96e-16
Natural Gas Prod.	Halogenated matter (organic)	secondary	2.36e-15	1.19e-16
Fuel Oil #6 Prod.	Halogenated hydrocarbons (unspecified)	secondary	9.87e-16	5.00e-17
Fuel Oil #2 Prod.	Halogenated hydrocarbons (unspecified)	secondary	8.19e-16	4.15e-17
Fuel Oil #4 Prod.	Halogenated hydrocarbons (unspecified)	secondary	6.65e-17	3.37e-18
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	5.89e-18	2.98e-19
Total Manufacturing			**9.46e+01**	**4.79e+00**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Sulfur dioxide	model/secondary	1.65e+03	8.34e+01
US electric grid	Nitrogen oxides	model/secondary	1.18e+00	5.96e-02
US electric grid	Carbon monoxide	model/secondary	1.01e+00	5.12e-02
US electric grid	Methane	model/secondary	6.45e-01	3.27e-02
US electric grid	Arsenic	model/secondary	5.58e-01	2.83e-02
US electric grid	Hydrochloric acid	model/secondary	4.93e-01	2.50e-02
US electric grid	Selenium	model/secondary	9.28e-02	4.70e-03

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	Vanadium	model/secondary	6.98e-02	3.54e-03
US electric grid	PM-10	model/secondary	5.78e-02	2.93e-03
US electric grid	Hydrofluoric acid	model/secondary	1.35e-02	6.81e-04
US electric grid	Formaldehyde	model/secondary	9.69e-03	4.91e-04
US electric grid	Benzene	model/secondary	6.97e-03	3.53e-04
US electric grid	Phosphorus (yellow or white)	model/secondary	3.93e-03	1.99e-04
US electric grid	Nitrous oxide	model/secondary	3.40e-03	1.72e-04
US electric grid	Zinc (elemental)	model/secondary	1.81e-03	9.18e-05
US electric grid	Antimony	model/secondary	1.48e-03	7.51e-05
US electric grid	Molybdenum	model/secondary	4.96e-04	2.51e-05
US electric grid	2-Chloroacetophenone	model/secondary	4.31e-04	2.18e-05
US electric grid	Bromomethane	model/secondary	4.27e-04	2.16e-05
US electric grid	Cyanide (-1)	model/secondary	2.24e-04	1.14e-05
US electric grid	2,3,7,8-TCDD	model/secondary	1.70e-04	8.59e-06
US electric grid	Nickel	model/secondary	1.63e-04	8.26e-06
US electric grid	Naphthalene	model/secondary	1.35e-04	6.84e-06
US electric grid	Barium	model/secondary	1.16e-04	5.90e-06
US electric grid	Carbon disulfide	model/secondary	8.01e-05	4.06e-06
US electric grid	Benzyl chloride	model/secondary	6.28e-05	3.18e-06
US electric grid	Chloroform	model/secondary	4.88e-05	2.47e-06
US electric grid	Manganese	model/secondary	4.56e-05	2.31e-06
US electric grid	Chromium (VI)	model/secondary	3.43e-05	1.74e-06
US electric grid	Acrolein	model/secondary	2.60e-05	1.32e-06
US electric grid	Copper	model/secondary	2.24e-05	1.13e-06
US electric grid	Methyl chloride	model/secondary	2.11e-05	1.07e-06
US electric grid	Fluoride	model/secondary	1.95e-05	9.89e-07
US electric grid	Methyl hydrazine	model/secondary	1.52e-05	7.72e-07
US electric grid	Lead	model/secondary	1.27e-05	6.46e-07
US electric grid	Cobalt	model/secondary	1.22e-05	6.16e-07
US electric grid	Propionaldehyde	model/secondary	1.17e-05	5.93e-07
US electric grid	Acetaldehyde	model/secondary	1.17e-05	5.93e-07
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	8.99e-06	4.56e-07
US electric grid	Mercury	model/secondary	7.51e-06	3.81e-07
US electric grid	Hexane	model/secondary	6.01e-06	3.04e-07
US electric grid	Cadmium	model/secondary	4.82e-06	2.44e-07
US electric grid	Dimethyl sulfate	model/secondary	4.30e-06	2.18e-07
US electric grid	Toluene	model/secondary	4.25e-06	2.15e-07
US electric grid	Isophorone	model/secondary	4.13e-06	2.09e-07
US electric grid	Methyl ethyl ketone	model/secondary	3.33e-06	1.69e-07
US electric grid	Tetrachloroethylene	model/secondary	3.28e-06	1.66e-07
US electric grid	Methyl methacrylate	model/secondary	2.85e-06	1.44e-07
US electric grid	1,2-Dichloroethane	model/secondary	2.37e-06	1.20e-07
US electric grid	Bromoform	model/secondary	2.33e-06	1.18e-07
US electric grid	Dichloromethane	model/secondary	2.24e-06	1.14e-07
US electric grid	Beryllium	model/secondary	1.91e-06	9.67e-08
US electric grid	Chlorobenzene	model/secondary	1.88e-06	9.52e-08
US electric grid	2,4-Dinitrotoluene	model/secondary	1.49e-06	7.57e-08
US electric grid	Ethylbenzene	model/secondary	7.41e-07	3.75e-08
US electric grid	Methyl tert-butyl ether	model/secondary	3.74e-07	1.89e-08
US electric grid	Phenol	model/secondary	2.85e-07	1.44e-08

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	Styrene	model/secondary	2.73e-07	1.38e-08
US electric grid	Vinyl acetate	model/secondary	2.66e-07	1.35e-08
US electric grid	Phenanthrene	model/secondary	2.51e-07	1.27e-08
US electric grid	Xylene (mixed isomers)	model/secondary	2.21e-07	1.12e-08
US electric grid	Chromium (III)	model/secondary	1.97e-07	9.98e-09
US electric grid	1,1,1-Trichloroethane	model/secondary	1.08e-07	5.49e-09
US electric grid	Ethylene dibromide	model/secondary	1.08e-07	5.45e-09
US electric grid	Ethyl Chloride	model/secondary	7.19e-08	3.64e-09
US electric grid	Cumene	model/secondary	6.08e-08	3.08e-09
US electric grid	Acetophenone	model/secondary	3.78e-08	1.92e-09
US electric grid	Biphenyl	model/secondary	3.63e-08	1.84e-09
US electric grid	Acenaphthylene	model/secondary	2.26e-08	1.14e-09
US electric grid	Acenaphthene	model/secondary	1.93e-08	9.78e-10
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	1.06e-08	5.39e-10
US electric grid	Chrysene	model/secondary	1.02e-08	5.17e-10
US electric grid	Benzo[a]anthracene	model/secondary	9.27e-09	4.70e-10
US electric grid	Fluorene	model/secondary	7.99e-09	4.05e-10
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	6.59e-09	3.34e-10
US electric grid	Fluoranthene	model/secondary	6.39e-09	3.24e-10
US electric grid	Pyrene	model/secondary	5.28e-09	2.68e-10
US electric grid	o-xylene	model/secondary	3.79e-09	1.92e-10
US electric grid	Benzo[g,h,i]perylene	model/secondary	3.60e-09	1.83e-10
US electric grid	Benzo[a]pyrene	model/secondary	3.41e-09	1.73e-10
US electric grid	2-Methylnaphthalene	model/secondary	2.67e-09	1.35e-10
US electric grid	5-Methyl chrysene	model/secondary	1.97e-09	1.00e-10
US electric grid	Dibenzo[a,h]anthracene	model/secondary	8.74e-10	4.43e-11
US electric grid	Anthracene	model/secondary	2.32e-10	1.17e-11
US electric grid	2,3,7,8-TCDF	model/secondary	4.57e-12	2.32e-13
Total Use, Maintenance and Repiar			**1.65e+03**	**8.36e+01**
End-of-life Life-cycle Stage				
CRT Incineration	Sulfur dioxide	secondary	1.98e-01	1.00e-02
CRT landfilling	Sulfur dioxide	primary	1.85e-01	9.37e-03
US electric grid	Sulfur dioxide	model/secondary	1.65e-01	8.35e-03
CRT landfilling	Carbon monoxide	primary	9.22e-03	4.67e-04
CRT landfilling	Nitrogen dioxide	primary	1.85e-03	9.38e-05
CRT landfilling	PM	primary	2.08e-04	1.06e-05
US electric grid	Nitrogen oxides	model/secondary	1.18e-04	5.97e-06
CRT landfilling	Arsenic cmpds	primary	1.02e-04	5.18e-06
US electric grid	Carbon monoxide	model/secondary	1.01e-04	5.12e-06
CRT Incineration	Arsenic cmpds	secondary	9.83e-05	4.98e-06
US electric grid	Methane	model/secondary	6.45e-05	3.27e-06
US electric grid	Arsenic	model/secondary	5.58e-05	2.83e-06
CRT landfilling	Methane	primary	5.44e-05	2.76e-06
US electric grid	Hydrochloric acid	model/secondary	4.93e-05	2.50e-06
LPG Production	Carbon monoxide	secondary	4.61e-05	2.34e-06
CRT landfilling	Benzene	primary	4.04e-05	2.05e-06
CRT Incineration	Lead	secondary	1.43e-05	7.24e-07
CRT Incineration	Barium cmpds	secondary	1.27e-05	6.45e-07
CRT Incineration	Silver compounds	secondary	1.12e-05	5.68e-07
CRT landfilling	Silver compounds	primary	1.05e-05	5.30e-07

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
CRT landfilling	Barium cmpds	primary	1.01e-05	5.13e-07
US electric grid	Selenium	model/secondary	9.28e-06	4.70e-07
LPG Production	Vanadium	secondary	9.04e-06	4.58e-07
LPG Production	Benzene	secondary	7.40e-06	3.75e-07
LPG Production	Methane	secondary	7.24e-06	3.67e-07
US electric grid	Vanadium	model/secondary	6.98e-06	3.54e-07
LPG Production	Sulfur oxides	secondary	6.92e-06	3.50e-07
US electric grid	PM-10	model/secondary	5.78e-06	2.93e-07
LPG Production	Nitrogen oxides	secondary	4.94e-06	2.51e-07
CRT landfilling	Hydrochloric acid	primary	4.69e-06	2.37e-07
CRT landfilling	Ammonia	primary	2.41e-06	1.22e-07
LPG Production	Arsenic	secondary	1.78e-06	9.03e-08
US electric grid	Hydrofluoric acid	model/secondary	1.35e-06	6.82e-08
LPG Production	Formaldehyde	secondary	1.16e-06	5.86e-08
LPG Production	PM	secondary	1.11e-06	5.64e-08
CRT landfilling	Cadmium cmpds	primary	9.72e-07	4.92e-08
US electric grid	Formaldehyde	model/secondary	9.70e-07	4.91e-08
CRT Incineration	Cadmium cmpds	secondary	9.41e-07	4.77e-08
US electric grid	Benzene	model/secondary	6.98e-07	3.53e-08
US electric grid	Phosphorus (yellow or white)	model/secondary	3.93e-07	1.99e-08
US electric grid	Nitrous oxide	model/secondary	3.40e-07	1.72e-08
LPG Production	Hydrochloric acid	secondary	3.18e-07	1.61e-08
CRT landfilling	Hydrogen sulfide	primary	2.30e-07	1.17e-08
US electric grid	Zinc (elemental)	model/secondary	1.81e-07	9.19e-09
US electric grid	Antimony	model/secondary	1.48e-07	7.52e-09
LPG Production	Nitrous oxide	secondary	1.40e-07	7.09e-09
LPG Production	Phosphorus (yellow or white)	secondary	8.47e-08	4.29e-09
LPG Production	Fluorides (F-)	secondary	6.48e-08	3.28e-09
LPG Production	Selenium	secondary	6.40e-08	3.24e-09
US electric grid	Molybdenum	model/secondary	4.97e-08	2.52e-09
US electric grid	2-Chloroacetophenone	model/secondary	4.32e-08	2.19e-09
US electric grid	Bromomethane	model/secondary	4.27e-08	2.16e-09
LPG Production	Ammonia	secondary	3.23e-08	1.63e-09
CRT landfilling	Selenium	primary	3.21e-08	1.62e-09
CRT landfilling	Chromium (VI)	primary	2.84e-08	1.44e-09
LPG Production	Hydrogen sulfide	secondary	2.65e-08	1.34e-09
US electric grid	Cyanide (-1)	model/secondary	2.24e-08	1.14e-09
CRT Incineration	Carbon tetrachloride	secondary	1.80e-08	9.11e-10
US electric grid	2,3,7,8-TCDD	model/secondary	1.70e-08	8.59e-10
CRT landfilling	Carbon tetrachloride	primary	1.68e-08	8.50e-10
US electric grid	Nickel	model/secondary	1.63e-08	8.26e-10
LPG Production	Molybdenum	secondary	1.42e-08	7.20e-10
US electric grid	Naphthalene	model/secondary	1.35e-08	6.85e-10
CRT landfilling	Chloroform	primary	1.30e-08	6.59e-10
US electric grid	Barium	model/secondary	1.17e-08	5.90e-10
CRT landfilling	Mercury compounds	primary	1.15e-08	5.84e-10
CRT Incineration	Mercury compounds	secondary	1.13e-08	5.72e-10
LPG Production	Zinc (elemental)	secondary	1.04e-08	5.24e-10
LPG Production	Hydrofluoric acid	secondary	8.66e-09	4.39e-10
CRT landfilling	Toluene	primary	8.22e-09	4.17e-10

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	Carbon disulfide	model/secondary	8.01e-09	4.06e-10
LPG Production	Ethane	secondary	6.70e-09	3.39e-10
US electric grid	Benzyl chloride	model/secondary	6.28e-09	3.18e-10
LPG Production	Phenol	secondary	6.17e-09	3.13e-10
LPG Production	Pentane	secondary	5.62e-09	2.84e-10
US electric grid	Chloroform	model/secondary	4.88e-09	2.47e-10
US electric grid	Manganese	model/secondary	4.56e-09	2.31e-10
LPG Production	Hexane	secondary	3.89e-09	1.97e-10
US electric grid	Chromium (VI)	model/secondary	3.44e-09	1.74e-10
US electric grid	Acrolein	model/secondary	2.60e-09	1.32e-10
LPG Production	Nickel	secondary	2.51e-09	1.27e-10
US electric grid	Copper	model/secondary	2.24e-09	1.13e-10
US electric grid	Methyl chloride	model/secondary	2.11e-09	1.07e-10
US electric grid	Fluoride	model/secondary	1.95e-09	9.90e-11
LPG Production	PM-10	secondary	1.94e-09	9.84e-11
LPG Production	Antimony	secondary	1.85e-09	9.35e-11
CRT landfilling	Xylene (mixed isomers)	primary	1.69e-09	8.59e-11
US electric grid	Methyl hydrazine	model/secondary	1.53e-09	7.73e-11
US electric grid	Lead	model/secondary	1.28e-09	6.46e-11
LPG Production	Aluminum (+3)	secondary	1.22e-09	6.19e-11
US electric grid	Cobalt	model/secondary	1.22e-09	6.16e-11
CRT landfilling	Tetrachloroethylene	primary	1.20e-09	6.07e-11
US electric grid	Propionaldehyde	model/secondary	1.17e-09	5.93e-11
US electric grid	Acetaldehyde	model/secondary	1.17e-09	5.93e-11
CRT landfilling	1,2-Dichloroethane	primary	9.32e-10	4.72e-11
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	9.00e-10	4.56e-11
LPG Production	Chromium (VI)	secondary	8.70e-10	4.41e-11
CRT Incineration	Lead cmpds	secondary	8.10e-10	4.11e-11
CRT landfilling	Lead cmpds	primary	7.89e-10	4.00e-11
US electric grid	Mercury	model/secondary	7.52e-10	3.81e-11
CRT Incineration	Trichloroethylene	secondary	7.50e-10	3.80e-11
CRT landfilling	Trichloroethylene	primary	6.99e-10	3.54e-11
US electric grid	Hexane	model/secondary	6.01e-10	3.05e-11
LPG Production	Nitrate	secondary	5.23e-10	2.65e-11
US electric grid	Cadmium	model/secondary	4.82e-10	2.44e-11
CRT landfilling	Ethylbenzene	primary	4.44e-10	2.25e-11
US electric grid	Dimethyl sulfate	model/secondary	4.31e-10	2.18e-11
US electric grid	Toluene	model/secondary	4.25e-10	2.15e-11
US electric grid	Isophorone	model/secondary	4.13e-10	2.09e-11
US electric grid	Methyl ethyl ketone	model/secondary	3.33e-10	1.69e-11
US electric grid	Tetrachloroethylene	model/secondary	3.28e-10	1.66e-11
LPG Production	Copper	secondary	3.01e-10	1.52e-11
US electric grid	Methyl methacrylate	model/secondary	2.85e-10	1.44e-11
LPG Production	2-Chloroacetophenone	secondary	2.78e-10	1.41e-11
LPG Production	Dimethylbenzanthracene	secondary	2.75e-10	1.40e-11
LPG Production	Bromomethane	secondary	2.75e-10	1.39e-11
US electric grid	1,2-Dichloroethane	model/secondary	2.37e-10	1.20e-11
US electric grid	Bromoform	model/secondary	2.33e-10	1.18e-11
US electric grid	Dichloromethane	model/secondary	2.25e-10	1.14e-11
LPG Production	Naphthalene	secondary	2.23e-10	1.13e-11
CRT landfilling	Dichloromethane	primary	1.94e-10	9.85e-12

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Manganese	secondary	1.93e-10	9.76e-12
US electric grid	Beryllium	model/secondary	1.91e-10	9.67e-12
US electric grid	Chlorobenzene	model/secondary	1.88e-10	9.52e-12
LPG Production	Barium	secondary	1.61e-10	8.15e-12
US electric grid	2,4-Dinitrotoluene	model/secondary	1.49e-10	7.57e-12
LPG Production	Silicon	secondary	1.46e-10	7.40e-12
LPG Production	Cyanide (-1)	secondary	1.44e-10	7.31e-12
LPG Production	Barium cmpds	secondary	1.37e-10	6.94e-12
LPG Production	Lead	secondary	1.07e-10	5.40e-12
US electric grid	Ethylbenzene	model/secondary	7.41e-11	3.75e-12
CRT Incineration	o-xylene	secondary	5.21e-11	2.64e-12
LPG Production	Carbon disulfide	secondary	5.16e-11	2.61e-12
CRT landfilling	Chromium (III)	primary	4.83e-11	2.45e-12
LPG Production	Benzyl chloride	secondary	4.04e-11	2.05e-12
US electric grid	Methyl tert-butyl ether	model/secondary	3.74e-11	1.89e-12
LPG Production	Aluminum (elemental)	secondary	3.34e-11	1.69e-12
LPG Production	Chloroform	secondary	3.14e-11	1.59e-12
US electric grid	Phenol	model/secondary	2.85e-11	1.44e-12
US electric grid	Styrene	model/secondary	2.73e-11	1.38e-12
US electric grid	Vinyl acetate	model/secondary	2.66e-11	1.35e-12
US electric grid	Phenanthrene	model/secondary	2.51e-11	1.27e-12
US electric grid	Xylene (mixed isomers)	model/secondary	2.21e-11	1.12e-12
LPG Production	Cobalt	secondary	2.17e-11	1.10e-12
US electric grid	Chromium (III)	model/secondary	1.97e-11	9.99e-13
LPG Production	Acrolein	secondary	1.67e-11	8.48e-13
LPG Production	Methyl chloride	secondary	1.36e-11	6.87e-13
LPG Production	Beryllium	secondary	1.21e-11	6.14e-13
US electric grid	1,1,1-Trichloroethane	model/secondary	1.08e-11	5.50e-13
US electric grid	Ethylene dibromide	model/secondary	1.08e-11	5.45e-13
LPG Production	Methyl hydrazine	secondary	9.82e-12	4.97e-13
LPG Production	Acetaldehyde	secondary	7.54e-12	3.82e-13
LPG Production	Propionaldehyde	secondary	7.54e-12	3.82e-13
LPG Production	Mercury	secondary	7.50e-12	3.80e-13
US electric grid	Ethyl Chloride	model/secondary	7.19e-12	3.64e-13
LPG Production	Cadmium	secondary	6.99e-12	3.54e-13
US electric grid	Cumene	model/secondary	6.08e-12	3.08e-13
LPG Production	Cadmium cmpds	secondary	5.99e-12	3.04e-13
LPG Production	Di(2-ethylhexyl)phthalate	secondary	5.79e-12	2.93e-13
LPG Production	Toluene	secondary	5.38e-12	2.72e-13
US electric grid	Acetophenone	model/secondary	3.79e-12	1.92e-13
US electric grid	Biphenyl	model/secondary	3.63e-12	1.84e-13
LPG Production	1,4-Dichlorobenzene	secondary	3.08e-12	1.56e-13
CRT Incineration	Vinyl chloride	secondary	2.97e-12	1.51e-13
CRT landfilling	Vinyl chloride	primary	2.77e-12	1.41e-13
LPG Production	Dimethyl sulfate	secondary	2.77e-12	1.40e-13
LPG Production	Isophorone	secondary	2.66e-12	1.35e-13
US electric grid	Acenaphthylene	model/secondary	2.26e-12	1.14e-13
LPG Production	Methyl ethyl ketone	secondary	2.14e-12	1.09e-13
LPG Production	Tetrachloroethylene	secondary	2.11e-12	1.07e-13
US electric grid	Acenaphthene	model/secondary	1.93e-12	9.79e-14

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Methyl methacrylate	secondary	1.83e-12	9.28e-14
LPG Production	1,2-Dichloroethane	secondary	1.53e-12	7.74e-14
LPG Production	Bromoform	secondary	1.50e-12	7.59e-14
LPG Production	Chromium (III)	secondary	1.48e-12	7.51e-14
LPG Production	Dichloromethane	secondary	1.45e-12	7.32e-14
LPG Production	Chlorobenzene	secondary	1.21e-12	6.13e-14
LPG Production	Aromatic hydrocarbons	secondary	1.21e-12	6.12e-14
LPG Production	Copper (+1 & +2)	secondary	1.13e-12	5.73e-14
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	1.06e-12	5.39e-14
US electric grid	Chrysene	model/secondary	1.02e-12	5.18e-14
LPG Production	2,4-Dinitrotoluene	secondary	9.62e-13	4.87e-14
US electric grid	Benzo[a]anthracene	model/secondary	9.28e-13	4.70e-14
US electric grid	Fluorene	model/secondary	8.00e-13	4.05e-14
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	6.59e-13	3.34e-14
US electric grid	Fluoranthene	model/secondary	6.39e-13	3.24e-14
LPG Production	o-xylene	secondary	5.92e-13	3.00e-14
US electric grid	Pyrene	model/secondary	5.29e-13	2.68e-14
LPG Production	Ethylbenzene	secondary	4.80e-13	2.43e-14
US electric grid	o-xylene	model/secondary	3.80e-13	1.92e-14
US electric grid	Benzo[g,h,i]perylene	model/secondary	3.61e-13	1.83e-14
US electric grid	Benzo[a]pyrene	model/secondary	3.41e-13	1.73e-14
US electric grid	2-Methylnaphthalene	model/secondary	2.67e-13	1.35e-14
LPG Production	Methyl tert-butyl ether	secondary	2.41e-13	1.22e-14
US electric grid	5-Methyl chrysene	model/secondary	1.97e-13	1.00e-14
LPG Production	Phenanthrene	secondary	1.96e-13	9.91e-15
LPG Production	Styrene	secondary	1.76e-13	8.89e-15
LPG Production	Vinyl acetate	secondary	1.71e-13	8.68e-15
LPG Production	3-Methylcholanthrene	secondary	1.62e-13	8.19e-15
LPG Production	Zinc (+2)	secondary	1.01e-13	5.13e-15
US electric grid	Dibenzo[a,h]anthracene	model/secondary	8.75e-14	4.43e-15
LPG Production	Ethylene dibromide	secondary	6.93e-14	3.51e-15
LPG Production	1,1,1-Trichloroethane	secondary	6.53e-14	3.31e-15
LPG Production	2-Methylnaphthalene	secondary	5.18e-14	2.63e-15
LPG Production	Ethyl Chloride	secondary	4.63e-14	2.35e-15
LPG Production	Chlorine	secondary	4.59e-14	2.33e-15
LPG Production	Cumene	secondary	3.92e-14	1.98e-15
LPG Production	Acetophenone	secondary	2.44e-14	1.23e-15
LPG Production	Biphenyl	secondary	2.34e-14	1.18e-15
US electric grid	Anthracene	model/secondary	2.32e-14	1.17e-15
LPG Production	Acenaphthylene	secondary	1.85e-14	9.36e-16
LPG Production	Acenaphthene	secondary	1.54e-14	7.80e-16
LPG Production	Nickel cmpds	secondary	1.20e-14	6.07e-16
LPG Production	Benzo[a]anthracene	secondary	1.08e-14	5.46e-16
LPG Production	Chrysene	secondary	1.03e-14	5.24e-16
LPG Production	Lead cmpds	secondary	1.01e-14	5.10e-16
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	8.02e-15	4.06e-16
LPG Production	Benzo[b,j,k]fluoranthene	secondary	6.35e-15	3.22e-16
LPG Production	Mercury compounds	secondary	6.10e-15	3.09e-16
LPG Production	Benzo[a]pyrene	secondary	5.90e-15	2.99e-16
LPG Production	Fluorene	secondary	5.70e-15	2.89e-16

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Pyrene	secondary	4.93e-15	2.50e-16
LPG Production	Benzo[g,h,i]perylene	secondary	4.79e-15	2.43e-16
LPG Production	Fluoranthene	secondary	4.65e-15	2.36e-16
LPG Production	HALON-1301	secondary	4.38e-15	2.22e-16
LPG Production	Benzo[b]fluoranthene	secondary	4.31e-15	2.18e-16
LPG Production	Dibenzo[a,h]anthracene	secondary	3.06e-15	1.55e-16
LPG Production	5-Methyl chrysene	secondary	1.27e-15	6.44e-17
LPG Production	Halogenated matter (organic)	secondary	1.01e-15	5.10e-17
US electric grid	2,3,7,8-TCDF	model/secondary	4.58e-16	2.32e-17
LPG Production	Anthracene	secondary	2.14e-16	1.09e-17
LPG Production	Halogenated hydrocarbons (unspecified)	secondary	2.52e-18	1.28e-19
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	-2.95e-18	-1.50e-19
CRT Incineration	Halogenated hydrocarbons (unspecified)	secondary	-4.35e-17	-2.20e-18
Fuel Oil #4 Prod.	Halogenated hydrocarbons (unspecified)	secondary	-7.15e-16	-3.62e-17
Natural Gas Prod.	Halogenated matter (organic)	secondary	-1.18e-15	-5.99e-17
Natural Gas Prod.	HALON-1301	secondary	-5.15e-15	-2.61e-16
Natural Gas Prod.	Mercury compounds	secondary	-7.16e-15	-3.63e-16
Natural Gas Prod.	Lead cmpds	secondary	-1.18e-14	-5.99e-16
Natural Gas Prod.	Nickel cmpds	secondary	-1.41e-14	-7.13e-16
CRT Incineration	Halogenated matter (organic)	secondary	-1.84e-14	-9.30e-16
Natural Gas Prod.	Anthracene	secondary	-4.79e-14	-2.43e-15
CRT Incineration	HALON-1301	secondary	-7.99e-14	-4.05e-15
Fuel Oil #4 Prod.	Anthracene	secondary	-8.41e-14	-4.26e-15
Natural Gas Prod.	5-Methyl chrysene	secondary	-1.28e-13	-6.49e-15
CRT Incineration	Nickel cmpds	secondary	-2.18e-13	-1.11e-14
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	-2.86e-13	-1.45e-14
CRT Incineration	Dibenzo[a,h]anthracene	secondary	-4.49e-13	-2.28e-14
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	-5.29e-13	-2.68e-14
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	-6.40e-13	-3.24e-14
CRT Incineration	Benzo[b]fluoranthene	secondary	-6.65e-13	-3.37e-14
Natural Gas Prod.	Fluoranthene	secondary	-7.34e-13	-3.72e-14
Natural Gas Prod.	Fluorene	secondary	-8.22e-13	-4.16e-14
Fuel Oil #4 Prod.	Dibenzo[a,h]anthracene	secondary	-1.04e-12	-5.28e-14
Natural Gas Prod.	Pyrene	secondary	-1.23e-12	-6.22e-14
Fuel Oil #4 Prod.	HALON-1301	secondary	-1.24e-12	-6.30e-14
Natural Gas Prod.	Copper (+1 & +2)	secondary	-1.33e-12	-6.73e-14
Natural Gas Prod.	Aromatic hydrocarbons	secondary	-1.42e-12	-7.19e-14
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	-1.42e-12	-7.20e-14
Fuel Oil #4 Prod.	Benzo[b]fluoranthene	secondary	-1.48e-12	-7.50e-14
Natural Gas Prod.	Benzo[a]pyrene	secondary	-1.58e-12	-8.00e-14
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	-1.60e-12	-8.11e-14
Fuel Oil #4 Prod.	Mercury compounds	secondary	-1.73e-12	-8.77e-14
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	-1.74e-12	-8.81e-14
Fuel Oil #4 Prod.	Fluoranthene	secondary	-1.88e-12	-9.52e-14
Fuel Oil #4 Prod.	Pyrene	secondary	-1.91e-12	-9.70e-14
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	-2.09e-12	-1.06e-13
Natural Gas Prod.	Acenaphthene	secondary	-2.26e-12	-1.14e-13
Fuel Oil #4 Prod.	Fluorene	secondary	-2.32e-12	-1.18e-13
Natural Gas Prod.	Biphenyl	secondary	-2.35e-12	-1.19e-13
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	-2.36e-12	-1.19e-13

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Acetophenone	secondary	-2.46e-12	-1.24e-13
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	-2.47e-12	-1.25e-13
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	-2.65e-12	-1.34e-13
Natural Gas Prod.	Chrysene	secondary	-2.71e-12	-1.37e-13
Natural Gas Prod.	Benzo[a]anthracene	secondary	-2.81e-12	-1.42e-13
Fuel Oil #4 Prod.	Lead cmpds	secondary	-2.86e-12	-1.45e-13
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	-3.00e-12	-1.52e-13
Fuel Oil #4 Prod.	Nickel cmpds	secondary	-3.40e-12	-1.72e-13
Natural Gas Prod.	Acenaphthylene	secondary	-3.51e-12	-1.78e-13
CRT Incineration	Anthracene	secondary	-3.73e-12	-1.89e-13
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	-3.93e-12	-1.99e-13
Natural Gas Prod.	Cumene	secondary	-3.95e-12	-2.00e-13
Fuel Oil #4 Prod.	Chrysene	secondary	-3.96e-12	-2.01e-13
Natural Gas Prod.	Ethyl Chloride	secondary	-4.66e-12	-2.36e-13
Fuel Oil #4 Prod.	Acenaphthene	secondary	-5.79e-12	-2.93e-13
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-6.58e-12	-3.33e-13
Natural Gas Prod.	Ethylene dibromide	secondary	-6.98e-12	-3.54e-13
Natural Gas Prod.	Cadmium cmpds	secondary	-7.04e-12	-3.57e-13
Fuel Oil #4 Prod.	Acenaphthylene	secondary	-7.42e-12	-3.76e-13
CRT Incineration	2-Methylnaphthalene	secondary	-8.71e-12	-4.41e-13
Fuel Oil #4 Prod.	Biphenyl	secondary	-9.73e-12	-4.93e-13
Fuel Oil #4 Prod.	Acetophenone	secondary	-1.02e-11	-5.14e-13
Fuel Oil #4 Prod.	Chlorine	secondary	-1.58e-11	-7.99e-13
Fuel Oil #4 Prod.	Cumene	secondary	-1.63e-11	-8.26e-13
Natural Gas Prod.	Vinyl acetate	secondary	-1.73e-11	-8.75e-13
Natural Gas Prod.	Styrene	secondary	-1.77e-11	-8.96e-13
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	-1.81e-11	-9.19e-13
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	-1.93e-11	-9.77e-13
CRT Incineration	Chlorine	secondary	-1.94e-11	-9.81e-13
CRT Incineration	Copper (+1 & +2)	secondary	-2.06e-11	-1.04e-12
CRT Incineration	Aromatic hydrocarbons	secondary	-2.20e-11	-1.12e-12
CRT Incineration	Zinc (+2)	secondary	-2.24e-11	-1.13e-12
Natural Gas Prod.	Methyl tert-butyl ether	secondary	-2.42e-11	-1.23e-12
Natural Gas Prod.	2-Methylnaphthalene	secondary	-2.71e-11	-1.37e-12
CRT Incineration	3-Methylcholanthrene	secondary	-2.72e-11	-1.38e-12
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-2.72e-11	-1.38e-12
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	-2.89e-11	-1.46e-12
Fuel Oil #4 Prod.	Zinc (+2)	secondary	-3.21e-11	-1.63e-12
CRT Incineration	5-Methyl chrysene	secondary	-3.27e-11	-1.66e-12
Natural Gas Prod.	Phenanthrene	secondary	-3.53e-11	-1.79e-12
CRT Incineration	Benzo[g,h,i]perylene	secondary	-4.06e-11	-2.06e-12
Natural Gas Prod.	Aluminum (elemental)	secondary	-4.26e-11	-2.16e-12
Natural Gas Prod.	Ethylbenzene	secondary	-4.85e-11	-2.45e-12
CRT Incineration	Dichlorobenzene (mixed isomers)	secondary	-4.90e-11	-2.48e-12
Fuel Oil #4 Prod.	3-Methylcholanthrene	secondary	-5.66e-11	-2.87e-12
CRT Incineration	Benzo[a]pyrene	secondary	-5.70e-11	-2.89e-12
Fuel Oil #4 Prod.	Vinyl acetate	secondary	-7.14e-11	-3.62e-12
Fuel Oil #4 Prod.	Styrene	secondary	-7.31e-11	-3.71e-12
CRT Incineration	Pyrene	secondary	-7.81e-11	-3.96e-12
Fuel Oil #4 Prod.	Phenanthrene	secondary	-7.87e-11	-3.99e-12

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Chromium (III)	secondary	-8.08e-11	-4.09e-12
Natural Gas Prod.	3-Methylcholanthrene	secondary	-8.46e-11	-4.29e-12
CRT Incineration	Indeno(1,2,3-cd)pyrene	secondary	-9.14e-11	-4.63e-12
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	-9.70e-11	-4.91e-12
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	-1.00e-10	-5.08e-12
CRT Incineration	Fluoranthene	secondary	-1.01e-10	-5.10e-12
CRT Incineration	Benzo[a]anthracene	secondary	-1.20e-10	-6.06e-12
Natural Gas Prod.	Chlorobenzene	secondary	-1.22e-10	-6.17e-12
CRT Incineration	Fluorene	secondary	-1.29e-10	-6.53e-12
Natural Gas Prod.	Dichloromethane	secondary	-1.46e-10	-7.38e-12
CRT Incineration	Chrysene	secondary	-1.49e-10	-7.57e-12
Natural Gas Prod.	Bromoform	secondary	-1.51e-10	-7.64e-12
Natural Gas Prod.	1,2-Dichloroethane	secondary	-1.54e-10	-7.80e-12
Natural Gas Prod.	Barium cmpds	secondary	-1.61e-10	-8.15e-12
CRT Incineration	Benzo[b,j,k]fluoranthene	secondary	-1.64e-10	-8.29e-12
Natural Gas Prod.	Methyl methacrylate	secondary	-1.85e-10	-9.36e-12
Natural Gas Prod.	Silicon	secondary	-1.86e-10	-9.43e-12
Fuel Oil #4 Prod.	Ethylbenzene	secondary	-1.99e-10	-1.01e-11
Natural Gas Prod.	Tetrachloroethylene	secondary	-2.13e-10	-1.08e-11
Natural Gas Prod.	Methyl ethyl ketone	secondary	-2.16e-10	-1.09e-11
Fuel Oil #4 Prod.	o-xylene	secondary	-2.16e-10	-1.10e-11
Natural Gas Prod.	Chlorine	secondary	-2.37e-10	-1.20e-11
CRT Incineration	Acenaphthene	secondary	-2.58e-10	-1.31e-11
Natural Gas Prod.	Zinc (+2)	secondary	-2.63e-10	-1.33e-11
Natural Gas Prod.	Isophorone	secondary	-2.68e-10	-1.36e-11
Natural Gas Prod.	Dimethyl sulfate	secondary	-2.79e-10	-1.42e-11
Fuel Oil #4 Prod.	Chromium (III)	secondary	-3.09e-10	-1.57e-11
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	-3.21e-10	-1.63e-11
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	-3.43e-10	-1.74e-11
CRT Incineration	Acenaphthylene	secondary	-3.72e-10	-1.89e-11
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	-4.01e-10	-2.03e-11
Fuel Oil #4 Prod.	Chlorobenzene	secondary	-5.04e-10	-2.55e-11
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	-5.84e-10	-2.96e-11
CRT Incineration	Biphenyl	secondary	-6.02e-10	-3.05e-11
Fuel Oil #4 Prod.	Dichloromethane	secondary	-6.02e-10	-3.05e-11
Fuel Oil #4 Prod.	Bromoform	secondary	-6.24e-10	-3.16e-11
CRT Incineration	Acetophenone	secondary	-6.27e-10	-3.18e-11
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	-6.36e-10	-3.22e-11
Natural Gas Prod.	Cadmium	secondary	-7.04e-10	-3.56e-11
Natural Gas Prod.	Propionaldehyde	secondary	-7.60e-10	-3.85e-11
Natural Gas Prod.	Acetaldehyde	secondary	-7.60e-10	-3.85e-11
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	-7.64e-10	-3.87e-11
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	-8.79e-10	-4.46e-11
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	-8.93e-10	-4.53e-11
Natural Gas Prod.	Mercury	secondary	-9.44e-10	-4.78e-11
Natural Gas Prod.	Methyl hydrazine	secondary	-9.89e-10	-5.01e-11
CRT Incineration	Cumene	secondary	-1.01e-09	-5.11e-11
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	-1.08e-09	-5.47e-11
CRT Incineration	Aluminum (elemental)	secondary	-1.08e-09	-5.49e-11
Fuel Oil #4 Prod.	Isophorone	secondary	-1.11e-09	-5.61e-11

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Dimethyl sulfate	secondary	-1.15e-09	-5.85e-11
CRT Incineration	Ethyl Chloride	secondary	-1.19e-09	-6.04e-11
Natural Gas Prod.	Cobalt	secondary	-1.32e-09	-6.71e-11
Natural Gas Prod.	Methyl chloride	secondary	-1.37e-09	-6.93e-11
Natural Gas Prod.	Beryllium	secondary	-1.40e-09	-7.11e-11
Natural Gas Prod.	Aluminum (+3)	secondary	-1.44e-09	-7.27e-11
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	-1.61e-09	-8.18e-11
CRT Incineration	1,1,1-Trichloroethane	secondary	-1.68e-09	-8.52e-11
Natural Gas Prod.	Acrolein	secondary	-1.69e-09	-8.55e-11
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	-1.70e-09	-8.62e-11
CRT Incineration	Ethylene dibromide	secondary	-1.78e-09	-9.04e-11
Fuel Oil #4 Prod.	Toluene	secondary	-2.04e-09	-1.03e-10
CRT Incineration	Xylene (mixed isomers)	secondary	-2.13e-09	-1.08e-10
Natural Gas Prod.	o-xylene	secondary	-2.31e-09	-1.17e-10
Fuel Oil #4 Prod.	Di(2-ethylhexyl)phthalate	secondary	-2.41e-09	-1.22e-10
Natural Gas Prod.	PM-10	secondary	-2.48e-09	-1.25e-10
Fuel Oil #4 Prod.	Cadmium	secondary	-2.87e-09	-1.45e-10
Fuel Oil #4 Prod.	Mercury	secondary	-3.11e-09	-1.57e-10
Fuel Oil #4 Prod.	Propionaldehyde	secondary	-3.14e-09	-1.59e-10
Fuel Oil #4 Prod.	Acetaldehyde	secondary	-3.14e-09	-1.59e-10
Natural Gas Prod.	Chloroform	secondary	-3.17e-09	-1.60e-10
CRT Incineration	Phenanthrene	secondary	-4.02e-09	-2.04e-10
Natural Gas Prod.	Benzyl chloride	secondary	-4.07e-09	-2.06e-10
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	-4.09e-09	-2.07e-10
Natural Gas Prod.	Toluene	secondary	-4.33e-09	-2.19e-10
CRT Incineration	Vinyl acetate	secondary	-4.41e-09	-2.23e-10
CRT Incineration	Styrene	secondary	-4.52e-09	-2.29e-10
CRT Incineration	Silicon	secondary	-4.73e-09	-2.40e-10
Fuel Oil #4 Prod.	Beryllium	secondary	-5.02e-09	-2.54e-10
Natural Gas Prod.	Carbon disulfide	secondary	-5.20e-09	-2.63e-10
Fuel Oil #4 Prod.	Methyl chloride	secondary	-5.65e-09	-2.86e-10
CRT Incineration	Methyl tert-butyl ether	secondary	-6.19e-09	-3.14e-10
Fuel Oil #4 Prod.	Acrolein	secondary	-6.98e-09	-3.53e-10
Natural Gas Prod.	Phenol	secondary	-7.32e-09	-3.71e-10
Natural Gas Prod.	Nitrate	secondary	-7.54e-09	-3.82e-10
Fuel Oil #4 Prod.	Cobalt	secondary	-9.27e-09	-4.69e-10
CRT Incineration	Chloroacetophenone	secondary	-1.04e-08	-5.27e-10
Natural Gas Prod.	Lead	secondary	-1.09e-08	-5.50e-10
CRT Incineration	Ethylbenzene	secondary	-1.18e-08	-5.97e-10
Fuel Oil #4 Prod.	Chloroform	secondary	-1.31e-08	-6.63e-10
Natural Gas Prod.	Cyanide (-1)	secondary	-1.45e-08	-7.37e-10
Fuel Oil #4 Prod.	Aluminum (elemental)	secondary	-1.61e-08	-8.15e-10
Fuel Oil #4 Prod.	Benzyl chloride	secondary	-1.68e-08	-8.53e-10
CRT Incineration	Chromium (III)	secondary	-1.69e-08	-8.58e-10
Natural Gas Prod.	Manganese	secondary	-1.98e-08	-1.00e-09
Fuel Oil #4 Prod.	Carbon disulfide	secondary	-2.15e-08	-1.09e-09
CRT Incineration	Aluminum (+3)	secondary	-2.23e-08	-1.13e-09
CRT Incineration	2,4-Dinitrotoluene	secondary	-2.48e-08	-1.25e-09
Natural Gas Prod.	Copper	secondary	-2.65e-08	-1.34e-09
Natural Gas Prod.	Bromomethane	secondary	-2.77e-08	-1.40e-09

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	2-Chloroacetophenone	secondary	-2.80e-08	-1.42e-09
Natural Gas Prod.	Barium	secondary	-2.96e-08	-1.50e-09
CRT Incineration	Chlorobenzene	secondary	-3.11e-08	-1.58e-09
Natural Gas Prod.	Hydrogen sulfide	secondary	-3.37e-08	-1.71e-09
CRT Incineration	Dichloromethane	secondary	-3.70e-08	-1.87e-09
CRT Incineration	1,2-Dichloroethane	secondary	-3.83e-08	-1.94e-09
CRT Incineration	Bromoform	secondary	-3.85e-08	-1.95e-09
Fuel Oil #4 Prod.	Barium cmpds	secondary	-3.89e-08	-1.97e-09
Fuel Oil #4 Prod.	Lead	secondary	-4.45e-08	-2.25e-09
CRT Incineration	Methyl methacrylate	secondary	-4.72e-08	-2.39e-09
Natural Gas Prod.	Chromium (VI)	secondary	-4.74e-08	-2.40e-09
CRT Incineration	Dimethylbenzanthracene	secondary	-4.82e-08	-2.44e-09
CRT Incineration	Tetrachloroethylene	secondary	-5.31e-08	-2.69e-09
Fuel Oil #4 Prod.	Barium	secondary	-5.46e-08	-2.77e-09
CRT Incineration	Methyl ethyl ketone	secondary	-5.52e-08	-2.80e-09
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	-6.02e-08	-3.05e-09
CRT Incineration	Cadmium	secondary	-6.06e-08	-3.07e-09
Natural Gas Prod.	Nickel	secondary	-6.16e-08	-3.12e-09
CRT Incineration	PM-10	secondary	-6.30e-08	-3.19e-09
Natural Gas Prod.	Naphthalene	secondary	-6.53e-08	-3.31e-09
CRT Incineration	Toluene	secondary	-6.65e-08	-3.37e-09
CRT Incineration	Isophorone	secondary	-6.84e-08	-3.47e-09
Fuel Oil #4 Prod.	Silicon	secondary	-7.03e-08	-3.56e-09
CRT Incineration	Dimethyl sulfate	secondary	-7.14e-08	-3.62e-09
Fuel Oil #4 Prod.	Manganese	secondary	-8.00e-08	-4.05e-09
Fuel Oil #4 Prod.	Naphthalene	secondary	-8.01e-08	-4.06e-09
Fuel Oil #4 Prod.	Dimethylbenzanthracene	secondary	-9.64e-08	-4.88e-09
CRT Incineration	Mercury	secondary	-1.12e-07	-5.66e-09
Fuel Oil #4 Prod.	Bromomethane	secondary	-1.15e-07	-5.80e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	-1.16e-07	-5.86e-09
CRT Incineration	Phenol	secondary	-1.17e-07	-5.94e-09
Fuel Oil #4 Prod.	Copper	secondary	-1.34e-07	-6.79e-09
Natural Gas Prod.	Dimethylbenzanthracene	secondary	-1.44e-07	-7.30e-09
CRT Incineration	Di(2-ethylhexyl)phthalate	secondary	-1.49e-07	-7.55e-09
Fuel Oil #4 Prod.	Nitrate	secondary	-1.58e-07	-7.99e-09
Fuel Oil #4 Prod.	Chromium (VI)	secondary	-1.82e-07	-9.21e-09
CRT Incineration	Cobalt	secondary	-1.92e-07	-9.71e-09
CRT Incineration	Acetaldehyde	secondary	-1.94e-07	-9.83e-09
CRT Incineration	Propionaldehyde	secondary	-1.94e-07	-9.83e-09
Natural Gas Prod.	Antimony	secondary	-2.23e-07	-1.13e-08
CRT Incineration	Methyl hydrazine	secondary	-2.53e-07	-1.28e-08
CRT Incineration	Beryllium	secondary	-3.00e-07	-1.52e-08
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	-3.47e-07	-1.76e-08
CRT Incineration	Methyl chloride	secondary	-3.49e-07	-1.77e-08
CRT Incineration	Copper	secondary	-4.12e-07	-2.09e-08
CRT Incineration	Acrolein	secondary	-4.31e-07	-2.18e-08
CRT Incineration	Hydrogen sulfide	secondary	-6.11e-07	-3.10e-08
Fuel Oil #4 Prod.	Antimony	secondary	-6.37e-07	-3.23e-08
CRT Incineration	Hexane	secondary	-7.53e-07	-3.81e-08
CRT Incineration	Chloroform	secondary	-7.95e-07	-4.03e-08

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Hydrofluoric acid	secondary	-8.74e-07	-4.43e-08
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	-8.87e-07	-4.49e-08
Fuel Oil #4 Prod.	PM-10	secondary	-9.35e-07	-4.74e-08
CRT Incineration	Pentane	secondary	-9.44e-07	-4.78e-08
CRT Incineration	Benzyl chloride	secondary	-1.04e-06	-5.27e-08
CRT Incineration	Ethane	secondary	-1.13e-06	-5.70e-08
Fuel Oil #4 Prod.	Nickel	secondary	-1.16e-06	-5.87e-08
Natural Gas Prod.	Molybdenum	secondary	-1.16e-06	-5.87e-08
CRT Incineration	Barium	secondary	-1.31e-06	-6.66e-08
CRT Incineration	Carbon disulfide	secondary	-1.33e-06	-6.73e-08
Fuel Oil #4 Prod.	Hexane	secondary	-1.36e-06	-6.90e-08
Fuel Oil #4 Prod.	Phenol	secondary	-1.75e-06	-8.88e-08
CRT Incineration	Nitrate	secondary	-1.80e-06	-9.11e-08
Fuel Oil #4 Prod.	Pentane	secondary	-1.97e-06	-9.96e-08
CRT Incineration	Naphthalene	secondary	-2.03e-06	-1.03e-07
Natural Gas Prod.	Hexane	secondary	-2.03e-06	-1.03e-07
Fuel Oil #4 Prod.	Ethane	secondary	-2.34e-06	-1.19e-07
Natural Gas Prod.	Pentane	secondary	-2.94e-06	-1.49e-07
Natural Gas Prod.	Ethane	secondary	-3.50e-06	-1.77e-07
Fuel Oil #4 Prod.	Zinc (elemental)	secondary	-3.56e-06	-1.80e-07
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	-3.61e-06	-1.83e-07
CRT Incineration	Cyanide (-1)	secondary	-3.72e-06	-1.88e-07
Natural Gas Prod.	Zinc (elemental)	secondary	-4.26e-06	-2.16e-07
CRT Incineration	Manganese	secondary	-4.89e-06	-2.48e-07
Natural Gas Prod.	Nitrous oxide	secondary	-5.79e-06	-2.93e-07
Natural Gas Prod.	Selenium	secondary	-6.09e-06	-3.08e-07
Fuel Oil #4 Prod.	Molybdenum	secondary	-6.48e-06	-3.28e-07
Natural Gas Prod.	Fluorides (F-)	secondary	-6.78e-06	-3.44e-07
CRT Incineration	Bromomethane	secondary	-7.08e-06	-3.59e-07
CRT Incineration	Nickel	secondary	-9.71e-06	-4.92e-07
CRT Incineration	Chromium (VI)	secondary	-9.94e-06	-5.04e-07
CRT Incineration	Molybdenum	secondary	-9.95e-06	-5.04e-07
Fuel Oil #4 Prod.	Ammonia	secondary	-1.10e-05	-5.57e-07
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	-1.27e-05	-6.45e-07
Natural Gas Prod.	Formaldehyde	secondary	-1.39e-05	-7.04e-07
CRT Incineration	Antimony	secondary	-2.16e-05	-1.09e-06
CRT Incineration	Zinc (elemental)	secondary	-2.54e-05	-1.29e-06
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	-2.64e-05	-1.34e-06
Fuel Oil #4 Prod.	Selenium	secondary	-2.69e-05	-1.36e-06
Natural Gas Prod.	Hydrochloric acid	secondary	-3.20e-05	-1.62e-06
Natural Gas Prod.	Vanadium	secondary	-3.49e-05	-1.77e-06
Fuel Oil #4 Prod.	Phosphorus (yellow or white)	secondary	-3.98e-05	-2.02e-06
CRT Incineration	Ammonia	secondary	-4.51e-05	-2.28e-06
CRT Incineration	Phosphorus (yellow or white)	secondary	-5.50e-05	-2.78e-06
Fuel Oil #4 Prod.	Nitrous oxide	secondary	-6.18e-05	-3.13e-06
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	-1.32e-04	-6.70e-06
Natural Gas Prod.	Ammonia	secondary	-1.35e-04	-6.83e-06
Natural Gas Prod.	Sulfur oxides	secondary	-1.38e-04	-7.00e-06
Natural Gas Prod.	Arsenic	secondary	-1.58e-04	-7.99e-06
Natural Gas Prod.	PM	secondary	-2.08e-04	-1.05e-05

Table M-39. CRT LCIA Results for the Terrestrial Toxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
CRT Incineration	Hydrofluoric acid	secondary	-2.23e-04	-1.13e-05
Fuel Oil #4 Prod.	PM	secondary	-4.35e-04	-2.20e-05
CRT Incineration	Formaldehyde	secondary	-4.47e-04	-2.26e-05
Fuel Oil #4 Prod.	Formaldehyde	secondary	-5.52e-04	-2.80e-05
Fuel Oil #4 Prod.	Arsenic	secondary	-7.57e-04	-3.83e-05
CRT Incineration	Nitrous oxide	secondary	-1.04e-03	-5.27e-05
CRT Incineration	Vanadium	secondary	-1.17e-03	-5.94e-05
CRT Incineration	Selenium	secondary	-1.53e-03	-7.76e-05
CRT Incineration	Fluorides (F-)	secondary	-1.56e-03	-7.91e-05
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	-1.93e-03	-9.77e-05
Fuel Oil #4 Prod.	Benzene	secondary	-2.59e-03	-1.31e-04
Fuel Oil #4 Prod.	Sulfur oxides	secondary	-2.63e-03	-1.33e-04
Fuel Oil #4 Prod.	Methane	secondary	-2.80e-03	-1.42e-04
CRT Incineration	Benzene	secondary	-3.18e-03	-1.61e-04
Fuel Oil #4 Prod.	Vanadium	secondary	-4.33e-03	-2.19e-04
CRT Incineration	Hydrochloric acid	secondary	-4.66e-03	-2.36e-04
Natural Gas Prod.	Nitrogen oxides	secondary	-4.68e-03	-2.37e-04
CRT Incineration	Nitrogen oxides	secondary	-1.25e-02	-6.36e-04
CRT Incineration	Carbon monoxide	secondary	-1.44e-02	-7.31e-04
Fuel Oil #4 Prod.	Carbon monoxide	secondary	-1.51e-02	-7.64e-04
CRT Incineration	Methane	secondary	-1.52e-02	-7.68e-04
CRT Incineration	PM	secondary	-1.83e-02	-9.29e-04
Natural Gas Prod.	Methane	secondary	-2.52e-02	-1.27e-03
CRT Incineration	Sulfur oxides	secondary	-2.70e-02	-1.37e-03
Natural Gas Prod.	Carbon monoxide	secondary	-3.19e-02	-1.62e-03
Natural Gas Prod.	Benzene	secondary	-3.79e-02	-1.92e-03
CRT Incineration	Arsenic	secondary	-3.84e-02	-1.95e-03
Total End-of-life			**2.88e-01**	**1.46e-02**
Total All Life-cycle Stages			**1.97e+03**	**1.00e+02**

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Materials Processing Life-cycle Stage				
Steel Prod., cold-rolled, semi-finished	Sulfur dioxide	secondary	1.24e+01	1.39e+00
PMMA Sheet Prod.	Sulfur dioxide	secondary	8.61e+00	9.63e-01
Natural Gas Prod.	Benzene	secondary	5.28e+00	5.91e-01
Aluminum Prod.	Sulfur dioxide	secondary	5.13e+00	5.74e-01
Natural Gas Prod.	Carbon monoxide	secondary	4.44e+00	4.97e-01
Polycarbonate Production	Sulfur dioxide	secondary	4.43e+00	4.95e-01
Natural Gas Prod.	Methane	secondary	3.50e+00	3.92e-01
Natural Gas Prod.	Nitrogen oxides	secondary	6.51e-01	7.28e-02
Aluminum Prod.	Titanium tetrachloride	secondary	2.68e-01	3.00e-02
Steel Prod., cold-rolled, semi-finished	Carbon monoxide	secondary	1.36e-01	1.52e-02
Aluminum Prod.	Manganese cmpds	secondary	6.03e-02	6.74e-03
Steel Prod., cold-rolled, semi-finished	PM	secondary	5.14e-02	5.75e-03
Aluminum Prod.	Vanadium	secondary	4.00e-02	4.47e-03
Natural Gas Prod.	PM	secondary	2.89e-02	3.23e-03
PET Resin Production	Carbon monoxide	secondary	2.61e-02	2.92e-03
Steel Prod., cold-rolled, semi-finished	Vanadium	secondary	2.53e-02	2.82e-03
PMMA Sheet Prod.	Carbon monoxide	secondary	2.35e-02	2.62e-03
Polycarbonate Production	Carbon monoxide	secondary	2.32e-02	2.59e-03
Natural Gas Prod.	Arsenic	secondary	2.20e-02	2.46e-03
Natural Gas Prod.	Sulfur oxides	secondary	1.93e-02	2.15e-03
Natural Gas Prod.	Ammonia	secondary	1.88e-02	2.10e-03
Aluminum Prod.	Arsenic cmpds	secondary	1.77e-02	1.98e-03
PMMA Sheet Prod.	Methane	secondary	1.15e-02	1.29e-03
Polycarbonate Production	Methane	secondary	1.13e-02	1.27e-03
Polycarbonate Production	Nitrogen dioxide	secondary	1.08e-02	1.21e-03
PMMA Sheet Prod.	Nitrogen dioxide	secondary	1.07e-02	1.20e-03
Steel Prod., cold-rolled, semi-finished	Fluorides (F-)	secondary	9.36e-03	1.05e-03
Steel Prod., cold-rolled, semi-finished	Manganese cmpds	secondary	7.30e-03	8.17e-04
Styrene-butadiene Copolymer Prod.	Carbon monoxide	secondary	7.00e-03	7.83e-04
Steel Prod., cold-rolled, semi-finished	Nitrogen dioxide	secondary	6.86e-03	7.67e-04
Aluminum Prod.	Carbon monoxide	secondary	6.42e-03	7.18e-04
Steel Prod., cold-rolled, semi-finished	Methane	secondary	5.34e-03	5.97e-04
Natural Gas Prod.	Vanadium	secondary	4.86e-03	5.44e-04
Natural Gas Prod.	Hydrochloric acid	secondary	4.46e-03	4.99e-04
PET Resin Production	Sulfur oxides	secondary	3.99e-03	4.47e-04
Aluminum Prod.	Barium cmpds	secondary	3.89e-03	4.35e-04
Polycarbonate Production	PM	secondary	3.61e-03	4.04e-04
Aluminum Prod.	PM	secondary	3.31e-03	3.71e-04
PMMA Sheet Prod.	PM	secondary	3.22e-03	3.60e-04
Styrene-butadiene Copolymer Prod.	Nitrogen oxides	secondary	3.06e-03	3.42e-04
Styrene-butadiene Copolymer Prod.	Methane	secondary	3.00e-03	3.36e-04
Aluminum Prod.	Methane	secondary	3.00e-03	3.35e-04
Aluminum Prod.	Nitrogen dioxide	secondary	2.66e-03	2.97e-04
Styrene-butadiene Copolymer Prod.	Sulfur oxides	secondary	2.50e-03	2.79e-04
Aluminum Prod.	Selenium	secondary	2.34e-03	2.62e-04
Steel Prod., cold-rolled, semi-finished	Arsenic	secondary	2.22e-03	2.48e-04
Steel Prod., cold-rolled, semi-finished	Phosphorus (yellow or white)	secondary	1.99e-03	2.23e-04
Natural Gas Prod.	Formaldehyde	secondary	1.93e-03	2.16e-04
PET Resin Production	Nitrogen oxides	secondary	1.72e-03	1.93e-04

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
PMMA Sheet Prod.	Ammonia	secondary	1.04e-03	1.16e-04
Steel Prod., cold-rolled, semi-finished	Hydrochloric acid	secondary	1.00e-03	1.12e-04
PET Resin Production	Methane	secondary	9.98e-04	1.12e-04
Natural Gas Prod.	Fluorides (F-)	secondary	9.45e-04	1.06e-04
Steel Prod., cold-rolled, semi-finished	Benzene	secondary	8.62e-04	9.64e-05
Steel Prod., cold-rolled, semi-finished	Barium cmpds	secondary	8.49e-04	9.49e-05
Natural Gas Prod.	Selenium	secondary	8.48e-04	9.48e-05
Natural Gas Prod.	Nitrous oxide	secondary	8.07e-04	9.02e-05
Steel Prod., cold-rolled, semi-finished	Arsenic cmpds	secondary	7.53e-04	8.42e-05
PET Resin Production	PM	secondary	6.99e-04	7.82e-05
Aluminum Prod.	Hydrochloric acid	secondary	6.64e-04	7.43e-05
Natural Gas Prod.	Zinc (elemental)	secondary	5.94e-04	6.64e-05
Aluminum Prod.	Aluminum (+3)	secondary	5.91e-04	6.61e-05
PMMA Sheet Prod.	Nitrates/nitrites	secondary	5.70e-04	6.38e-05
Natural Gas Prod.	Ethane	secondary	4.88e-04	5.46e-05
Aluminum Prod.	Cadmium cmpds	secondary	4.36e-04	4.88e-05
Styrene-butadiene Copolymer Prod.	PM	secondary	4.34e-04	4.85e-05
Natural Gas Prod.	Pentane	secondary	4.09e-04	4.58e-05
Steel Prod., cold-rolled, semi-finished	Titanium tetrachloride	secondary	4.08e-04	4.56e-05
Steel Prod., cold-rolled, semi-finished	Ammonia	secondary	3.91e-04	4.38e-05
Steel Prod., cold-rolled, semi-finished	Nitrous oxide	secondary	3.81e-04	4.26e-05
PMMA Sheet Prod.	Hydrogen cyanide	secondary	3.73e-04	4.17e-05
PMMA Sheet Prod.	Hydrochloric acid	secondary	2.99e-04	3.34e-05
Natural Gas Prod.	Hexane	secondary	2.83e-04	3.17e-05
Polycarbonate Production	Hydrochloric acid	secondary	2.60e-04	2.91e-05
Steel Prod., cold-rolled, semi-finished	Silicon	secondary	2.48e-04	2.77e-05
Aluminum Prod.	Benzene	secondary	2.12e-04	2.37e-05
Steel Prod., cold-rolled, semi-finished	Formaldehyde	secondary	2.03e-04	2.27e-05
Polycarbonate Production	Sulfuric acid	secondary	1.77e-04	1.98e-05
Aluminum Prod.	Barium sulfate	secondary	1.69e-04	1.89e-05
Natural Gas Prod.	Molybdenum	secondary	1.61e-04	1.81e-05
Steel Prod., cold-rolled, semi-finished	Titanium	secondary	1.60e-04	1.79e-05
Steel Prod., cold-rolled, semi-finished	Selenium	secondary	1.47e-04	1.64e-05
PET Resin Production	Hydrochloric acid	secondary	1.45e-04	1.63e-05
Polycarbonate Production	Mercury compounds	secondary	1.36e-04	1.52e-05
PMMA Sheet Prod.	Sulfuric acid	secondary	1.32e-04	1.47e-05
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	1.24e-04	1.38e-05
Natural Gas Prod.	Hydrofluoric acid	secondary	1.22e-04	1.36e-05
Steel Prod., cold-rolled, semi-finished	Ethane	secondary	1.20e-04	1.35e-05
Steel Prod., cold-rolled, semi-finished	Zinc (elemental)	secondary	1.06e-04	1.19e-05
PMMA Sheet Prod.	Mercury compounds	secondary	1.01e-04	1.13e-05
Steel Prod., cold-rolled, semi-finished	Molybdenum	secondary	9.20e-05	1.03e-05
Aluminum Prod.	Hydrofluoric acid	secondary	8.95e-05	1.00e-05
Aluminum Prod.	Zinc (elemental)	secondary	8.55e-05	9.56e-06
Aluminum Prod.	Titanium	secondary	8.47e-05	9.48e-06
Aluminum Prod.	Copper (+1 & +2)	secondary	6.70e-05	7.50e-06
PET Resin Production	Sulfuric acid	secondary	6.23e-05	6.97e-06
Styrene-butadiene Copolymer Prod.	Sulfuric acid	secondary	6.21e-05	6.95e-06
Steel Prod., cold-rolled, semi-finished	Barium	secondary	6.03e-05	6.74e-06

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Aluminum Prod.	Nitrous oxide	secondary	5.14e-05	5.75e-06
Polycarbonate Production	Fluorides (F-)	secondary	5.11e-05	5.72e-06
Steel Prod., cold-rolled, semi-finished	Tin (Sn++, Sn4+)	secondary	5.11e-05	5.71e-06
Aluminum Prod.	Perfluoromethane	secondary	4.83e-05	5.40e-06
Styrene-butadiene Copolymer Prod.	Mercury compounds	secondary	4.76e-05	5.32e-06
Steel Prod., cold-rolled, semi-finished	Antimony	secondary	4.66e-05	5.21e-06
Polycarbonate Production	Aromatic hydrocarbons	secondary	4.59e-05	5.13e-06
Aluminum Prod.	Silicon	secondary	4.07e-05	4.55e-06
PMMA Sheet Prod.	Fluorine	secondary	3.80e-05	4.25e-06
Natural Gas Prod.	Antimony	secondary	3.10e-05	3.47e-06
Steel Prod., cold-rolled, semi-finished	Silver compounds	secondary	3.03e-05	3.38e-06
Styrene-butadiene Copolymer Prod.	Hydrochloric acid	secondary	2.98e-05	3.33e-06
Styrene-butadiene Copolymer Prod.	Aromatic hydrocarbons	secondary	2.97e-05	3.32e-06
Steel Prod., cold-rolled, semi-finished	Nitrates/nitrites	secondary	2.45e-05	2.74e-06
Steel Prod., cold-rolled, semi-finished	Boron	secondary	2.41e-05	2.70e-06
Steel Prod., cold-rolled, semi-finished	Mercury compounds	secondary	2.22e-05	2.48e-06
Natural Gas Prod.	Dimethylbenzanthracene	secondary	2.01e-05	2.24e-06
PET Resin Production	Fluorine	secondary	1.80e-05	2.01e-06
Styrene-butadiene Copolymer Prod.	Fluorides (F-)	secondary	1.79e-05	2.01e-06
Aluminum Prod.	Nitrate	secondary	1.70e-05	1.90e-06
Steel Prod., cold-rolled, semi-finished	Barium sulfate	secondary	1.68e-05	1.88e-06
Aluminum Prod.	Barium	secondary	1.46e-05	1.63e-06
Steel Prod., cold-rolled, semi-finished	Cadmium cmpds	secondary	1.32e-05	1.48e-06
Steel Prod., cold-rolled, semi-finished	Aluminum (elemental)	secondary	1.21e-05	1.35e-06
Steel Prod., cold-rolled, semi-finished	Acetylene	secondary	1.14e-05	1.28e-06
Steel Prod., cold-rolled, semi-finished	Hydrofluoric acid	secondary	9.28e-06	1.04e-06
Natural Gas Prod.	Naphthalene	secondary	9.09e-06	1.02e-06
Aluminum Prod.	Copper	secondary	8.87e-06	9.92e-07
Natural Gas Prod.	Nickel	secondary	8.58e-06	9.60e-07
Steel Prod., cold-rolled, semi-finished	Pentane	secondary	8.31e-06	9.29e-07
Steel Prod., cold-rolled, semi-finished	Aluminum (+3)	secondary	7.72e-06	8.64e-07
Aluminum Prod.	Nickel cmpds	secondary	7.09e-06	7.93e-07
Steel Prod., cold-rolled, semi-finished	Hydrogen sulfide	secondary	6.66e-06	7.45e-07
Aluminum Prod.	Nickel	secondary	6.62e-06	7.40e-07
Natural Gas Prod.	Chromium (VI)	secondary	6.61e-06	7.39e-07
Aluminum Prod.	Zinc (+2)	secondary	6.49e-06	7.25e-07
Steel Prod., cold-rolled, semi-finished	Copper	secondary	5.99e-06	6.70e-07
Polycarbonate Production	Copper (+1 & +2)	secondary	5.79e-06	6.48e-07
Aluminum Prod.	Ammonia	secondary	5.76e-06	6.44e-07
Aluminum Prod.	Aromatic hydrocarbons	secondary	5.27e-06	5.89e-07
Polycarbonate Production	Phenol	secondary	5.22e-06	5.83e-07
Aluminum Prod.	Nitrites	secondary	5.03e-06	5.63e-07
Natural Gas Prod.	Hydrogen sulfide	secondary	4.70e-06	5.26e-07
PMMA Sheet Prod.	Copper (+1 & +2)	secondary	4.31e-06	4.81e-07
Steel Prod., cold-rolled, semi-finished	Copper (+1 & +2)	secondary	4.21e-06	4.71e-07
Natural Gas Prod.	Barium	secondary	4.12e-06	4.61e-07
Steel Prod., cold-rolled, semi-finished	Nickel	secondary	3.99e-06	4.46e-07
Aluminum Prod.	Aluminum (elemental)	secondary	3.92e-06	4.38e-07
Natural Gas Prod.	2-Chloroacetophenone	secondary	3.90e-06	4.36e-07
Natural Gas Prod.	Bromomethane	secondary	3.86e-06	4.32e-07

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
PMMA Sheet Prod.	Cyanide (-1)	secondary	3.83e-06	4.29e-07
Aluminum Prod.	Strontium (Sr II)	secondary	3.72e-06	4.16e-07
Natural Gas Prod.	Copper	secondary	3.69e-06	4.12e-07
Steel Prod., cold-rolled, semi-finished	Aromatic hydrocarbons	secondary	3.51e-06	3.93e-07
PMMA Sheet Prod.	Hydrofluoric acid	secondary	3.45e-06	3.86e-07
Aluminum Prod.	Fluoride	secondary	3.39e-06	3.79e-07
Aluminum Prod.	Lead cmpds	secondary	3.25e-06	3.63e-07
Aluminum Prod.	Vanadium (V3+, V5+)	secondary	3.03e-06	3.39e-07
Natural Gas Prod.	Manganese	secondary	2.76e-06	3.09e-07
Steel Prod., cold-rolled, semi-finished	Strontium (Sr II)	secondary	2.29e-06	2.56e-07
Steel Prod., cold-rolled, semi-finished	Hexane	secondary	2.17e-06	2.43e-07
Polycarbonate Production	Ammonia	secondary	2.07e-06	2.31e-07
Polycarbonate Production	Hydrofluoric acid	secondary	2.06e-06	2.31e-07
PET Resin Production	Copper (+1 & +2)	secondary	2.04e-06	2.28e-07
Styrene-butadiene Copolymer Prod.	Copper (+1 & +2)	secondary	2.03e-06	2.27e-07
Natural Gas Prod.	Cyanide (-1)	secondary	2.03e-06	2.27e-07
Aluminum Prod.	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	1.84e-06	2.06e-07
PMMA Sheet Prod.	Phenol	secondary	1.75e-06	1.96e-07
Steel Prod., cold-rolled, semi-finished	Chromium (VI)	secondary	1.62e-06	1.81e-07
PMMA Sheet Prod.	Hydrogen sulfide	secondary	1.53e-06	1.72e-07
Natural Gas Prod.	Lead	secondary	1.51e-06	1.69e-07
Aluminum Prod.	Hydrogen sulfide	secondary	1.40e-06	1.57e-07
Styrene-butadiene Copolymer Prod.	Nitrate	secondary	1.27e-06	1.42e-07
Steel Prod., cold-rolled, semi-finished	Boric acid	secondary	1.06e-06	1.19e-07
Natural Gas Prod.	Nitrate	secondary	1.05e-06	1.18e-07
Polycarbonate Production	Halogenated hydrocarbons (unspecified)	secondary	1.03e-06	1.15e-07
Polycarbonate Production	Hydrogen sulfide	secondary	1.03e-06	1.15e-07
Natural Gas Prod.	Phenol	secondary	1.02e-06	1.14e-07
Steel Prod., cold-rolled, semi-finished	Bromine	secondary	9.94e-07	1.11e-07
PET Resin Production	Hydrofluoric acid	secondary	9.08e-07	1.01e-07
Steel Prod., cold-rolled, semi-finished	Uranium	secondary	8.25e-07	9.23e-08
PMMA Sheet Prod.	Aromatic hydrocarbons	secondary	7.67e-07	8.58e-08
Steel Prod., cold-rolled, semi-finished	Toluene	secondary	7.44e-07	8.32e-08
Natural Gas Prod.	Carbon disulfide	secondary	7.24e-07	8.10e-08
Aluminum Prod.	Toluene	secondary	6.75e-07	7.55e-08
Natural Gas Prod.	Toluene	secondary	6.03e-07	6.74e-08
Steel Prod., cold-rolled, semi-finished	Ethylene	secondary	6.02e-07	6.73e-08
Steel Prod., cold-rolled, semi-finished	Cyanide (-1)	secondary	5.92e-07	6.62e-08
Steel Prod., cold-rolled, semi-finished	Methanol	secondary	5.84e-07	6.54e-08
Natural Gas Prod.	Benzyl chloride	secondary	5.67e-07	6.35e-08
Steel Prod., cold-rolled, semi-finished	Xylene (mixed isomers)	secondary	5.50e-07	6.15e-08
Steel Prod., cold-rolled, semi-finished	Lead	secondary	5.40e-07	6.04e-08
Steel Prod., cold-rolled, semi-finished	Naphthalene	secondary	5.39e-07	6.02e-08
Polycarbonate Production	Chlorine	secondary	5.16e-07	5.77e-08
Aluminum Prod.	Xylene (mixed isomers)	secondary	5.13e-07	5.73e-08
Steel Prod., cold-rolled, semi-finished	Phenol	secondary	4.75e-07	5.31e-08
Steel Prod., cold-rolled, semi-finished	Heptane	secondary	4.57e-07	5.12e-08
PMMA Sheet Prod.	Nickel cmpds	secondary	4.56e-07	5.10e-08

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Aluminum Prod.	Lead	secondary	4.47e-07	5.00e-08
Natural Gas Prod.	Chloroform	secondary	4.41e-07	4.93e-08
Steel Prod., cold-rolled, semi-finished	Lead cmpds	secondary	4.33e-07	4.84e-08
PMMA Sheet Prod.	Chlorine	secondary	3.83e-07	4.29e-08
Styrene-butadiene Copolymer Prod.	Aluminum (+3)	secondary	3.62e-07	4.05e-08
Natural Gas Prod.	PM-10	secondary	3.45e-07	3.86e-08
Aluminum Prod.	Chromium (VI)	secondary	3.31e-07	3.71e-08
Natural Gas Prod.	o-xylene	secondary	3.21e-07	3.59e-08
Steel Prod., cold-rolled, semi-finished	Nickel cmpds	secondary	2.92e-07	3.26e-08
Steel Prod., cold-rolled, semi-finished	Zinc (+2)	secondary	2.60e-07	2.91e-08
Polycarbonate Production	Aluminum (+3)	secondary	2.58e-07	2.88e-08
Polycarbonate Production	Ethanethiol	secondary	2.58e-07	2.88e-08
Polycarbonate Production	Lead	secondary	2.58e-07	2.88e-08
Polycarbonate Production	Mercury	secondary	2.58e-07	2.88e-08
Polycarbonate Production	Nickel (+2)	secondary	2.58e-07	2.88e-08
Polycarbonate Production	Nitrate	secondary	2.58e-07	2.88e-08
Polycarbonate Production	Nitrous oxide	secondary	2.58e-07	2.88e-08
Polycarbonate Production	Zinc (+2)	secondary	2.58e-07	2.88e-08
Aluminum Prod.	Phenol	secondary	2.38e-07	2.66e-08
Natural Gas Prod.	Acrolein	secondary	2.35e-07	2.63e-08
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	2.25e-07	2.51e-08
Styrene-butadiene Copolymer Prod.	Phenol	secondary	2.15e-07	2.41e-08
Natural Gas Prod.	Aluminum (+3)	secondary	2.00e-07	2.24e-08
Steel Prod., cold-rolled, semi-finished	Cobalt	secondary	1.98e-07	2.22e-08
PET Resin Production	Phenol	secondary	1.98e-07	2.21e-08
Natural Gas Prod.	Beryllium	secondary	1.95e-07	2.19e-08
PMMA Sheet Prod.	Aluminum (+3)	secondary	1.92e-07	2.14e-08
PMMA Sheet Prod.	Ethanethiol	secondary	1.92e-07	2.14e-08
PMMA Sheet Prod.	Lead	secondary	1.92e-07	2.14e-08
PMMA Sheet Prod.	Mercury	secondary	1.92e-07	2.14e-08
PMMA Sheet Prod.	Nitrous oxide	secondary	1.92e-07	2.14e-08
PMMA Sheet Prod.	Zinc (+2)	secondary	1.92e-07	2.14e-08
Natural Gas Prod.	Methyl chloride	secondary	1.90e-07	2.13e-08
Natural Gas Prod.	Cobalt	secondary	1.85e-07	2.06e-08
PET Resin Production	Chlorine	secondary	1.82e-07	2.03e-08
PET Resin Production	Mercury	secondary	1.82e-07	2.03e-08
Styrene-butadiene Copolymer Prod.	Chlorine	secondary	1.81e-07	2.02e-08
Styrene-butadiene Copolymer Prod.	Hydrofluoric acid	secondary	1.81e-07	2.02e-08
Steel Prod., cold-rolled, semi-finished	Manganese	secondary	1.76e-07	1.97e-08
Aluminum Prod.	Acetic acid	secondary	1.57e-07	1.76e-08
PET Resin Production	Ammonia	secondary	1.56e-07	1.74e-08
Styrene-butadiene Copolymer Prod.	Ammonia	secondary	1.55e-07	1.74e-08
Aluminum Prod.	Cobalt	secondary	1.53e-07	1.71e-08
Steel Prod., cold-rolled, semi-finished	Vanadium (V3+, V5+)	secondary	1.45e-07	1.63e-08
Natural Gas Prod.	Methyl hydrazine	secondary	1.38e-07	1.54e-08
Steel Prod., cold-rolled, semi-finished	Boron (B III)	secondary	1.32e-07	1.48e-08
Natural Gas Prod.	Mercury	secondary	1.32e-07	1.47e-08
Aluminum Prod.	Cadmium	secondary	1.10e-07	1.23e-08
Natural Gas Prod.	Acetaldehyde	secondary	1.06e-07	1.18e-08
Natural Gas Prod.	Propionaldehyde	secondary	1.06e-07	1.18e-08

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Steel Prod., cold-rolled, semi-finished	Acetic acid	secondary	1.00e-07	1.12e-08
Natural Gas Prod.	Cadmium	secondary	9.80e-08	1.10e-08
Steel Prod., cold-rolled, semi-finished	Triethylene glycol	secondary	9.39e-08	1.05e-08
PET Resin Production	Aluminum (+3)	secondary	9.08e-08	1.01e-08
PET Resin Production	Hydrogen sulfide	secondary	9.08e-08	1.01e-08
PET Resin Production	Lead	secondary	9.08e-08	1.01e-08
PET Resin Production	Nickel (+2)	secondary	9.08e-08	1.01e-08
PET Resin Production	Nitrate	secondary	9.08e-08	1.01e-08
PET Resin Production	Nitrous oxide	secondary	9.08e-08	1.01e-08
PET Resin Production	Zinc (+2)	secondary	9.08e-08	1.01e-08
Styrene-butadiene Copolymer Prod.	Halogenated hydrocarbons (unspecified)	secondary	9.04e-08	1.01e-08
Styrene-butadiene Copolymer Prod.	Hydrogen sulfide	secondary	9.04e-08	1.01e-08
Styrene-butadiene Copolymer Prod.	Lead	secondary	9.04e-08	1.01e-08
Styrene-butadiene Copolymer Prod.	Mercury	secondary	9.04e-08	1.01e-08
Styrene-butadiene Copolymer Prod.	Nickel (+2)	secondary	9.04e-08	1.01e-08
Styrene-butadiene Copolymer Prod.	Nitrous oxide	secondary	9.04e-08	1.01e-08
Styrene-butadiene Copolymer Prod.	Zinc (+2)	secondary	9.04e-08	1.01e-08
Aluminum Prod.	Triethylene glycol	secondary	9.03e-08	1.01e-08
Steel Prod., cold-rolled, semi-finished	Morpholine	secondary	8.78e-08	9.82e-09
Steel Prod., cold-rolled, semi-finished	Strontium	secondary	8.69e-08	9.72e-09
Steel Prod., cold-rolled, semi-finished	Propylene	secondary	8.67e-08	9.70e-09
Steel Prod., cold-rolled, semi-finished	Cadmium	secondary	8.54e-08	9.55e-09
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	8.13e-08	9.09e-09
Aluminum Prod.	Mercury	secondary	7.51e-08	8.40e-09
Steel Prod., cold-rolled, semi-finished	Acetaldehyde	secondary	7.50e-08	8.39e-09
Aluminum Prod.	Cyanide (-1)	secondary	7.05e-08	7.89e-09
Aluminum Prod.	HALON-1301	secondary	6.72e-08	7.51e-09
Steel Prod., cold-rolled, semi-finished	Rubidium ion (Rb+)	secondary	5.93e-08	6.64e-09
Steel Prod., cold-rolled, semi-finished	Fluorine	secondary	5.57e-08	6.23e-09
Aluminum Prod.	Chromium (III)	secondary	4.88e-08	5.46e-09
Steel Prod., cold-rolled, semi-finished	Molybdenum (Mo II, Mo III, Mo IV, Mo V, Mo VI)	secondary	4.44e-08	4.97e-09
Steel Prod., cold-rolled, semi-finished	Benzo[a]pyrene	secondary	4.37e-08	4.89e-09
Natural Gas Prod.	Dimethyl sulfate	secondary	3.89e-08	4.35e-09
Steel Prod., cold-rolled, semi-finished	Acetone	secondary	3.87e-08	4.33e-09
Natural Gas Prod.	Isophorone	secondary	3.73e-08	4.17e-09
Natural Gas Prod.	Zinc (+2)	secondary	3.66e-08	4.09e-09
Natural Gas Prod.	Chlorine	secondary	3.31e-08	3.70e-09
Natural Gas Prod.	Methyl ethyl ketone	secondary	3.01e-08	3.37e-09
Natural Gas Prod.	Tetrachloroethylene	secondary	2.96e-08	3.31e-09
Steel Prod., cold-rolled, semi-finished	Lanthanum	secondary	2.63e-08	2.95e-09
Natural Gas Prod.	Silicon	secondary	2.59e-08	2.90e-09
Natural Gas Prod.	Methyl methacrylate	secondary	2.57e-08	2.88e-09
Steel Prod., cold-rolled, semi-finished	Ethylbenzene	secondary	2.57e-08	2.88e-09
Steel Prod., cold-rolled, semi-finished	Beryllium	secondary	2.31e-08	2.58e-09
Natural Gas Prod.	Barium cmpds	secondary	2.24e-08	2.51e-09
Natural Gas Prod.	1,2-Dichloroethane	secondary	2.14e-08	2.40e-09
Natural Gas Prod.	Bromoform	secondary	2.10e-08	2.35e-09
Natural Gas Prod.	Dichloromethane	secondary	2.03e-08	2.27e-09

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Chlorobenzene	secondary	1.70e-08	1.90e-09
Aluminum Prod.	Strontium	secondary	1.67e-08	1.87e-09
Steel Prod., cold-rolled, semi-finished	Mercury	secondary	1.60e-08	1.79e-09
Steel Prod., cold-rolled, semi-finished	Thorium	secondary	1.41e-08	1.58e-09
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	1.35e-08	1.51e-09
Steel Prod., cold-rolled, semi-finished	HALON-1301	secondary	1.23e-08	1.38e-09
Natural Gas Prod.	3-Methylcholanthrene	secondary	1.18e-08	1.32e-09
Natural Gas Prod.	Chromium (III)	secondary	1.13e-08	1.26e-09
Steel Prod., cold-rolled, semi-finished	Tin	secondary	8.21e-09	9.19e-10
Steel Prod., cold-rolled, semi-finished	Phosphorus pentoxide	secondary	7.88e-09	8.81e-10
Natural Gas Prod.	Ethylbenzene	secondary	6.75e-09	7.55e-10
Steel Prod., cold-rolled, semi-finished	Scandium	secondary	6.40e-09	7.16e-10
Natural Gas Prod.	Aluminum (elemental)	secondary	5.93e-09	6.64e-10
Steel Prod., cold-rolled, semi-finished	Chlorine	secondary	5.59e-09	6.25e-10
Natural Gas Prod.	Phenanthrene	secondary	4.92e-09	5.50e-10
Steel Prod., cold-rolled, semi-finished	Thallium	secondary	4.36e-09	4.87e-10
Aluminum Prod.	1,2-Dichlorotetrafluoroethane	secondary	3.88e-09	4.34e-10
Natural Gas Prod.	2-Methylnaphthalene	secondary	3.78e-09	4.23e-10
Natural Gas Prod.	Methyl tert-butyl ether	secondary	3.38e-09	3.78e-10
Aluminum Prod.	Perfluoroethane	secondary	3.15e-09	3.52e-10
Steel Prod., cold-rolled, semi-finished	Chromium (III)	secondary	2.59e-09	2.90e-10
Steel Prod., cold-rolled, semi-finished	Nitrites	secondary	2.54e-09	2.85e-10
Natural Gas Prod.	Styrene	secondary	2.46e-09	2.76e-10
Natural Gas Prod.	Vinyl acetate	secondary	2.40e-09	2.69e-10
Natural Gas Prod.	Cadmium cmpds	secondary	9.80e-10	1.10e-10
Natural Gas Prod.	Ethylene dibromide	secondary	9.73e-10	1.09e-10
Steel Prod., cold-rolled, semi-finished	Edetic acid (EDTA)	secondary	9.46e-10	1.06e-10
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	9.17e-10	1.03e-10
Steel Prod., cold-rolled, semi-finished	Hypochlorous acid	secondary	8.62e-10	9.64e-11
Steel Prod., cold-rolled, semi-finished	Cobalt (Co I, Co II, Co III)	secondary	7.70e-10	8.61e-11
Steel Prod., cold-rolled, semi-finished	Dichloromethane	secondary	7.10e-10	7.94e-11
Natural Gas Prod.	Ethyl Chloride	secondary	6.50e-10	7.27e-11
Natural Gas Prod.	Cumene	secondary	5.50e-10	6.15e-11
Natural Gas Prod.	Acenaphthylene	secondary	4.89e-10	5.47e-11
Natural Gas Prod.	Benzo[a]anthracene	secondary	3.92e-10	4.38e-11
Natural Gas Prod.	Chrysene	secondary	3.77e-10	4.22e-11
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	3.44e-10	3.85e-11
Natural Gas Prod.	Acetophenone	secondary	3.42e-10	3.83e-11
Natural Gas Prod.	Biphenyl	secondary	3.28e-10	3.67e-11
Natural Gas Prod.	Acenaphthene	secondary	3.14e-10	3.52e-11
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	2.91e-10	3.26e-11
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	2.23e-10	2.49e-11
Natural Gas Prod.	Benzo[a]pyrene	secondary	2.20e-10	2.46e-11
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	1.98e-10	2.21e-11
Natural Gas Prod.	Aromatic hydrocarbons	secondary	1.98e-10	2.21e-11
Natural Gas Prod.	Copper (+1 & +2)	secondary	1.85e-10	2.07e-11
Natural Gas Prod.	Pyrene	secondary	1.71e-10	1.91e-11
Natural Gas Prod.	Fluorene	secondary	1.14e-10	1.28e-11
Natural Gas Prod.	Fluoranthene	secondary	1.02e-10	1.14e-11
Steel Prod., cold-rolled, semi-finished	Isopropylpropionate	secondary	9.91e-11	1.11e-11

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	8.92e-11	9.97e-12
Steel Prod., cold-rolled, semi-finished	Lithium salts	secondary	4.86e-11	5.43e-12
Steel Prod., cold-rolled, semi-finished	Chloroform	secondary	2.65e-11	2.96e-12
Steel Prod., cold-rolled, semi-finished	Zirconium	secondary	2.28e-11	2.55e-12
Steel Prod., cold-rolled, semi-finished	Perfluoromethane	secondary	2.20e-11	2.46e-12
Natural Gas Prod.	5-Methyl chrysene	secondary	1.78e-11	1.99e-12
Natural Gas Prod.	Anthracene	secondary	6.68e-12	7.47e-13
Natural Gas Prod.	Nickel cmpds	secondary	1.96e-12	2.19e-13
Natural Gas Prod.	Lead cmpds	secondary	1.65e-12	1.84e-13
Natural Gas Prod.	Mercury compounds	secondary	9.98e-13	1.12e-13
Natural Gas Prod.	HALON-1301	secondary	7.17e-13	8.02e-14
Steel Prod., cold-rolled, semi-finished	Trichloroethylene	secondary	3.80e-13	4.25e-14
Natural Gas Prod.	Halogenated matter (organic)	secondary	1.65e-13	1.84e-14
Steel Prod., cold-rolled, semi-finished	Propionaldehyde	secondary	2.61e-14	2.91e-15
Steel Prod., cold-rolled, semi-finished	Tetrachloroethylene	secondary	1.07e-14	1.20e-15
Steel Prod., cold-rolled, semi-finished	Benzaldehyde	secondary	2.32e-15	2.59e-16
Steel Prod., cold-rolled, semi-finished	1,1,1-Trichloroethane	secondary	1.57e-15	1.76e-16
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	4.11e-16	4.60e-17
Steel Prod., cold-rolled, semi-finished	Hexachloroethane	secondary	6.02e-17	6.73e-18
Total Materials Processing			**4.54e+01**	**5.08e+00**
Manufacturing Life-cycle Stage				
Japanese Electric Grid	Sulfur dioxide	model/secondary	1.92e+02	2.14e+01
Monitor/module	Phosphine	primary	2.87e+01	3.21e+00
Monitor/module	Phosphorus (yellow or white)	primary	3.42e+00	3.82e-01
US electric grid	Sulfur dioxide	model/secondary	3.19e+00	3.57e-01
Monitor/module	Fluorides (F-)	primary	2.54e+00	2.84e-01
Monitor/module	Tetramethyl ammonium hydroxide	primary	6.43e-01	7.19e-02
Monitor/module	Nitrogen oxides	primary	5.48e-01	6.13e-02
Monitor/module	Hydrochloric acid	primary	2.77e-01	3.10e-02
LPG Production	Carbon monoxide	secondary	2.56e-01	2.87e-02
Monitor/module	Nitrogen fluoride	primary	2.45e-01	2.74e-02
Japanese Electric Grid	Nitrogen oxides	model/secondary	1.37e-01	1.53e-02
Natural Gas Prod.	Benzene	secondary	1.19e-01	1.33e-02
Japanese Electric Grid	Carbon monoxide	model/secondary	1.18e-01	1.32e-02
Monitor/module	Ammonia	primary	1.07e-01	1.20e-02
Natural Gas Prod.	Carbon monoxide	secondary	1.00e-01	1.12e-02
Natural Gas Prod.	Methane	secondary	7.91e-02	8.85e-03
Japanese Electric Grid	Vanadium	model/secondary	7.62e-02	8.53e-03
Monitor/module	Hydrofluoric acid	primary	5.21e-02	5.82e-03
LPG Production	Vanadium	secondary	5.02e-02	5.62e-03
LPG Production	Benzene	secondary	4.11e-02	4.60e-03
LPG Production	Methane	secondary	4.02e-02	4.50e-03
LPG Production	Sulfur oxides	secondary	3.85e-02	4.30e-03
Japanese Electric Grid	Arsenic	model/secondary	3.51e-02	3.92e-03
Backlight	Nitrogen oxides	primary	2.95e-02	3.29e-03
LPG Production	Nitrogen oxides	secondary	2.75e-02	3.07e-03
LCD glass mfg.	Fluorides (F-)	primary	2.70e-02	3.01e-03
Japanese Electric Grid	Hydrochloric acid	model/secondary	2.11e-02	2.36e-03
Panel components	Phosphorus (yellow or white)	primary	1.97e-02	2.20e-03

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Nitrogen oxides	secondary	1.47e-02	1.64e-03
LPG Production	Arsenic	secondary	9.91e-03	1.11e-03
Monitor/module	N-bromoacetamide	primary	9.18e-03	1.03e-03
Monitor/module	Sulfur hexafluoride	primary	7.30e-03	8.16e-04
Japanese Electric Grid	PM-10	model/secondary	6.72e-03	7.52e-04
LPG Production	Formaldehyde	secondary	6.43e-03	7.19e-04
LPG Production	PM	secondary	6.19e-03	6.92e-04
Monitor/module	Isopropyl alcohol	primary	4.55e-03	5.09e-04
Japanese Electric Grid	Fluorides (F-)	model/secondary	4.41e-03	4.93e-04
Japanese Electric Grid	Selenium	model/secondary	4.29e-03	4.80e-04
Japanese Electric Grid	Formaldehyde	model/secondary	3.93e-03	4.39e-04
US electric grid	Nitrogen oxides	model/secondary	2.28e-03	2.55e-04
Fuel Oil #4 Prod.	Carbon monoxide	secondary	2.16e-03	2.42e-04
Japanese Electric Grid	Zinc (elemental)	model/secondary	2.06e-03	2.31e-04
LCD glass mfg.	Nitrogen oxides	primary	2.04e-03	2.29e-04
PWB Mfg.	Formaldehyde	model/secondary	1.96e-03	2.19e-04
US electric grid	Carbon monoxide	model/secondary	1.96e-03	2.19e-04
LPG Production	Hydrochloric acid	secondary	1.77e-03	1.97e-04
Monitor/module	Arsenic	primary	1.70e-03	1.90e-04
Monitor/module	Monosilane	primary	1.54e-03	1.72e-04
US electric grid	Methane	model/secondary	1.25e-03	1.40e-04
Monitor/module	Sulfur oxides	primary	1.12e-03	1.25e-04
Japanese Electric Grid	Antimony	model/secondary	1.09e-03	1.22e-04
US electric grid	Arsenic	model/secondary	1.08e-03	1.21e-04
US electric grid	Hydrochloric acid	model/secondary	9.54e-04	1.07e-04
Fuel Oil #6 Prod.	Carbon monoxide	secondary	8.92e-04	9.98e-05
LPG Production	Nitrous oxide	secondary	7.78e-04	8.71e-05
Fuel Oil #2 Prod.	Carbon monoxide	secondary	7.27e-04	8.13e-05
Natural Gas Prod.	PM	secondary	6.53e-04	7.30e-05
Fuel Oil #4 Prod.	Vanadium	secondary	6.21e-04	6.94e-05
Monitor/module	Hexane	primary	5.88e-04	6.58e-05
Japanese Electric Grid	Hydrofluoric acid	model/secondary	5.77e-04	6.45e-05
Natural Gas Prod.	Arsenic	secondary	4.96e-04	5.55e-05
LPG Production	Phosphorus (yellow or white)	secondary	4.71e-04	5.27e-05
Japanese Electric Grid	Molybdenum	model/secondary	4.42e-04	4.94e-05
Natural Gas Prod.	Sulfur oxides	secondary	4.35e-04	4.86e-05
Natural Gas Prod.	Ammonia	secondary	4.24e-04	4.74e-05
Panel components	Nitrogen oxides	primary	4.11e-04	4.60e-05
Fuel Oil #4 Prod.	Methane	secondary	4.02e-04	4.49e-05
Fuel Oil #4 Prod.	Sulfur oxides	secondary	3.77e-04	4.22e-05
Japanese Electric Grid	Nitrous oxide	model/secondary	3.76e-04	4.20e-05
Fuel Oil #4 Prod.	Benzene	secondary	3.71e-04	4.15e-05
Fuel Oil #6 Prod.	Vanadium	secondary	3.67e-04	4.10e-05
LPG Production	Fluorides (F-)	secondary	3.60e-04	4.03e-05
LPG Production	Selenium	secondary	3.56e-04	3.98e-05
Monitor/module	Zinc (elemental)	primary	3.13e-04	3.50e-05
Japanese Electric Grid	Benzene	model/secondary	3.06e-04	3.42e-05
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	2.77e-04	3.09e-05
Japanese Electric Grid	Methane	model/secondary	2.73e-04	3.06e-05
Monitor/module	Nitric acid	primary	2.68e-04	3.00e-05

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #6 Prod.	Methane	secondary	2.01e-04	2.24e-05
Fuel Oil #6 Prod.	Sulfur oxides	secondary	1.86e-04	2.08e-05
Monitor/module	Phosphoric acid	primary	1.85e-04	2.07e-05
US electric grid	Selenium	model/secondary	1.80e-04	2.01e-05
LPG Production	Ammonia	secondary	1.79e-04	2.01e-05
Fuel Oil #6 Prod.	Benzene	secondary	1.67e-04	1.86e-05
Fuel Oil #2 Prod.	Vanadium	secondary	1.61e-04	1.80e-05
LPG Production	Hydrogen sulfide	secondary	1.47e-04	1.65e-05
Panel components	HCFC-225ca	primary	1.40e-04	1.56e-05
Panel components	HCFC-225cb	primary	1.40e-04	1.56e-05
Fuel Oil #6 Prod.	Nitrogen oxides	secondary	1.39e-04	1.56e-05
US electric grid	Vanadium	model/secondary	1.35e-04	1.51e-05
Fuel Oil #2 Prod.	Methane	secondary	1.20e-04	1.34e-05
Fuel Oil #2 Prod.	Benzene	secondary	1.19e-04	1.33e-05
Japanese Electric Grid	Nickel	model/secondary	1.18e-04	1.32e-05
Fuel Oil #2 Prod.	Sulfur oxides	secondary	1.14e-04	1.27e-05
US electric grid	PM-10	model/secondary	1.12e-04	1.25e-05
Natural Gas Prod.	Vanadium	secondary	1.10e-04	1.23e-05
Fuel Oil #4 Prod.	Arsenic	secondary	1.08e-04	1.21e-05
Natural Gas Prod.	Hydrochloric acid	secondary	1.01e-04	1.13e-05
Japanese Electric Grid	Barium	model/secondary	9.88e-05	1.10e-05
Monitor/module	Acetic acid	primary	8.27e-05	9.25e-06
Fuel Oil #2 Prod.	Nitrogen oxides	secondary	8.20e-05	9.17e-06
Fuel Oil #4 Prod.	Formaldehyde	secondary	7.91e-05	8.85e-06
LPG Production	Molybdenum	secondary	7.90e-05	8.84e-06
Fuel Oil #4 Prod.	PM	secondary	6.24e-05	6.97e-06
Fuel Oil #6 Prod.	Arsenic	secondary	5.87e-05	6.57e-06
LPG Production	Zinc (elemental)	secondary	5.75e-05	6.44e-06
Japanese Electric Grid	Naphthalene	model/secondary	5.50e-05	6.15e-06
LPG Production	Hydrofluoric acid	secondary	4.82e-05	5.39e-06
Fuel Oil #6 Prod.	Formaldehyde	secondary	4.66e-05	5.21e-06
Natural Gas Prod.	Formaldehyde	secondary	4.37e-05	4.88e-06
Monitor/module	Antimony	primary	3.88e-05	4.34e-06
LPG Production	Ethane	secondary	3.72e-05	4.16e-06
LPG Production	Phenol	secondary	3.43e-05	3.84e-06
Panel components	Hydrochloric acid	primary	3.35e-05	3.75e-06
Panel components	Heptane	primary	3.28e-05	3.66e-06
Fuel Oil #6 Prod.	PM	secondary	3.15e-05	3.52e-06
LPG Production	Pentane	secondary	3.12e-05	3.49e-06
Fuel Oil #2 Prod.	Arsenic	secondary	3.04e-05	3.40e-06
Panel components	PM	primary	2.74e-05	3.07e-06
US electric grid	Hydrofluoric acid	model/secondary	2.60e-05	2.91e-06
Japanese Electric Grid	Copper	model/secondary	2.40e-05	2.69e-06
Monitor/module	Acetone	primary	2.22e-05	2.48e-06
LPG Production	Hexane	secondary	2.16e-05	2.42e-06
Natural Gas Prod.	Fluorides (F-)	secondary	2.13e-05	2.38e-06
Monitor/module	Copper	primary	2.06e-05	2.30e-06
Fuel Oil #2 Prod.	Formaldehyde	secondary	2.06e-05	2.30e-06
Monitor/module	Polychlorinated biphenyls	primary	1.94e-05	2.17e-06

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Selenium	secondary	1.91e-05	2.14e-06
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	1.90e-05	2.12e-06
US electric grid	Formaldehyde	model/secondary	1.88e-05	2.10e-06
Japanese Electric Grid	2-Chloroacetophenone	model/secondary	1.85e-05	2.07e-06
Fuel Oil #2 Prod.	PM	secondary	1.85e-05	2.07e-06
Japanese Electric Grid	Bromomethane	model/secondary	1.83e-05	2.05e-06
Natural Gas Prod.	Nitrous oxide	secondary	1.82e-05	2.04e-06
LPG Production	Nickel	secondary	1.39e-05	1.56e-06
US electric grid	Benzene	model/secondary	1.35e-05	1.51e-06
Natural Gas Prod.	Zinc (elemental)	secondary	1.34e-05	1.50e-06
Natural Gas Prod.	Ethane	secondary	1.10e-05	1.23e-06
Monitor/module	PM	primary	1.10e-05	1.23e-06
LPG Production	PM-10	secondary	1.08e-05	1.21e-06
LPG Production	Antimony	secondary	1.03e-05	1.15e-06
Fuel Oil #6 Prod.	Hydrochloric acid	secondary	1.01e-05	1.13e-06
Japanese Electric Grid	Cyanide (-1)	model/secondary	9.61e-06	1.07e-06
Natural Gas Prod.	Pentane	secondary	9.24e-06	1.03e-06
Panel components	Toluene	primary	9.09e-06	1.02e-06
Fuel Oil #4 Prod.	Nitrous oxide	secondary	8.86e-06	9.91e-07
Monitor/module	Chromium	primary	8.84e-06	9.88e-07
US electric grid	Phosphorus (yellow or white)	model/secondary	7.61e-06	8.51e-07
Japanese Electric Grid	2,3,7,8-TCDD	model/secondary	7.47e-06	8.36e-07
LPG Production	Aluminum (+3)	secondary	6.79e-06	7.60e-07
US electric grid	Nitrous oxide	model/secondary	6.58e-06	7.36e-07
Natural Gas Prod.	Hexane	secondary	6.40e-06	7.15e-07
Monitor/module	Boron	primary	6.19e-06	6.93e-07
Monitor/module	Lead	primary	6.17e-06	6.90e-07
Fuel Oil #4 Prod.	Phosphorus (yellow or white)	secondary	5.71e-06	6.38e-07
Fuel Oil #2 Prod.	Hydrochloric acid	secondary	5.39e-06	6.02e-07
LCD glass mfg.	PM	primary	5.06e-06	5.66e-07
Fuel Oil #6 Prod.	Nitrous oxide	secondary	4.94e-06	5.53e-07
LPG Production	Chromium (VI)	secondary	4.84e-06	5.41e-07
Japanese Electric Grid	Cobalt	model/secondary	3.98e-06	4.45e-07
Fuel Oil #4 Prod.	Selenium	secondary	3.85e-06	4.31e-07
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	3.79e-06	4.24e-07
Monitor/module	Cyanide (-1)	primary	3.66e-06	4.10e-07
Natural Gas Prod.	Molybdenum	secondary	3.64e-06	4.08e-07
US electric grid	Zinc (elemental)	model/secondary	3.51e-06	3.93e-07
Japanese Electric Grid	Carbon disulfide	model/secondary	3.43e-06	3.84e-07
Fuel Oil #6 Prod.	Phosphorus (yellow or white)	secondary	3.33e-06	3.72e-07
LPG Production	Nitrate	secondary	2.91e-06	3.25e-07
US electric grid	Antimony	model/secondary	2.87e-06	3.21e-07
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	2.79e-06	3.12e-07
Natural Gas Prod.	Hydrofluoric acid	secondary	2.75e-06	3.07e-07
Japanese Electric Grid	Benzyl chloride	model/secondary	2.69e-06	3.01e-07
LCD glass mfg.	Carbon monoxide	primary	2.59e-06	2.89e-07
Fuel Oil #2 Prod.	Nitrous oxide	secondary	2.42e-06	2.71e-07
LCD glass mfg.	Sulfur oxides	primary	2.35e-06	2.63e-07
Monitor/module	Cyclohexane	primary	2.22e-06	2.48e-07
Backlight	Diethyl ether	primary	2.20e-06	2.47e-07
Japanese Electric Grid	Chromium (VI)	model/secondary	2.15e-06	2.40e-07

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Japanese Electric Grid	Chloroform	model/secondary	2.09e-06	2.34e-07
Fuel Oil #6 Prod.	Selenium	secondary	2.07e-06	2.31e-07
LCD glass mfg.	Lead	primary	2.01e-06	2.25e-07
Fuel Oil #6 Prod.	Fluorides (F-)	secondary	1.99e-06	2.22e-07
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	1.83e-06	2.04e-07
LPG Production	Copper	secondary	1.67e-06	1.87e-07
Fuel Oil #4 Prod.	Ammonia	secondary	1.58e-06	1.76e-07
LPG Production	2-Chloroacetophenone	secondary	1.54e-06	1.73e-07
LPG Production	Dimethylbenzanthracene	secondary	1.53e-06	1.71e-07
LPG Production	Bromomethane	secondary	1.53e-06	1.71e-07
Fuel Oil #2 Prod.	Phosphorus (yellow or white)	secondary	1.50e-06	1.68e-07
Monitor/module	Hexamethyldisilizane	primary	1.37e-06	1.53e-07
LPG Production	Naphthalene	secondary	1.24e-06	1.38e-07
Japanese Electric Grid	Acrolein	model/secondary	1.11e-06	1.25e-07
Fuel Oil #2 Prod.	Fluorides (F-)	secondary	1.09e-06	1.22e-07
Monitor/module	Chromium (VI)	primary	1.09e-06	1.22e-07
Fuel Oil #2 Prod.	Selenium	secondary	1.09e-06	1.22e-07
Fuel Oil #6 Prod.	Hydrogen sulfide	secondary	1.08e-06	1.21e-07
LPG Production	Manganese	secondary	1.07e-06	1.20e-07
US electric grid	Molybdenum	model/secondary	9.61e-07	1.07e-07
Fuel Oil #4 Prod.	Molybdenum	secondary	9.29e-07	1.04e-07
Monitor/module	Diethylene glycol	primary	9.23e-07	1.03e-07
Japanese Electric Grid	Methyl chloride	model/secondary	9.03e-07	1.01e-07
LPG Production	Barium	secondary	8.94e-07	1.00e-07
US electric grid	2-Chloroacetophenone	model/secondary	8.35e-07	9.34e-08
US electric grid	Bromomethane	model/secondary	8.27e-07	9.24e-08
LPG Production	Silicon	secondary	8.12e-07	9.08e-08
Japanese Electric Grid	Toluene	model/secondary	8.04e-07	8.99e-08
LPG Production	Cyanide (-1)	secondary	8.03e-07	8.98e-08
LPG Production	Barium cmpds	secondary	7.62e-07	8.52e-08
Natural Gas Prod.	Antimony	secondary	7.01e-07	7.84e-08
Fuel Oil #6 Prod.	Ammonia	secondary	6.85e-07	7.66e-08
Japanese Electric Grid	Methyl hydrazine	model/secondary	6.54e-07	7.31e-08
LPG Production	Lead	secondary	5.93e-07	6.63e-08
Monitor/module	Nickel	primary	5.45e-07	6.10e-08
Fuel Oil #6 Prod.	Molybdenum	secondary	5.30e-07	5.93e-08
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	5.17e-07	5.79e-08
Fuel Oil #2 Prod.	Ammonia	secondary	5.14e-07	5.75e-08
Fuel Oil #4 Prod.	Zinc (elemental)	secondary	5.10e-07	5.71e-08
Japanese Electric Grid	Acetaldehyde	model/secondary	5.02e-07	5.61e-08
Japanese Electric Grid	Propionaldehyde	model/secondary	5.02e-07	5.61e-08
Japanese Electric Grid	Cadmium	model/secondary	4.74e-07	5.30e-08
Fuel Oil #2 Prod.	Hydrogen sulfide	secondary	4.72e-07	5.28e-08
Monitor/module	Tin	primary	4.58e-07	5.12e-08
Natural Gas Prod.	Dimethylbenzanthracene	secondary	4.53e-07	5.07e-08
US electric grid	Cyanide (-1)	model/secondary	4.34e-07	4.85e-08
Japanese Electric Grid	Mercury	model/secondary	3.97e-07	4.44e-08
Japanese Electric Grid	Di(2-ethylhexyl)phthalate	model/secondary	3.86e-07	4.31e-08
Fuel Oil #4 Prod.	Ethane	secondary	3.36e-07	3.76e-08

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	2,3,7,8-TCDD	model/secondary	3.28e-07	3.67e-08
US electric grid	Nickel	model/secondary	3.16e-07	3.53e-08
LPG Production	Carbon disulfide	secondary	2.87e-07	3.21e-08
Fuel Oil #4 Prod.	Pentane	secondary	2.82e-07	3.15e-08
Fuel Oil #6 Prod.	Hydrofluoric acid	secondary	2.76e-07	3.08e-08
US electric grid	Naphthalene	model/secondary	2.62e-07	2.92e-08
Japanese Electric Grid	Hexane	model/secondary	2.58e-07	2.88e-08
Fuel Oil #4 Prod.	Phenol	secondary	2.51e-07	2.81e-08
Fuel Oil #2 Prod.	Molybdenum	secondary	2.49e-07	2.78e-08
Monitor/module	Manganese	primary	2.29e-07	2.56e-08
US electric grid	Barium	model/secondary	2.25e-07	2.52e-08
LPG Production	Benzyl chloride	secondary	2.25e-07	2.51e-08
Fuel Oil #6 Prod.	Zinc (elemental)	secondary	2.25e-07	2.51e-08
Natural Gas Prod.	Naphthalene	secondary	2.05e-07	2.29e-08
Fuel Oil #4 Prod.	Hexane	secondary	1.95e-07	2.18e-08
Natural Gas Prod.	Nickel	secondary	1.94e-07	2.17e-08
LPG Production	Aluminum (elemental)	secondary	1.86e-07	2.08e-08
Japanese Electric Grid	Dimethyl sulfate	model/secondary	1.85e-07	2.06e-08
LCD glass mfg.	Nitrate	primary	1.83e-07	2.05e-08
Japanese Electric Grid	Isophorone	model/secondary	1.77e-07	1.98e-08
LPG Production	Chloroform	secondary	1.75e-07	1.95e-08
Fuel Oil #4 Prod.	Nickel	secondary	1.66e-07	1.86e-08
Fuel Oil #2 Prod.	Zinc (elemental)	secondary	1.65e-07	1.85e-08
US electric grid	Carbon disulfide	model/secondary	1.55e-07	1.73e-08
Fuel Oil #6 Prod.	Ethane	secondary	1.51e-07	1.69e-08
Natural Gas Prod.	Chromium (VI)	secondary	1.49e-07	1.67e-08
Fuel Oil #2 Prod.	Hydrofluoric acid	secondary	1.47e-07	1.64e-08
Japanese Electric Grid	Methyl ethyl ketone	model/secondary	1.43e-07	1.60e-08
Japanese Electric Grid	Tetrachloroethylene	model/secondary	1.41e-07	1.57e-08
Fuel Oil #4 Prod.	PM-10	secondary	1.34e-07	1.50e-08
Fuel Oil #6 Prod.	Pentane	secondary	1.27e-07	1.42e-08
Japanese Electric Grid	Methyl methacrylate	model/secondary	1.22e-07	1.36e-08
US electric grid	Benzyl chloride	model/secondary	1.22e-07	1.36e-08
LPG Production	Cobalt	secondary	1.21e-07	1.35e-08
Monitor/module	Cadmium	primary	1.14e-07	1.28e-08
Japanese Electric Grid	Beryllium	model/secondary	1.09e-07	1.22e-08
Fuel Oil #2 Prod.	Ethane	secondary	1.08e-07	1.20e-08
Natural Gas Prod.	Hydrogen sulfide	secondary	1.06e-07	1.19e-08
Japanese Electric Grid	1,2-Dichloroethane	model/secondary	1.02e-07	1.14e-08
Japanese Electric Grid	Bromoform	model/secondary	9.97e-08	1.11e-08
Monitor/module	Mercury	primary	9.69e-08	1.08e-08
Japanese Electric Grid	Dichloromethane	model/secondary	9.62e-08	1.08e-08
Fuel Oil #6 Prod.	Nickel	secondary	9.56e-08	1.07e-08
US electric grid	Chloroform	model/secondary	9.45e-08	1.06e-08
Fuel Oil #2 Prod.	Phenol	secondary	9.37e-08	1.05e-08
LPG Production	Acrolein	secondary	9.31e-08	1.04e-08
Natural Gas Prod.	Barium	secondary	9.30e-08	1.04e-08
Fuel Oil #4 Prod.	Antimony	secondary	9.13e-08	1.02e-08
Fuel Oil #2 Prod.	Pentane	secondary	9.02e-08	1.01e-08
US electric grid	Manganese	model/secondary	8.83e-08	9.87e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	8.80e-08	9.84e-09

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #6 Prod.	Hexane	secondary	8.78e-08	9.82e-09
Natural Gas Prod.	Bromomethane	secondary	8.71e-08	9.74e-09
Natural Gas Prod.	Copper	secondary	8.32e-08	9.31e-09
Fuel Oil #6 Prod.	Phenol	secondary	8.24e-08	9.21e-09
Japanese Electric Grid	Chlorobenzene	model/secondary	8.05e-08	9.01e-09
Fuel Oil #6 Prod.	PM-10	secondary	7.94e-08	8.88e-09
LPG Production	Methyl chloride	secondary	7.54e-08	8.43e-09
Panel components	Methyl ethyl ketone	primary	6.97e-08	7.79e-09
LPG Production	Beryllium	secondary	6.74e-08	7.54e-09
US electric grid	Chromium (VI)	model/secondary	6.65e-08	7.44e-09
Japanese Electric Grid	2,4-Dinitrotoluene	model/secondary	6.39e-08	7.14e-09
Fuel Oil #2 Prod.	Hexane	secondary	6.25e-08	6.99e-09
Natural Gas Prod.	Manganese	secondary	6.23e-08	6.97e-09
LPG Production	Methyl hydrazine	secondary	5.46e-08	6.10e-09
US electric grid	Acrolein	model/secondary	5.04e-08	5.63e-09
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	4.98e-08	5.57e-09
Natural Gas Prod.	Cyanide (-1)	secondary	4.57e-08	5.12e-09
Monitor/module	Phenol	primary	4.54e-08	5.08e-09
Japanese Electric Grid	Cumene hydroperoxide	model/secondary	4.51e-08	5.05e-09
Fuel Oil #2 Prod.	Nickel	secondary	4.40e-08	4.93e-09
US electric grid	Copper	model/secondary	4.33e-08	4.84e-09
LPG Production	Acetaldehyde	secondary	4.19e-08	4.69e-09
LPG Production	Propionaldehyde	secondary	4.19e-08	4.69e-09
LPG Production	Mercury	secondary	4.17e-08	4.66e-09
US electric grid	Methyl chloride	model/secondary	4.08e-08	4.56e-09
Fuel Oil #6 Prod.	Antimony	secondary	4.03e-08	4.51e-09
LPG Production	Cadmium	secondary	3.89e-08	4.35e-09
US electric grid	Fluoride	model/secondary	3.78e-08	4.23e-09
Japanese Electric Grid	Ethylbenzene	model/secondary	3.49e-08	3.91e-09
Fuel Oil #2 Prod.	PM-10	secondary	3.47e-08	3.88e-09
Natural Gas Prod.	Lead	secondary	3.42e-08	3.82e-09
LPG Production	Cadmium cmpds	secondary	3.33e-08	3.73e-09
LPG Production	Di(2-ethylhexyl)phthalate	secondary	3.22e-08	3.60e-09
LPG Production	Toluene	secondary	2.99e-08	3.34e-09
US electric grid	Methyl hydrazine	model/secondary	2.95e-08	3.30e-09
Fuel Oil #2 Prod.	Antimony	secondary	2.95e-08	3.30e-09
Fuel Oil #4 Prod.	Chromium (VI)	secondary	2.60e-08	2.91e-09
US electric grid	Lead	model/secondary	2.47e-08	2.76e-09
Natural Gas Prod.	Nitrate	secondary	2.37e-08	2.65e-09
US electric grid	Cobalt	model/secondary	2.35e-08	2.63e-09
Natural Gas Prod.	Phenol	secondary	2.30e-08	2.57e-09
US electric grid	Propionaldehyde	model/secondary	2.27e-08	2.53e-09
US electric grid	Acetaldehyde	model/secondary	2.27e-08	2.53e-09
Fuel Oil #4 Prod.	Nitrate	secondary	2.26e-08	2.53e-09
Monitor/module	Tetrachloroethylene	primary	1.95e-08	2.18e-09
Fuel Oil #4 Prod.	Copper	secondary	1.92e-08	2.15e-09
Fuel Oil #2 Prod.	Aluminum (+3)	secondary	1.85e-08	2.07e-09
Japanese Electric Grid	Phenanthrene	model/secondary	1.75e-08	1.96e-09
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	1.74e-08	1.95e-09

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	1,4-Dichlorobenzene	secondary	1.71e-08	1.92e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	1.66e-08	1.85e-09
Fuel Oil #4 Prod.	Bromomethane	secondary	1.64e-08	1.84e-09
Natural Gas Prod.	Carbon disulfide	secondary	1.63e-08	1.83e-09
Fuel Oil #6 Prod.	Aluminum (+3)	secondary	1.63e-08	1.82e-09
Japanese Electric Grid	Methyl tert-butyl ether	model/secondary	1.60e-08	1.79e-09
LPG Production	Dimethyl sulfate	secondary	1.54e-08	1.72e-09
Japanese Electric Grid	Chromium (III)	model/secondary	1.51e-08	1.68e-09
LPG Production	Isophorone	secondary	1.48e-08	1.65e-09
US electric grid	Mercury	model/secondary	1.45e-08	1.63e-09
Fuel Oil #6 Prod.	Chromium (VI)	secondary	1.39e-08	1.56e-09
Fuel Oil #4 Prod.	Dimethylbenzanthracene	secondary	1.38e-08	1.55e-09
Natural Gas Prod.	Toluene	secondary	1.36e-08	1.52e-09
Natural Gas Prod.	Benzyl chloride	secondary	1.28e-08	1.43e-09
Japanese Electric Grid	1,1,1-Trichloroethane	model/secondary	1.23e-08	1.37e-09
Japanese Electric Grid	Phenol	model/secondary	1.22e-08	1.36e-09
LPG Production	Methyl ethyl ketone	secondary	1.19e-08	1.33e-09
LPG Production	Tetrachloroethylene	secondary	1.17e-08	1.31e-09
Japanese Electric Grid	Styrene	model/secondary	1.17e-08	1.31e-09
US electric grid	Hexane	model/secondary	1.16e-08	1.30e-09
Fuel Oil #4 Prod.	Naphthalene	secondary	1.15e-08	1.28e-09
Fuel Oil #4 Prod.	Manganese	secondary	1.15e-08	1.28e-09
Japanese Electric Grid	Vinyl acetate	model/secondary	1.14e-08	1.27e-09
Monitor/module	Trichloroethylene	primary	1.14e-08	1.27e-09
Fuel Oil #6 Prod.	Copper	secondary	1.08e-08	1.21e-09
LCD glass mfg.	Chromium	primary	1.02e-08	1.14e-09
LPG Production	Methyl methacrylate	secondary	1.02e-08	1.14e-09
Fuel Oil #4 Prod.	Silicon	secondary	1.01e-08	1.13e-09
Natural Gas Prod.	Chloroform	secondary	9.96e-09	1.11e-09
Japanese Electric Grid	Xylene (mixed isomers)	model/secondary	9.46e-09	1.06e-09
US electric grid	Cadmium	model/secondary	9.33e-09	1.04e-09
LCD glass mfg.	Nickel	primary	9.05e-09	1.01e-09
Fuel Oil #6 Prod.	2-Chloroacetophenone	secondary	8.84e-09	9.89e-10
Fuel Oil #6 Prod.	Bromomethane	secondary	8.75e-09	9.79e-10
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	8.62e-09	9.64e-10
LPG Production	1,2-Dichloroethane	secondary	8.49e-09	9.50e-10
US electric grid	Dimethyl sulfate	model/secondary	8.33e-09	9.32e-10
LPG Production	Bromoform	secondary	8.32e-09	9.31e-10
Fuel Oil #6 Prod.	Nitrate	secondary	8.26e-09	9.24e-10
LPG Production	Chromium (III)	secondary	8.24e-09	9.21e-10
US electric grid	Toluene	model/secondary	8.23e-09	9.20e-10
Fuel Oil #2 Prod.	Nitrate	secondary	8.06e-09	9.01e-10
LPG Production	Dichloromethane	secondary	8.04e-09	8.99e-10
US electric grid	Isophorone	model/secondary	7.99e-09	8.94e-10
Fuel Oil #4 Prod.	Barium	secondary	7.83e-09	8.76e-10
Natural Gas Prod.	PM-10	secondary	7.79e-09	8.71e-10
Fuel Oil #2 Prod.	Chromium (VI)	secondary	7.39e-09	8.26e-10
Natural Gas Prod.	o-xylene	secondary	7.25e-09	8.11e-10
LPG Production	Chlorobenzene	secondary	6.72e-09	7.52e-10
LPG Production	Aromatic hydrocarbons	secondary	6.72e-09	7.51e-10
US electric grid	Methyl ethyl ketone	model/secondary	6.45e-09	7.21e-10

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Lead	secondary	6.38e-09	7.13e-10
US electric grid	Tetrachloroethylene	model/secondary	6.35e-09	7.10e-10
LPG Production	Copper (+1 & +2)	secondary	6.29e-09	7.03e-10
Fuel Oil #6 Prod.	Dimethylbenzanthracene	secondary	6.21e-09	6.95e-10
Fuel Oil #6 Prod.	Manganese	secondary	6.09e-09	6.81e-10
Fuel Oil #6 Prod.	Silicon	secondary	5.97e-09	6.67e-10
Fuel Oil #4 Prod.	Barium cmpds	secondary	5.58e-09	6.24e-10
US electric grid	Methyl methacrylate	model/secondary	5.51e-09	6.16e-10
LPG Production	2,4-Dinitrotoluene	secondary	5.35e-09	5.98e-10
Fuel Oil #6 Prod.	Naphthalene	secondary	5.32e-09	5.95e-10
Natural Gas Prod.	Acrolein	secondary	5.31e-09	5.93e-10
Fuel Oil #2 Prod.	Copper	secondary	5.22e-09	5.84e-10
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	5.07e-09	5.67e-10
Japanese Electric Grid	Acenaphthene	model/secondary	4.94e-09	5.52e-10
Fuel Oil #2 Prod.	2-Chloroacetophenone	secondary	4.71e-09	5.27e-10
Fuel Oil #2 Prod.	Bromomethane	secondary	4.66e-09	5.22e-10
Japanese Electric Grid	Ethylene dibromide	model/secondary	4.61e-09	5.16e-10
Fuel Oil #6 Prod.	Cyanide (-1)	secondary	4.60e-09	5.14e-10
US electric grid	1,2-Dichloroethane	model/secondary	4.59e-09	5.14e-10
Natural Gas Prod.	Aluminum (+3)	secondary	4.51e-09	5.05e-10
US electric grid	Bromoform	model/secondary	4.50e-09	5.04e-10
Fuel Oil #2 Prod.	Dimethylbenzanthracene	secondary	4.43e-09	4.95e-10
Natural Gas Prod.	Beryllium	secondary	4.41e-09	4.93e-10
US electric grid	Dichloromethane	model/secondary	4.35e-09	4.86e-10
Japanese Electric Grid	o-xylene	model/secondary	4.31e-09	4.83e-10
Natural Gas Prod.	Methyl chloride	secondary	4.30e-09	4.81e-10
Natural Gas Prod.	Cobalt	secondary	4.16e-09	4.66e-10
US electric grid	Beryllium	model/secondary	3.69e-09	4.13e-10
US electric grid	Chlorobenzene	model/secondary	3.64e-09	4.07e-10
Fuel Oil #2 Prod.	Naphthalene	secondary	3.60e-09	4.03e-10
Fuel Oil #6 Prod.	Lead	secondary	3.40e-09	3.81e-10
Fuel Oil #6 Prod.	Barium	secondary	3.39e-09	3.80e-10
LPG Production	o-xylene	secondary	3.29e-09	3.68e-10
Fuel Oil #2 Prod.	Manganese	secondary	3.26e-09	3.65e-10
Natural Gas Prod.	Methyl hydrazine	secondary	3.11e-09	3.48e-10
Japanese Electric Grid	Ethyl Chloride	model/secondary	3.08e-09	3.45e-10
Fuel Oil #4 Prod.	Carbon disulfide	secondary	3.08e-09	3.44e-10
Natural Gas Prod.	Mercury	secondary	2.97e-09	3.32e-10
US electric grid	2,4-Dinitrotoluene	model/secondary	2.89e-09	3.24e-10
Japanese Electric Grid	Benzo[a]anthracene	model/secondary	2.69e-09	3.01e-10
LPG Production	Ethylbenzene	secondary	2.67e-09	2.98e-10
Fuel Oil #2 Prod.	Silicon	secondary	2.60e-09	2.91e-10
Fuel Oil #2 Prod.	Barium	secondary	2.56e-09	2.87e-10
Fuel Oil #2 Prod.	Cyanide (-1)	secondary	2.45e-09	2.74e-10
Fuel Oil #4 Prod.	Benzyl chloride	secondary	2.41e-09	2.70e-10
Natural Gas Prod.	Acetaldehyde	secondary	2.39e-09	2.67e-10
Natural Gas Prod.	Propionaldehyde	secondary	2.39e-09	2.67e-10
Fuel Oil #4 Prod.	Aluminum (elemental)	secondary	2.31e-09	2.58e-10
Natural Gas Prod.	Cadmium	secondary	2.21e-09	2.47e-10

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #2 Prod.	Barium cmpds	secondary	2.08e-09	2.32e-10
Fuel Oil #4 Prod.	Chloroform	secondary	1.88e-09	2.10e-10
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	1.84e-09	2.05e-10
Fuel Oil #6 Prod.	Barium cmpds	secondary	1.83e-09	2.04e-10
Fuel Oil #2 Prod.	Lead	secondary	1.81e-09	2.02e-10
Japanese Electric Grid	Chrysene	model/secondary	1.80e-09	2.01e-10
Fuel Oil #6 Prod.	Carbon disulfide	secondary	1.64e-09	1.84e-10
Japanese Electric Grid	Acetophenone	model/secondary	1.62e-09	1.81e-10
Japanese Electric Grid	Biphenyl	model/secondary	1.56e-09	1.74e-10
Japanese Electric Grid	Indeno(1,2,3-cd)pyrene	model/secondary	1.51e-09	1.68e-10
Japanese Electric Grid	Benzo[g,h,i]perylene	model/secondary	1.45e-09	1.62e-10
US electric grid	Ethylbenzene	model/secondary	1.43e-09	1.60e-10
Fuel Oil #6 Prod.	Aluminum (elemental)	secondary	1.37e-09	1.53e-10
LPG Production	Methyl tert-butyl ether	secondary	1.34e-09	1.50e-10
Fuel Oil #4 Prod.	Cobalt	secondary	1.33e-09	1.49e-10
Japanese Electric Grid	Benzo[b,j,k]fluoranthene	model/secondary	1.31e-09	1.46e-10
Monitor/module	1,1,1-Trichloroethane	primary	1.30e-09	1.45e-10
Fuel Oil #6 Prod.	Benzyl chloride	secondary	1.29e-09	1.44e-10
Japanese Electric Grid	Acenaphthylene	model/secondary	1.11e-09	1.24e-10
LPG Production	Phenanthrene	secondary	1.09e-09	1.22e-10
Fuel Oil #6 Prod.	Chloroform	secondary	1.00e-09	1.12e-10
Fuel Oil #4 Prod.	Acrolein	secondary	1.00e-09	1.12e-10
Japanese Electric Grid	Dibenzo[a,h]anthracene	model/secondary	9.95e-10	1.11e-10
LPG Production	Styrene	secondary	9.76e-10	1.09e-10
LPG Production	Vinyl acetate	secondary	9.52e-10	1.07e-10
LPG Production	3-Methylcholanthrene	secondary	8.99e-10	1.01e-10
Natural Gas Prod.	Dimethyl sulfate	secondary	8.78e-10	9.82e-11
Fuel Oil #2 Prod.	Carbon disulfide	secondary	8.75e-10	9.79e-11
Natural Gas Prod.	Isophorone	secondary	8.42e-10	9.42e-11
Natural Gas Prod.	Zinc (+2)	secondary	8.26e-10	9.24e-11
Fuel Oil #4 Prod.	Methyl chloride	secondary	8.10e-10	9.06e-11
Japanese Electric Grid	2-Methylnaphthalene	model/secondary	8.00e-10	8.94e-11
Natural Gas Prod.	Chlorine	secondary	7.46e-10	8.34e-11
US electric grid	Methyl tert-butyl ether	model/secondary	7.23e-10	8.09e-11
Fuel Oil #6 Prod.	Cobalt	secondary	7.23e-10	8.08e-11
Fuel Oil #4 Prod.	Beryllium	secondary	7.19e-10	8.04e-11
Fuel Oil #2 Prod.	Benzyl chloride	secondary	6.86e-10	7.67e-11
Natural Gas Prod.	Methyl ethyl ketone	secondary	6.79e-10	7.60e-11
Japanese Electric Grid	Pyrene	model/secondary	6.73e-10	7.52e-11
Natural Gas Prod.	Tetrachloroethylene	secondary	6.69e-10	7.48e-11
Fuel Oil #2 Prod.	Aluminum (elemental)	secondary	5.96e-10	6.67e-11
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	5.86e-10	6.56e-11
Japanese Electric Grid	Fluorene	model/secondary	5.86e-10	6.55e-11
Natural Gas Prod.	Silicon	secondary	5.85e-10	6.55e-11
Natural Gas Prod.	Methyl methacrylate	secondary	5.81e-10	6.49e-11
LPG Production	Zinc (+2)	secondary	5.63e-10	6.30e-11
Japanese Electric Grid	Fluoranthene	model/secondary	5.59e-10	6.26e-11
US electric grid	Phenol	model/secondary	5.51e-10	6.16e-11
Fuel Oil #2 Prod.	Chloroform	secondary	5.33e-10	5.96e-11
Fuel Oil #6 Prod.	Acrolein	secondary	5.33e-10	5.96e-11
US electric grid	Styrene	model/secondary	5.28e-10	5.90e-11

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	Vinyl acetate	model/secondary	5.15e-10	5.76e-11
Natural Gas Prod.	Barium cmpds	secondary	5.06e-10	5.66e-11
US electric grid	Phenanthrene	model/secondary	4.85e-10	5.43e-11
Natural Gas Prod.	1,2-Dichloroethane	secondary	4.84e-10	5.41e-11
Natural Gas Prod.	Bromoform	secondary	4.74e-10	5.31e-11
Natural Gas Prod.	Dichloromethane	secondary	4.58e-10	5.12e-11
Fuel Oil #4 Prod.	Acetaldehyde	secondary	4.50e-10	5.03e-11
Fuel Oil #4 Prod.	Propionaldehyde	secondary	4.50e-10	5.03e-11
Fuel Oil #4 Prod.	Mercury	secondary	4.46e-10	4.98e-11
Fuel Oil #6 Prod.	Methyl chloride	secondary	4.32e-10	4.83e-11
US electric grid	Xylene (mixed isomers)	model/secondary	4.27e-10	4.78e-11
Fuel Oil #4 Prod.	Cadmium	secondary	4.12e-10	4.60e-11
LPG Production	Ethylene dibromide	secondary	3.85e-10	4.31e-11
Natural Gas Prod.	Chlorobenzene	secondary	3.83e-10	4.29e-11
US electric grid	Chromium (III)	model/secondary	3.82e-10	4.27e-11
Fuel Oil #6 Prod.	Beryllium	secondary	3.81e-10	4.26e-11
Fuel Oil #2 Prod.	Cobalt	secondary	3.71e-10	4.15e-11
LPG Production	1,1,1-Trichloroethane	secondary	3.63e-10	4.06e-11
Fuel Oil #4 Prod.	Di(2-ethylhexyl)phthalate	secondary	3.46e-10	3.87e-11
Fuel Oil #6 Prod.	Methyl hydrazine	secondary	3.12e-10	3.49e-11
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	3.05e-10	3.41e-11
Fuel Oil #4 Prod.	Toluene	secondary	2.92e-10	3.27e-11
LPG Production	2-Methylnaphthalene	secondary	2.88e-10	3.22e-11
Fuel Oil #2 Prod.	Acrolein	secondary	2.84e-10	3.18e-11
Natural Gas Prod.	3-Methylcholanthrene	secondary	2.66e-10	2.98e-11
LPG Production	Ethyl Chloride	secondary	2.57e-10	2.88e-11
LPG Production	Chlorine	secondary	2.55e-10	2.86e-11
Natural Gas Prod.	Chromium (III)	secondary	2.54e-10	2.84e-11
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	2.44e-10	2.73e-11
Fuel Oil #6 Prod.	Acetaldehyde	secondary	2.40e-10	2.68e-11
Fuel Oil #6 Prod.	Propionaldehyde	secondary	2.40e-10	2.68e-11
Fuel Oil #6 Prod.	Mercury	secondary	2.36e-10	2.64e-11
Fuel Oil #2 Prod.	Methyl chloride	secondary	2.30e-10	2.57e-11
LPG Production	Cumene	secondary	2.18e-10	2.43e-11
Fuel Oil #6 Prod.	Cadmium	secondary	2.17e-10	2.42e-11
US electric grid	1,1,1-Trichloroethane	model/secondary	2.10e-10	2.35e-11
US electric grid	Ethylene dibromide	model/secondary	2.08e-10	2.33e-11
Fuel Oil #2 Prod.	Beryllium	secondary	2.05e-10	2.29e-11
Fuel Oil #6 Prod.	Di(2-ethylhexyl)phthalate	secondary	1.84e-10	2.06e-11
Fuel Oil #2 Prod.	Methyl hydrazine	secondary	1.67e-10	1.86e-11
Fuel Oil #4 Prod.	Dimethyl sulfate	secondary	1.66e-10	1.85e-11
Fuel Oil #4 Prod.	Isophorone	secondary	1.59e-10	1.77e-11
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	1.55e-10	1.73e-11
Natural Gas Prod.	Ethylbenzene	secondary	1.52e-10	1.70e-11
Japanese Electric Grid	Benzo[a]pyrene	model/secondary	1.46e-10	1.64e-11
Fuel Oil #6 Prod.	Toluene	secondary	1.43e-10	1.60e-11
US electric grid	Ethyl Chloride	model/secondary	1.39e-10	1.56e-11
LPG Production	Acetophenone	secondary	1.35e-10	1.52e-11
Natural Gas Prod.	Aluminum (elemental)	secondary	1.34e-10	1.50e-11

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Biphenyl	secondary	1.30e-10	1.45e-11
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	1.28e-10	1.43e-11
Fuel Oil #2 Prod.	Acetaldehyde	secondary	1.28e-10	1.43e-11
Fuel Oil #2 Prod.	Propionaldehyde	secondary	1.28e-10	1.43e-11
Fuel Oil #2 Prod.	Mercury	secondary	1.27e-10	1.42e-11
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	1.26e-10	1.41e-11
Fuel Oil #2 Prod.	Cadmium	secondary	1.18e-10	1.32e-11
US electric grid	Cumene	model/secondary	1.18e-10	1.32e-11
Natural Gas Prod.	Phenanthrene	secondary	1.11e-10	1.24e-11
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	1.09e-10	1.22e-11
LPG Production	Acenaphthylene	secondary	1.03e-10	1.15e-11
Fuel Oil #2 Prod.	Di(2-ethylhexyl)phthalate	secondary	9.83e-11	1.10e-11
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	9.12e-11	1.02e-11
Fuel Oil #2 Prod.	Cadmium cmpds	secondary	9.09e-11	1.02e-11
Fuel Oil #4 Prod.	Bromoform	secondary	8.94e-11	1.00e-11
Fuel Oil #2 Prod.	Toluene	secondary	8.85e-11	9.90e-12
Fuel Oil #6 Prod.	Dimethyl sulfate	secondary	8.82e-11	9.87e-12
Fuel Oil #4 Prod.	Dichloromethane	secondary	8.63e-11	9.65e-12
LPG Production	Acenaphthene	secondary	8.56e-11	9.57e-12
Natural Gas Prod.	2-Methylnaphthalene	secondary	8.53e-11	9.54e-12
Fuel Oil #6 Prod.	Isophorone	secondary	8.46e-11	9.46e-12
Japanese Electric Grid	5-Methyl chrysene	model/secondary	8.46e-11	9.46e-12
Fuel Oil #6 Prod.	Cadmium cmpds	secondary	8.00e-11	8.94e-12
Natural Gas Prod.	Methyl tert-butyl ether	secondary	7.62e-11	8.52e-12
US electric grid	Acetophenone	model/secondary	7.33e-11	8.19e-12
Fuel Oil #4 Prod.	Chlorobenzene	secondary	7.22e-11	8.08e-12
US electric grid	Biphenyl	model/secondary	7.03e-11	7.86e-12
Fuel Oil #6 Prod.	1,4-Dichlorobenzene	secondary	6.95e-11	7.78e-12
Fuel Oil #6 Prod.	Methyl ethyl ketone	secondary	6.82e-11	7.63e-12
Fuel Oil #6 Prod.	Tetrachloroethylene	secondary	6.72e-11	7.51e-12
LPG Production	Nickel cmpds	secondary	6.66e-11	7.45e-12
LPG Production	Benzo[a]anthracene	secondary	5.99e-11	6.70e-12
Fuel Oil #6 Prod.	Methyl methacrylate	secondary	5.83e-11	6.52e-12
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	5.75e-11	6.43e-12
LPG Production	Chrysene	secondary	5.75e-11	6.43e-12
LPG Production	Lead cmpds	secondary	5.60e-11	6.26e-12
Natural Gas Prod.	Styrene	secondary	5.56e-11	6.22e-12
Natural Gas Prod.	Vinyl acetate	secondary	5.43e-11	6.07e-12
Fuel Oil #2 Prod.	1,4-Dichlorobenzene	secondary	4.95e-11	5.54e-12
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	4.92e-11	5.50e-12
Fuel Oil #6 Prod.	1,2-Dichloroethane	secondary	4.86e-11	5.44e-12
Fuel Oil #6 Prod.	Bromoform	secondary	4.77e-11	5.33e-12
Fuel Oil #2 Prod.	Dimethyl sulfate	secondary	4.70e-11	5.26e-12
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	4.60e-11	5.15e-12
Fuel Oil #6 Prod.	Dichloromethane	secondary	4.60e-11	5.15e-12
Fuel Oil #2 Prod.	Isophorone	secondary	4.51e-11	5.04e-12
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	4.46e-11	4.98e-12
Fuel Oil #4 Prod.	Chromium (III)	secondary	4.44e-11	4.96e-12
US electric grid	Acenaphthylene	model/secondary	4.37e-11	4.88e-12
Fuel Oil #6 Prod.	Chlorobenzene	secondary	3.85e-11	4.31e-12
US electric grid	Acenaphthene	model/secondary	3.74e-11	4.18e-12

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #2 Prod.	Methyl ethyl ketone	secondary	3.64e-11	4.07e-12
Fuel Oil #2 Prod.	Tetrachloroethylene	secondary	3.58e-11	4.00e-12
LPG Production	Benzo[b,j,k]fluoranthene	secondary	3.53e-11	3.95e-12
LPG Production	Mercury compounds	secondary	3.39e-11	3.79e-12
LPG Production	Benzo[a]pyrene	secondary	3.28e-11	3.67e-12
LPG Production	Fluorene	secondary	3.17e-11	3.54e-12
Fuel Oil #2 Prod.	Methyl methacrylate	secondary	3.11e-11	3.48e-12
Fuel Oil #4 Prod.	o-xylene	secondary	3.10e-11	3.47e-12
Fuel Oil #6 Prod.	2,4-Dinitrotoluene	secondary	3.06e-11	3.42e-12
Fuel Oil #4 Prod.	Ethylbenzene	secondary	2.86e-11	3.20e-12
LPG Production	Pyrene	secondary	2.74e-11	3.06e-12
LPG Production	Benzo[g,h,i]perylene	secondary	2.66e-11	2.98e-12
Fuel Oil #2 Prod.	1,2-Dichloroethane	secondary	2.59e-11	2.90e-12
LPG Production	Fluoranthene	secondary	2.59e-11	2.89e-12
Fuel Oil #2 Prod.	Bromoform	secondary	2.54e-11	2.84e-12
Fuel Oil #2 Prod.	Dichloromethane	secondary	2.45e-11	2.74e-12
LPG Production	HALON-1301	secondary	2.44e-11	2.72e-12
LPG Production	Benzo[b]fluoranthene	secondary	2.39e-11	2.68e-12
Fuel Oil #6 Prod.	Chromium (III)	secondary	2.37e-11	2.65e-12
Natural Gas Prod.	Cadmium cmpds	secondary	2.21e-11	2.47e-12
Natural Gas Prod.	Ethylene dibromide	secondary	2.20e-11	2.46e-12
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	2.07e-11	2.31e-12
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	2.06e-11	2.30e-12
Fuel Oil #2 Prod.	Chlorobenzene	secondary	2.05e-11	2.29e-12
US electric grid	Chrysene	model/secondary	1.98e-11	2.21e-12
Fuel Oil #2 Prod.	Aromatic hydrocarbons	secondary	1.83e-11	2.05e-12
Japanese Electric Grid	Anthracene	model/secondary	1.82e-11	2.04e-12
US electric grid	Benzo[a]anthracene	model/secondary	1.80e-11	2.01e-12
Fuel Oil #2 Prod.	Copper (+1 & +2)	secondary	1.72e-11	1.92e-12
LPG Production	Dibenzo[a,h]anthracene	secondary	1.70e-11	1.90e-12
Fuel Oil #2 Prod.	2,4-Dinitrotoluene	secondary	1.63e-11	1.83e-12
Fuel Oil #6 Prod.	Aromatic hydrocarbons	secondary	1.61e-11	1.80e-12
US electric grid	Fluorene	model/secondary	1.55e-11	1.73e-12
Fuel Oil #6 Prod.	Ethylbenzene	secondary	1.52e-11	1.70e-12
Fuel Oil #6 Prod.	Copper (+1 & +2)	secondary	1.51e-11	1.69e-12
Natural Gas Prod.	Ethyl Chloride	secondary	1.47e-11	1.64e-12
Fuel Oil #6 Prod.	o-xylene	secondary	1.46e-11	1.63e-12
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	1.44e-11	1.61e-12
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	1.28e-11	1.43e-12
Fuel Oil #2 Prod.	Chromium (III)	secondary	1.26e-11	1.41e-12
Natural Gas Prod.	Cumene	secondary	1.24e-11	1.39e-12
US electric grid	Fluoranthene	model/secondary	1.24e-11	1.38e-12
Fuel Oil #4 Prod.	Phenanthrene	secondary	1.13e-11	1.26e-12
Natural Gas Prod.	Acenaphthylene	secondary	1.10e-11	1.23e-12
Fuel Oil #4 Prod.	Styrene	secondary	1.05e-11	1.17e-12
Fuel Oil #4 Prod.	Vinyl acetate	secondary	1.02e-11	1.14e-12
US electric grid	Pyrene	model/secondary	1.02e-11	1.14e-12
Fuel Oil #2 Prod.	o-xylene	secondary	9.63e-12	1.08e-12
Natural Gas Prod.	Benzo[a]anthracene	secondary	8.84e-12	9.88e-13

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Chrysene	secondary	8.52e-12	9.52e-13
Fuel Oil #2 Prod.	Ethylbenzene	secondary	8.13e-12	9.09e-13
Fuel Oil #4 Prod.	3-Methylcholanthrene	secondary	8.12e-12	9.08e-13
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	7.77e-12	8.69e-13
Natural Gas Prod.	Acetophenone	secondary	7.72e-12	8.63e-13
Fuel Oil #6 Prod.	Methyl tert-butyl ether	secondary	7.66e-12	8.56e-13
Natural Gas Prod.	Biphenyl	secondary	7.40e-12	8.28e-13
US electric grid	o-xylene	model/secondary	7.35e-12	8.22e-13
Natural Gas Prod.	Acenaphthene	secondary	7.10e-12	7.94e-13
LPG Production	5-Methyl chrysene	secondary	7.06e-12	7.90e-13
US electric grid	Benzo[g,h,i]perylene	model/secondary	6.98e-12	7.81e-13
US electric grid	Benzo[a]pyrene	model/secondary	6.60e-12	7.38e-13
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	6.58e-12	7.35e-13
Fuel Oil #6 Prod.	Phenanthrene	secondary	5.83e-12	6.52e-13
LPG Production	Halogenated matter (organic)	secondary	5.60e-12	6.26e-13
Fuel Oil #6 Prod.	Styrene	secondary	5.59e-12	6.25e-13
Fuel Oil #6 Prod.	Vinyl acetate	secondary	5.45e-12	6.10e-13
US electric grid	2-Methylnaphthalene	model/secondary	5.16e-12	5.78e-13
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	5.03e-12	5.63e-13
Natural Gas Prod.	Benzo[a]pyrene	secondary	4.96e-12	5.55e-13
Fuel Oil #4 Prod.	Zinc (+2)	secondary	4.60e-12	5.14e-13
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	4.47e-12	5.00e-13
Natural Gas Prod.	Aromatic hydrocarbons	secondary	4.46e-12	4.99e-13
Natural Gas Prod.	Copper (+1 & +2)	secondary	4.17e-12	4.67e-13
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	4.14e-12	4.63e-13
Fuel Oil #2 Prod.	Methyl tert-butyl ether	secondary	4.08e-12	4.56e-13
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	3.90e-12	4.36e-13
Natural Gas Prod.	Pyrene	secondary	3.86e-12	4.32e-13
US electric grid	5-Methyl chrysene	model/secondary	3.82e-12	4.27e-13
Fuel Oil #6 Prod.	3-Methylcholanthrene	secondary	3.65e-12	4.08e-13
Fuel Oil #2 Prod.	Phenanthrene	secondary	3.28e-12	3.67e-13
Fuel Oil #2 Prod.	Styrene	secondary	2.98e-12	3.33e-13
Fuel Oil #2 Prod.	Vinyl acetate	secondary	2.91e-12	3.25e-13
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	2.76e-12	3.09e-13
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	2.60e-12	2.91e-13
Fuel Oil #2 Prod.	3-Methylcholanthrene	secondary	2.60e-12	2.91e-13
Natural Gas Prod.	Fluorene	secondary	2.58e-12	2.89e-13
Fuel Oil #4 Prod.	Cumene	secondary	2.34e-12	2.62e-13
Natural Gas Prod.	Fluoranthene	secondary	2.31e-12	2.58e-13
Fuel Oil #4 Prod.	Chlorine	secondary	2.26e-12	2.53e-13
Fuel Oil #6 Prod.	Ethylene dibromide	secondary	2.21e-12	2.47e-13
Fuel Oil #6 Prod.	1,1,1-Trichloroethane	secondary	2.08e-12	2.32e-13
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	2.01e-12	2.25e-13
Fuel Oil #6 Prod.	Zinc (+2)	secondary	1.81e-12	2.03e-13
US electric grid	Dibenzo[a,h]anthracene	model/secondary	1.69e-12	1.89e-13
Fuel Oil #2 Prod.	Zinc (+2)	secondary	1.58e-12	1.77e-13
Fuel Oil #6 Prod.	Ethyl Chloride	secondary	1.47e-12	1.65e-13
Fuel Oil #4 Prod.	Acetophenone	secondary	1.46e-12	1.63e-13
Fuel Oil #4 Prod.	Biphenyl	secondary	1.40e-12	1.56e-13
Fuel Oil #6 Prod.	Cumene	secondary	1.25e-12	1.39e-13
LPG Production	Anthracene	secondary	1.19e-12	1.33e-13

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #2 Prod.	Ethylene dibromide	secondary	1.18e-12	1.31e-13
Fuel Oil #6 Prod.	2-Methylnaphthalene	secondary	1.17e-12	1.31e-13
Fuel Oil #2 Prod.	1,1,1-Trichloroethane	secondary	1.11e-12	1.24e-13
Fuel Oil #4 Prod.	Acenaphthylene	secondary	1.06e-12	1.19e-13
Fuel Oil #6 Prod.	Chlorine	secondary	1.01e-12	1.13e-13
Fuel Oil #2 Prod.	2-Methylnaphthalene	secondary	8.33e-13	9.31e-14
Fuel Oil #4 Prod.	Acenaphthene	secondary	8.30e-13	9.29e-14
Fuel Oil #2 Prod.	Ethyl Chloride	secondary	7.85e-13	8.78e-14
Fuel Oil #6 Prod.	Acetophenone	secondary	7.76e-13	8.67e-14
Fuel Oil #6 Prod.	Biphenyl	secondary	7.44e-13	8.32e-14
Fuel Oil #2 Prod.	Chlorine	secondary	7.28e-13	8.14e-14
Fuel Oil #2 Prod.	Cumene	secondary	6.64e-13	7.43e-14
Fuel Oil #4 Prod.	Chrysene	secondary	5.68e-13	6.35e-14
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	5.64e-13	6.31e-14
Fuel Oil #6 Prod.	Acenaphthylene	secondary	5.49e-13	6.14e-14
Fuel Oil #4 Prod.	Nickel cmpds	secondary	4.88e-13	5.46e-14
US electric grid	Anthracene	model/secondary	4.49e-13	5.02e-14
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	4.30e-13	4.81e-14
Fuel Oil #2 Prod.	Acetophenone	secondary	4.13e-13	4.62e-14
Fuel Oil #4 Prod.	Lead cmpds	secondary	4.10e-13	4.59e-14
Fuel Oil #6 Prod.	Acenaphthene	secondary	4.04e-13	4.51e-14
Natural Gas Prod.	5-Methyl chrysene	secondary	4.03e-13	4.50e-14
Fuel Oil #2 Prod.	Biphenyl	secondary	3.96e-13	4.43e-14
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	3.79e-13	4.24e-14
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	3.38e-13	3.78e-14
Fuel Oil #4 Prod.	Fluorene	secondary	3.33e-13	3.72e-14
Fuel Oil #2 Prod.	Acenaphthylene	secondary	3.10e-13	3.46e-14
Fuel Oil #6 Prod.	Chrysene	secondary	2.81e-13	3.14e-14
Fuel Oil #4 Prod.	Pyrene	secondary	2.74e-13	3.07e-14
Fuel Oil #4 Prod.	Fluoranthene	secondary	2.69e-13	3.01e-14
Fuel Oil #6 Prod.	Benzo[a]anthracene	secondary	2.65e-13	2.97e-14
Fuel Oil #2 Prod.	Acenaphthene	secondary	2.53e-13	2.83e-14
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	2.49e-13	2.79e-14
Fuel Oil #4 Prod.	Mercury compounds	secondary	2.48e-13	2.78e-14
Fuel Oil #4 Prod.	Benzo[b]fluoranthene	secondary	2.12e-13	2.37e-14
Fuel Oil #6 Prod.	Indeno(1,2,3-cd)pyrene	secondary	2.08e-13	2.33e-14
Fuel Oil #6 Prod.	Benzo[b,j,k]fluoranthene	secondary	2.02e-13	2.26e-14
Japanese Electric Grid	2,3,7,8-TCDF	model/secondary	1.96e-13	2.20e-14
Fuel Oil #2 Prod.	Nickel cmpds	secondary	1.82e-13	2.03e-14
Fuel Oil #4 Prod.	HALON-1301	secondary	1.78e-13	2.00e-14
Fuel Oil #2 Prod.	Benzo[a]anthracene	secondary	1.75e-13	1.96e-14
Fuel Oil #6 Prod.	Fluorene	secondary	1.74e-13	1.94e-14
Fuel Oil #6 Prod.	Benzo[a]pyrene	secondary	1.74e-13	1.94e-14
Fuel Oil #2 Prod.	Chrysene	secondary	1.71e-13	1.91e-14
Fuel Oil #6 Prod.	Nickel cmpds	secondary	1.60e-13	1.79e-14
Fuel Oil #2 Prod.	Lead cmpds	secondary	1.53e-13	1.71e-14
Natural Gas Prod.	Anthracene	secondary	1.51e-13	1.69e-14
Fuel Oil #4 Prod.	Dibenzo[a,h]anthracene	secondary	1.49e-13	1.67e-14
Fuel Oil #6 Prod.	Fluoranthene	secondary	1.40e-13	1.56e-14

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #6 Prod.	Pyrene	secondary	1.37e-13	1.54e-14
Fuel Oil #6 Prod.	Lead cmpds	secondary	1.34e-13	1.50e-14
Fuel Oil #2 Prod.	Indeno(1,2,3-cd)pyrene	secondary	1.31e-13	1.47e-14
Fuel Oil #6 Prod.	Benzo[g,h,i]perylene	secondary	1.17e-13	1.31e-14
Fuel Oil #2 Prod.	Benzo[b,j,k]fluoranthene	secondary	1.08e-13	1.21e-14
Fuel Oil #2 Prod.	Benzo[a]pyrene	secondary	9.87e-14	1.10e-14
Fuel Oil #2 Prod.	Fluorene	secondary	9.59e-14	1.07e-14
Fuel Oil #6 Prod.	Benzo[b]fluoranthene	secondary	9.33e-14	1.04e-14
Fuel Oil #2 Prod.	Mercury compounds	secondary	9.25e-14	1.04e-14
Fuel Oil #2 Prod.	Pyrene	secondary	8.17e-14	9.14e-15
Fuel Oil #6 Prod.	Mercury compounds	secondary	8.14e-14	9.10e-15
Fuel Oil #2 Prod.	Fluoranthene	secondary	7.81e-14	8.74e-15
Fuel Oil #2 Prod.	Benzo[g,h,i]perylene	secondary	7.78e-14	8.70e-15
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	7.59e-14	8.49e-15
Fuel Oil #2 Prod.	Benzo[b]fluoranthene	secondary	6.88e-14	7.70e-15
Fuel Oil #2 Prod.	HALON-1301	secondary	6.65e-14	7.44e-15
Fuel Oil #6 Prod.	Dibenzo[a,h]anthracene	secondary	6.48e-14	7.25e-15
Fuel Oil #6 Prod.	HALON-1301	secondary	5.85e-14	6.54e-15
Fuel Oil #2 Prod.	Dibenzo[a,h]anthracene	secondary	4.88e-14	5.46e-15
Natural Gas Prod.	Nickel cmpds	secondary	4.43e-14	4.95e-15
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	4.10e-14	4.59e-15
Fuel Oil #6 Prod.	5-Methyl chrysene	secondary	4.04e-14	4.52e-15
Natural Gas Prod.	Lead cmpds	secondary	3.72e-14	4.16e-15
Natural Gas Prod.	Mercury compounds	secondary	2.25e-14	2.52e-15
Fuel Oil #2 Prod.	5-Methyl chrysene	secondary	2.16e-14	2.41e-15
Natural Gas Prod.	HALON-1301	secondary	1.62e-14	1.81e-15
Fuel Oil #2 Prod.	Halogenated matter (organic)	secondary	1.53e-14	1.71e-15
LPG Production	Halogenated hydrocarbons (unspecified)	secondary	1.40e-14	1.57e-15
Fuel Oil #6 Prod.	Halogenated matter (organic)	secondary	1.34e-14	1.50e-15
Fuel Oil #4 Prod.	Anthracene	secondary	1.21e-14	1.35e-15
US electric grid	2,3,7,8-TCDF	model/secondary	8.86e-15	9.90e-16
Fuel Oil #6 Prod.	Anthracene	secondary	6.10e-15	6.82e-16
Natural Gas Prod.	Halogenated matter (organic)	secondary	3.72e-15	4.16e-16
Fuel Oil #2 Prod.	Anthracene	secondary	3.56e-15	3.99e-16
Fuel Oil #4 Prod.	Halogenated hydrocarbons (unspecified)	secondary	1.02e-16	1.15e-17
Fuel Oil #2 Prod.	Halogenated hydrocarbons (unspecified)	secondary	3.82e-17	4.27e-18
Fuel Oil #6 Prod.	Halogenated hydrocarbons (unspecified)	secondary	3.36e-17	3.76e-18
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	9.28e-18	1.04e-18
Total Manufacturing			**2.33e+02**	**2.60e+01**
Use, Maintenance and Repair Life-cycle Stage				
US electric grid	Sulfur dioxide	model/secondary	6.15e+02	6.87e+01
US electric grid	Nitrogen oxides	model/secondary	4.39e-01	4.91e-02
US electric grid	Carbon monoxide	model/secondary	3.77e-01	4.22e-02
US electric grid	Methane	model/secondary	2.41e-01	2.69e-02
US electric grid	Arsenic	model/secondary	2.08e-01	2.33e-02
US electric grid	Hydrochloric acid	model/secondary	1.84e-01	2.06e-02
US electric grid	Selenium	model/secondary	3.46e-02	3.87e-03
US electric grid	Vanadium	model/secondary	2.61e-02	2.91e-03
US electric grid	PM-10	model/secondary	2.16e-02	2.41e-03
US electric grid	Hydrofluoric acid	model/secondary	5.02e-03	5.62e-04

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	Formaldehyde	model/secondary	3.62e-03	4.04e-04
US electric grid	Benzene	model/secondary	2.60e-03	2.91e-04
US electric grid	Phosphorus (yellow or white)	model/secondary	1.47e-03	1.64e-04
US electric grid	Nitrous oxide	model/secondary	1.27e-03	1.42e-04
US electric grid	Zinc (elemental)	model/secondary	6.77e-04	7.57e-05
US electric grid	Antimony	model/secondary	5.54e-04	6.19e-05
US electric grid	Molybdenum	model/secondary	1.85e-04	2.07e-05
US electric grid	2-Chloroacetophenone	model/secondary	1.61e-04	1.80e-05
US electric grid	Bromomethane	model/secondary	1.59e-04	1.78e-05
US electric grid	Cyanide (-1)	model/secondary	8.37e-05	9.36e-06
US electric grid	2,3,7,8-TCDD	model/secondary	6.33e-05	7.08e-06
US electric grid	Nickel	model/secondary	6.09e-05	6.81e-06
US electric grid	Naphthalene	model/secondary	5.04e-05	5.64e-06
US electric grid	Barium	model/secondary	4.35e-05	4.86e-06
US electric grid	Carbon disulfide	model/secondary	2.99e-05	3.34e-06
US electric grid	Benzyl chloride	model/secondary	2.34e-05	2.62e-06
US electric grid	Chloroform	model/secondary	1.82e-05	2.04e-06
US electric grid	Manganese	model/secondary	1.70e-05	1.90e-06
US electric grid	Chromium (VI)	model/secondary	1.28e-05	1.43e-06
US electric grid	Acrolein	model/secondary	9.71e-06	1.09e-06
US electric grid	Copper	model/secondary	8.34e-06	9.33e-07
US electric grid	Methyl chloride	model/secondary	7.86e-06	8.79e-07
US electric grid	Fluoride	model/secondary	7.29e-06	8.15e-07
US electric grid	Methyl hydrazine	model/secondary	5.69e-06	6.36e-07
US electric grid	Lead	model/secondary	4.76e-06	5.32e-07
US electric grid	Cobalt	model/secondary	4.54e-06	5.07e-07
US electric grid	Acetaldehyde	model/secondary	4.37e-06	4.89e-07
US electric grid	Propionaldehyde	model/secondary	4.37e-06	4.89e-07
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	3.36e-06	3.75e-07
US electric grid	Mercury	model/secondary	2.80e-06	3.14e-07
US electric grid	Hexane	model/secondary	2.24e-06	2.51e-07
US electric grid	Cadmium	model/secondary	1.80e-06	2.01e-07
US electric grid	Dimethyl sulfate	model/secondary	1.61e-06	1.80e-07
US electric grid	Toluene	model/secondary	1.59e-06	1.77e-07
US electric grid	Isophorone	model/secondary	1.54e-06	1.72e-07
US electric grid	Methyl ethyl ketone	model/secondary	1.24e-06	1.39e-07
US electric grid	Tetrachloroethylene	model/secondary	1.22e-06	1.37e-07
US electric grid	Methyl methacrylate	model/secondary	1.06e-06	1.19e-07
US electric grid	1,2-Dichloroethane	model/secondary	8.85e-07	9.90e-08
US electric grid	Bromoform	model/secondary	8.68e-07	9.71e-08
US electric grid	Dichloromethane	model/secondary	8.38e-07	9.37e-08
US electric grid	Beryllium	model/secondary	7.12e-07	7.96e-08
US electric grid	Chlorobenzene	model/secondary	7.01e-07	7.84e-08
US electric grid	2,4-Dinitrotoluene	model/secondary	5.58e-07	6.24e-08
US electric grid	Ethylbenzene	model/secondary	2.76e-07	3.09e-08
US electric grid	Methyl tert-butyl ether	model/secondary	1.39e-07	1.56e-08
US electric grid	Phenol	model/secondary	1.06e-07	1.19e-08
US electric grid	Styrene	model/secondary	1.02e-07	1.14e-08
US electric grid	Vinyl acetate	model/secondary	9.93e-08	1.11e-08

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	Phenanthrene	model/secondary	9.35e-08	1.05e-08
US electric grid	Xylene (mixed isomers)	model/secondary	8.23e-08	9.21e-09
US electric grid	Chromium (III)	model/secondary	7.36e-08	8.23e-09
US electric grid	1,1,1-Trichloroethane	model/secondary	4.05e-08	4.53e-09
US electric grid	Ethylene dibromide	model/secondary	4.02e-08	4.49e-09
US electric grid	Ethyl Chloride	model/secondary	2.68e-08	3.00e-09
US electric grid	Cumene	model/secondary	2.27e-08	2.54e-09
US electric grid	Acetophenone	model/secondary	1.41e-08	1.58e-09
US electric grid	Biphenyl	model/secondary	1.35e-08	1.51e-09
US electric grid	Acenaphthylene	model/secondary	8.42e-09	9.41e-10
US electric grid	Acenaphthene	model/secondary	7.21e-09	8.06e-10
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	3.97e-09	4.44e-10
US electric grid	Chrysene	model/secondary	3.81e-09	4.26e-10
US electric grid	Benzo[a]anthracene	model/secondary	3.46e-09	3.87e-10
US electric grid	Fluorene	model/secondary	2.98e-09	3.34e-10
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	2.46e-09	2.75e-10
US electric grid	Fluoranthene	model/secondary	2.38e-09	2.67e-10
US electric grid	Pyrene	model/secondary	1.97e-09	2.21e-10
US electric grid	o-xylene	model/secondary	1.42e-09	1.58e-10
US electric grid	Benzo[g,h,i]perylene	model/secondary	1.35e-09	1.50e-10
US electric grid	Benzo[a]pyrene	model/secondary	1.27e-09	1.42e-10
US electric grid	2-Methylnaphthalene	model/secondary	9.95e-10	1.11e-10
US electric grid	5-Methyl chrysene	model/secondary	7.36e-10	8.24e-11
US electric grid	Dibenzo[a,h]anthracene	model/secondary	3.26e-10	3.65e-11
US electric grid	Anthracene	model/secondary	8.65e-11	9.67e-12
US electric grid	2,3,7,8-TCDF	model/secondary	1.71e-12	1.91e-13
Total Use, Maintenance, and Repair			**6.16e+02**	**6.89e+01**
End-of-life Life-cycle Stage				
US electric grid	Sulfur dioxide	model/secondary	1.17e-01	1.30e-02
LCD landfilling	Sulfur dioxide	primary	4.45e-02	4.98e-03
LCD incineration	Sulfur dioxide	secondary	3.45e-02	3.86e-03
LCD landfilling	Carbon monoxide	primary	2.22e-03	2.48e-04
LCD landfilling	Nitrogen dioxide	primary	4.46e-04	4.99e-05
US electric grid	Nitrogen oxides	model/secondary	8.34e-05	9.32e-06
US electric grid	Carbon monoxide	model/secondary	7.15e-05	8.00e-06
LCD landfilling	PM	primary	5.02e-05	5.61e-06
US electric grid	Methane	model/secondary	4.57e-05	5.11e-06
LCD incineration	Arsenic cmpds	secondary	4.30e-05	4.80e-06
US electric grid	Arsenic	model/secondary	3.95e-05	4.42e-06
LCD landfilling	Arsenic cmpds	primary	3.65e-05	4.08e-06
US electric grid	Hydrochloric acid	model/secondary	3.49e-05	3.90e-06
LPG Production	Carbon monoxide	secondary	2.11e-05	2.35e-06
LCD landfilling	Methane	primary	1.31e-05	1.47e-06
LCD landfilling	Benzene	primary	9.74e-06	1.09e-06
US electric grid	Selenium	model/secondary	6.57e-06	7.35e-07
US electric grid	Vanadium	model/secondary	4.94e-06	5.53e-07
LCD incineration	Lead	secondary	4.80e-06	5.37e-07
LPG Production	Vanadium	secondary	4.12e-06	4.61e-07
US electric grid	PM-10	model/secondary	4.09e-06	4.58e-07
LPG Production	Benzene	secondary	3.38e-06	3.78e-07

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Methane	secondary	3.30e-06	3.69e-07
LPG Production	Sulfur oxides	secondary	3.16e-06	3.53e-07
LCD landfilling	Silver compounds	primary	2.52e-06	2.82e-07
LCD incineration	Barium cmpds	secondary	2.33e-06	2.60e-07
LPG Production	Nitrogen oxides	secondary	2.26e-06	2.52e-07
LCD landfilling	Barium cmpds	primary	1.96e-06	2.19e-07
LCD incineration	Silver compounds	secondary	1.95e-06	2.19e-07
LCD landfilling	Hydrochloric acid	primary	1.13e-06	1.26e-07
US electric grid	Hydrofluoric acid	model/secondary	9.53e-07	1.07e-07
LPG Production	Arsenic	secondary	8.13e-07	9.10e-08
US electric grid	Formaldehyde	model/secondary	6.86e-07	7.67e-08
LCD landfilling	Ammonia	primary	5.79e-07	6.48e-08
LPG Production	Formaldehyde	secondary	5.28e-07	5.90e-08
LPG Production	PM	secondary	5.08e-07	5.68e-08
US electric grid	Benzene	model/secondary	4.94e-07	5.52e-08
LCD incineration	Cadmium cmpds	secondary	3.54e-07	3.96e-08
LCD landfilling	Cadmium cmpds	primary	3.27e-07	3.65e-08
US electric grid	Phosphorus (yellow or white)	model/secondary	2.78e-07	3.11e-08
US electric grid	Nitrous oxide	model/secondary	2.41e-07	2.69e-08
LPG Production	Hydrochloric acid	secondary	1.45e-07	1.62e-08
US electric grid	Zinc (elemental)	model/secondary	1.28e-07	1.44e-08
US electric grid	Antimony	model/secondary	1.05e-07	1.17e-08
LPG Production	Nitrous oxide	secondary	6.39e-08	7.15e-09
LCD landfilling	Hydrogen sulfide	primary	5.54e-08	6.20e-09
LPG Production	Phosphorus (yellow or white)	secondary	3.86e-08	4.32e-09
US electric grid	Molybdenum	model/secondary	3.51e-08	3.93e-09
US electric grid	2-Chloroacetophenone	model/secondary	3.05e-08	3.42e-09
US electric grid	Bromomethane	model/secondary	3.02e-08	3.38e-09
LPG Production	Fluorides (F-)	secondary	2.96e-08	3.31e-09
LPG Production	Selenium	secondary	2.92e-08	3.27e-09
US electric grid	Cyanide (-1)	model/secondary	1.59e-08	1.78e-09
LPG Production	Ammonia	secondary	1.47e-08	1.65e-09
LPG Production	Hydrogen sulfide	secondary	1.21e-08	1.35e-09
US electric grid	2,3,7,8-TCDD	model/secondary	1.20e-08	1.34e-09
US electric grid	Nickel	model/secondary	1.15e-08	1.29e-09
LCD landfilling	Selenium	primary	1.05e-08	1.17e-09
US electric grid	Naphthalene	model/secondary	9.56e-09	1.07e-09
US electric grid	Barium	model/secondary	8.25e-09	9.22e-10
LPG Production	Molybdenum	secondary	6.49e-09	7.25e-10
US electric grid	Carbon disulfide	model/secondary	5.67e-09	6.34e-10
LPG Production	Zinc (elemental)	secondary	4.72e-09	5.28e-10
LCD landfilling	Chromium (VI)	primary	4.65e-09	5.20e-10
LCD incineration	Mercury compounds	secondary	4.57e-09	5.11e-10
US electric grid	Benzyl chloride	model/secondary	4.45e-09	4.97e-10
LCD landfilling	Carbon tetrachloride	primary	4.04e-09	4.52e-10
LPG Production	Hydrofluoric acid	secondary	3.95e-09	4.42e-10
LCD landfilling	Mercury compounds	primary	3.95e-09	4.42e-10
US electric grid	Chloroform	model/secondary	3.46e-09	3.87e-10
US electric grid	Manganese	model/secondary	3.23e-09	3.61e-10

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LCD incineration	Carbon tetrachloride	secondary	3.13e-09	3.50e-10
LCD landfilling	Chloroform	primary	3.13e-09	3.50e-10
LPG Production	Ethane	secondary	3.06e-09	3.42e-10
LPG Production	Phenol	secondary	2.82e-09	3.15e-10
LPG Production	Pentane	secondary	2.56e-09	2.87e-10
US electric grid	Chromium (VI)	model/secondary	2.43e-09	2.72e-10
LCD landfilling	Toluene	primary	1.98e-09	2.21e-10
US electric grid	Acrolein	model/secondary	1.84e-09	2.06e-10
LPG Production	Hexane	secondary	1.78e-09	1.99e-10
US electric grid	Copper	model/secondary	1.58e-09	1.77e-10
US electric grid	Methyl chloride	model/secondary	1.49e-09	1.67e-10
US electric grid	Fluoride	model/secondary	1.38e-09	1.55e-10
LPG Production	Nickel	secondary	1.14e-09	1.28e-10
US electric grid	Methyl hydrazine	model/secondary	1.08e-09	1.21e-10
US electric grid	Lead	model/secondary	9.03e-10	1.01e-10
LPG Production	PM-10	secondary	8.86e-10	9.91e-11
US electric grid	Cobalt	model/secondary	8.61e-10	9.63e-11
LPG Production	Antimony	secondary	8.42e-10	9.42e-11
US electric grid	Propionaldehyde	model/secondary	8.29e-10	9.27e-11
US electric grid	Acetaldehyde	model/secondary	8.29e-10	9.27e-11
US electric grid	Di(2-ethylhexyl)phthalate	model/secondary	6.37e-10	7.12e-11
LPG Production	Aluminum (+3)	secondary	5.58e-10	6.24e-11
US electric grid	Mercury	model/secondary	5.32e-10	5.95e-11
US electric grid	Hexane	model/secondary	4.26e-10	4.76e-11
LCD landfilling	Xylene (mixed isomers)	primary	4.08e-10	4.56e-11
LPG Production	Chromium (VI)	secondary	3.97e-10	4.44e-11
US electric grid	Cadmium	model/secondary	3.41e-10	3.82e-11
US electric grid	Dimethyl sulfate	model/secondary	3.05e-10	3.41e-11
US electric grid	Toluene	model/secondary	3.01e-10	3.36e-11
US electric grid	Isophorone	model/secondary	2.92e-10	3.27e-11
LCD landfilling	Tetrachloroethylene	primary	2.89e-10	3.23e-11
LCD incineration	Lead cmpds	secondary	2.59e-10	2.90e-11
LCD landfilling	Lead cmpds	primary	2.40e-10	2.69e-11
LPG Production	Nitrate	secondary	2.39e-10	2.67e-11
US electric grid	Methyl ethyl ketone	model/secondary	2.36e-10	2.64e-11
US electric grid	Tetrachloroethylene	model/secondary	2.32e-10	2.60e-11
LCD landfilling	1,2-Dichloroethane	primary	2.24e-10	2.51e-11
US electric grid	Methyl methacrylate	model/secondary	2.02e-10	2.25e-11
LCD landfilling	Trichloroethylene	primary	1.68e-10	1.88e-11
US electric grid	1,2-Dichloroethane	model/secondary	1.68e-10	1.88e-11
US electric grid	Bromoform	model/secondary	1.65e-10	1.84e-11
US electric grid	Dichloromethane	model/secondary	1.59e-10	1.78e-11
LPG Production	Copper	secondary	1.37e-10	1.54e-11
US electric grid	Beryllium	model/secondary	1.35e-10	1.51e-11
US electric grid	Chlorobenzene	model/secondary	1.33e-10	1.49e-11
LCD incineration	Trichloroethylene	secondary	1.31e-10	1.46e-11
LPG Production	2-Chloroacetophenone	secondary	1.27e-10	1.42e-11
LPG Production	Dimethylbenzanthracene	secondary	1.26e-10	1.41e-11
LPG Production	Bromomethane	secondary	1.25e-10	1.40e-11
LCD landfilling	Ethylbenzene	primary	1.07e-10	1.19e-11
US electric grid	2,4-Dinitrotoluene	model/secondary	1.06e-10	1.18e-11

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Naphthalene	secondary	1.02e-10	1.14e-11
LPG Production	Manganese	secondary	8.79e-11	9.83e-12
LPG Production	Barium	secondary	7.34e-11	8.21e-12
LPG Production	Silicon	secondary	6.66e-11	7.45e-12
LPG Production	Cyanide (-1)	secondary	6.59e-11	7.37e-12
LPG Production	Barium cmpds	secondary	6.25e-11	6.99e-12
US electric grid	Ethylbenzene	model/secondary	5.24e-11	5.86e-12
LPG Production	Lead	secondary	4.87e-11	5.44e-12
LCD landfilling	Dichloromethane	primary	4.68e-11	5.24e-12
US electric grid	Methyl tert-butyl ether	model/secondary	2.65e-11	2.96e-12
LPG Production	Carbon disulfide	secondary	2.35e-11	2.63e-12
US electric grid	Phenol	model/secondary	2.02e-11	2.25e-12
US electric grid	Styrene	model/secondary	1.93e-11	2.16e-12
US electric grid	Vinyl acetate	model/secondary	1.88e-11	2.11e-12
LPG Production	Benzyl chloride	secondary	1.84e-11	2.06e-12
US electric grid	Phenanthrene	model/secondary	1.77e-11	1.98e-12
US electric grid	Xylene (mixed isomers)	model/secondary	1.56e-11	1.75e-12
LPG Production	Aluminum (elemental)	secondary	1.52e-11	1.71e-12
LPG Production	Chloroform	secondary	1.43e-11	1.60e-12
US electric grid	Chromium (III)	model/secondary	1.40e-11	1.56e-12
LPG Production	Cobalt	secondary	9.89e-12	1.11e-12
LCD incineration	o-xylene	secondary	9.08e-12	1.02e-12
LCD landfilling	Chromium (III)	primary	7.92e-12	8.86e-13
US electric grid	1,1,1-Trichloroethane	model/secondary	7.68e-12	8.59e-13
LPG Production	Acrolein	secondary	7.64e-12	8.55e-13
US electric grid	Ethylene dibromide	model/secondary	7.62e-12	8.52e-13
LPG Production	Methyl chloride	secondary	6.19e-12	6.92e-13
LPG Production	Beryllium	secondary	5.53e-12	6.19e-13
US electric grid	Ethyl Chloride	model/secondary	5.09e-12	5.69e-13
LPG Production	Methyl hydrazine	secondary	4.48e-12	5.01e-13
US electric grid	Cumene	model/secondary	4.31e-12	4.82e-13
LPG Production	Acetaldehyde	secondary	3.44e-12	3.85e-13
LPG Production	Propionaldehyde	secondary	3.44e-12	3.85e-13
LPG Production	Mercury	secondary	3.42e-12	3.83e-13
LPG Production	Cadmium	secondary	3.19e-12	3.57e-13
LPG Production	Cadmium cmpds	secondary	2.74e-12	3.06e-13
US electric grid	Acetophenone	model/secondary	2.68e-12	3.00e-13
LPG Production	Di(2-ethylhexyl)phthalate	secondary	2.64e-12	2.96e-13
US electric grid	Biphenyl	model/secondary	2.57e-12	2.87e-13
LPG Production	Toluene	secondary	2.45e-12	2.75e-13
US electric grid	Acenaphthylene	model/secondary	1.60e-12	1.79e-13
LPG Production	1,4-Dichlorobenzene	secondary	1.41e-12	1.57e-13
US electric grid	Acenaphthene	model/secondary	1.37e-12	1.53e-13
LPG Production	Dimethyl sulfate	secondary	1.27e-12	1.41e-13
LPG Production	Isophorone	secondary	1.21e-12	1.36e-13
LPG Production	Methyl ethyl ketone	secondary	9.79e-13	1.09e-13
LPG Production	Tetrachloroethylene	secondary	9.63e-13	1.08e-13
LPG Production	Methyl methacrylate	secondary	8.36e-13	9.35e-14
US electric grid	Benzo[b,j,k]fluoranthene	model/secondary	7.53e-13	8.43e-14

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
US electric grid	Chrysene	model/secondary	7.23e-13	8.09e-14
LPG Production	1,2-Dichloroethane	secondary	6.97e-13	7.79e-14
LPG Production	Bromoform	secondary	6.83e-13	7.64e-14
LPG Production	Chromium (III)	secondary	6.76e-13	7.56e-14
LCD landfilling	Vinyl chloride	primary	6.68e-13	7.47e-14
LPG Production	Dichloromethane	secondary	6.60e-13	7.38e-14
US electric grid	Benzo[a]anthracene	model/secondary	6.57e-13	7.34e-14
US electric grid	Fluorene	model/secondary	5.66e-13	6.33e-14
LPG Production	Chlorobenzene	secondary	5.52e-13	6.17e-14
LPG Production	Aromatic hydrocarbons	secondary	5.52e-13	6.17e-14
LCD incineration	Vinyl chloride	secondary	5.18e-13	5.79e-14
LPG Production	Copper (+1 & +2)	secondary	5.16e-13	5.77e-14
US electric grid	Indeno(1,2,3-cd)pyrene	model/secondary	4.67e-13	5.22e-14
US electric grid	Fluoranthene	model/secondary	4.52e-13	5.06e-14
LPG Production	2,4-Dinitrotoluene	secondary	4.39e-13	4.91e-14
US electric grid	Pyrene	model/secondary	3.74e-13	4.18e-14
LPG Production	o-xylene	secondary	2.70e-13	3.02e-14
US electric grid	o-xylene	model/secondary	2.69e-13	3.00e-14
US electric grid	Benzo[g,h,i]perylene	model/secondary	2.55e-13	2.85e-14
US electric grid	Benzo[a]pyrene	model/secondary	2.41e-13	2.70e-14
LPG Production	Ethylbenzene	secondary	2.19e-13	2.45e-14
US electric grid	2-Methylnaphthalene	model/secondary	1.89e-13	2.11e-14
US electric grid	5-Methyl chrysene	model/secondary	1.40e-13	1.56e-14
LPG Production	Methyl tert-butyl ether	secondary	1.10e-13	1.23e-14
LPG Production	Phenanthrene	secondary	8.93e-14	9.98e-15
LPG Production	Styrene	secondary	8.01e-14	8.96e-15
LPG Production	Vinyl acetate	secondary	7.82e-14	8.74e-15
LPG Production	3-Methylcholanthrene	secondary	7.38e-14	8.26e-15
US electric grid	Dibenzo[a,h]anthracene	model/secondary	6.19e-14	6.92e-15
LPG Production	Zinc (+2)	secondary	4.62e-14	5.17e-15
LPG Production	Ethylene dibromide	secondary	3.16e-14	3.54e-15
LPG Production	1,1,1-Trichloroethane	secondary	2.98e-14	3.33e-15
LPG Production	2-Methylnaphthalene	secondary	2.37e-14	2.65e-15
LPG Production	Ethyl Chloride	secondary	2.11e-14	2.36e-15
LPG Production	Chlorine	secondary	2.10e-14	2.34e-15
LPG Production	Cumene	secondary	1.79e-14	2.00e-15
US electric grid	Anthracene	model/secondary	1.64e-14	1.84e-15
LPG Production	Acetophenone	secondary	1.11e-14	1.24e-15
LPG Production	Biphenyl	secondary	1.07e-14	1.19e-15
LPG Production	Acenaphthylene	secondary	8.43e-15	9.43e-16
LPG Production	Acenaphthene	secondary	7.02e-15	7.86e-16
LPG Production	Nickel cmpds	secondary	5.47e-15	6.12e-16
LPG Production	Benzo[a]anthracene	secondary	4.92e-15	5.50e-16
LPG Production	Chrysene	secondary	4.72e-15	5.27e-16
LPG Production	Lead cmpds	secondary	4.60e-15	5.14e-16
LPG Production	Indeno(1,2,3-cd)pyrene	secondary	3.66e-15	4.09e-16
LPG Production	Benzo[b,j,k]fluoranthene	secondary	2.90e-15	3.24e-16
LPG Production	Mercury compounds	secondary	2.78e-15	3.11e-16
LPG Production	Benzo[a]pyrene	secondary	2.69e-15	3.01e-16
LPG Production	Fluorene	secondary	2.60e-15	2.91e-16
LPG Production	Pyrene	secondary	2.25e-15	2.52e-16

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
LPG Production	Benzo[g,h,i]perylene	secondary	2.19e-15	2.44e-16
LPG Production	Fluoranthene	secondary	2.12e-15	2.37e-16
LPG Production	HALON-1301	secondary	2.00e-15	2.24e-16
LPG Production	Benzo[b]fluoranthene	secondary	1.96e-15	2.20e-16
LPG Production	Dibenzo[a,h]anthracene	secondary	1.40e-15	1.56e-16
LPG Production	5-Methyl chrysene	secondary	5.80e-16	6.48e-17
LPG Production	Halogenated matter (organic)	secondary	4.60e-16	5.14e-17
US electric grid	2,3,7,8-TCDF	model/secondary	3.24e-16	3.62e-17
LPG Production	Anthracene	secondary	9.78e-17	1.09e-17
LPG Production	Halogenated hydrocarbons (unspecified)	secondary	1.15e-18	1.29e-19
Natural Gas Prod.	Halogenated hydrocarbons (unspecified)	secondary	-1.95e-18	-2.18e-19
LCD incineration	Halogenated hydrocarbons (unspecified)	secondary	-2.06e-17	-2.31e-18
Fuel Oil #4 Prod.	Halogenated hydrocarbons (unspecified)	secondary	-4.72e-16	-5.28e-17
Natural Gas Prod.	Halogenated matter (organic)	secondary	-7.81e-16	-8.73e-17
Natural Gas Prod.	HALON-1301	secondary	-3.40e-15	-3.80e-16
Natural Gas Prod.	Mercury compounds	secondary	-4.73e-15	-5.29e-16
Natural Gas Prod.	Lead cmpds	secondary	-7.81e-15	-8.73e-16
Natural Gas Prod.	Nickel cmpds	secondary	-9.29e-15	-1.04e-15
LCD incineration	Halogenated matter (organic)	secondary	-1.19e-14	-1.33e-15
Natural Gas Prod.	Anthracene	secondary	-3.17e-14	-3.54e-15
LCD incineration	HALON-1301	secondary	-5.17e-14	-5.79e-15
Fuel Oil #4 Prod.	Anthracene	secondary	-5.55e-14	-6.21e-15
Natural Gas Prod.	5-Methyl chrysene	secondary	-8.45e-14	-9.45e-15
LCD incineration	Nickel cmpds	secondary	-1.42e-13	-1.58e-14
Fuel Oil #4 Prod.	Halogenated matter (organic)	secondary	-1.89e-13	-2.11e-14
LCD incineration	Dibenzo[a,h]anthracene	secondary	-2.91e-13	-3.26e-14
Fuel Oil #4 Prod.	5-Methyl chrysene	secondary	-3.50e-13	-3.91e-14
Natural Gas Prod.	Benzo[b,j,k]fluoranthene	secondary	-4.23e-13	-4.73e-14
LCD incineration	Benzo[b]fluoranthene	secondary	-4.31e-13	-4.82e-14
Natural Gas Prod.	Fluoranthene	secondary	-4.85e-13	-5.42e-14
Natural Gas Prod.	Fluorene	secondary	-5.43e-13	-6.07e-14
Fuel Oil #4 Prod.	Dibenzo[a,h]anthracene	secondary	-6.88e-13	-7.70e-14
Natural Gas Prod.	Pyrene	secondary	-8.10e-13	-9.06e-14
Fuel Oil #4 Prod.	HALON-1301	secondary	-8.22e-13	-9.19e-14
Natural Gas Prod.	Copper (+1 & +2)	secondary	-8.77e-13	-9.80e-14
Natural Gas Prod.	Aromatic hydrocarbons	secondary	-9.37e-13	-1.05e-13
Natural Gas Prod.	Dibenzo[a,h]anthracene	secondary	-9.38e-13	-1.05e-13
Fuel Oil #4 Prod.	Benzo[b]fluoranthene	secondary	-9.78e-13	-1.09e-13
Natural Gas Prod.	Benzo[a]pyrene	secondary	-1.04e-12	-1.17e-13
Natural Gas Prod.	Benzo[g,h,i]perylene	secondary	-1.06e-12	-1.18e-13
Fuel Oil #4 Prod.	Mercury compounds	secondary	-1.14e-12	-1.28e-13
Fuel Oil #4 Prod.	Benzo[g,h,i]perylene	secondary	-1.15e-12	-1.28e-13
Fuel Oil #4 Prod.	Fluoranthene	secondary	-1.24e-12	-1.39e-13
Fuel Oil #4 Prod.	Pyrene	secondary	-1.26e-12	-1.41e-13
Natural Gas Prod.	Benzo[b]fluoranthene	secondary	-1.38e-12	-1.54e-13
Natural Gas Prod.	Acenaphthene	secondary	-1.49e-12	-1.67e-13
Fuel Oil #4 Prod.	Fluorene	secondary	-1.53e-12	-1.71e-13
Natural Gas Prod.	Biphenyl	secondary	-1.55e-12	-1.74e-13
Fuel Oil #4 Prod.	Benzo[a]pyrene	secondary	-1.56e-12	-1.74e-13

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Acetophenone	secondary	-1.62e-12	-1.81e-13
Natural Gas Prod.	Indeno(1,2,3-cd)pyrene	secondary	-1.63e-12	-1.83e-13
Fuel Oil #4 Prod.	Benzo[b,j,k]fluoranthene	secondary	-1.75e-12	-1.96e-13
Natural Gas Prod.	Chrysene	secondary	-1.79e-12	-2.00e-13
Natural Gas Prod.	Benzo[a]anthracene	secondary	-1.86e-12	-2.08e-13
Fuel Oil #4 Prod.	Lead cmpds	secondary	-1.89e-12	-2.11e-13
Fuel Oil #4 Prod.	Indeno(1,2,3-cd)pyrene	secondary	-1.98e-12	-2.22e-13
Fuel Oil #4 Prod.	Nickel cmpds	secondary	-2.25e-12	-2.51e-13
Natural Gas Prod.	Acenaphthylene	secondary	-2.32e-12	-2.59e-13
LCD incineration	Anthracene	secondary	-2.41e-12	-2.70e-13
Fuel Oil #4 Prod.	Benzo[a]anthracene	secondary	-2.60e-12	-2.91e-13
Natural Gas Prod.	Cumene	secondary	-2.61e-12	-2.91e-13
Fuel Oil #4 Prod.	Chrysene	secondary	-2.61e-12	-2.92e-13
Natural Gas Prod.	Ethyl Chloride	secondary	-3.08e-12	-3.44e-13
Fuel Oil #4 Prod.	Acenaphthene	secondary	-3.83e-12	-4.28e-13
Natural Gas Prod.	1,1,1-Trichloroethane	secondary	-4.35e-12	-4.86e-13
Natural Gas Prod.	Ethylene dibromide	secondary	-4.61e-12	-5.16e-13
Natural Gas Prod.	Cadmium cmpds	secondary	-4.65e-12	-5.20e-13
Fuel Oil #4 Prod.	Acenaphthylene	secondary	-4.90e-12	-5.48e-13
LCD incineration	2-Methylnaphthalene	secondary	-5.65e-12	-6.31e-13
Fuel Oil #4 Prod.	Biphenyl	secondary	-6.43e-12	-7.19e-13
Fuel Oil #4 Prod.	Acetophenone	secondary	-6.71e-12	-7.50e-13
Fuel Oil #4 Prod.	Chlorine	secondary	-1.04e-11	-1.17e-12
Fuel Oil #4 Prod.	Cumene	secondary	-1.08e-11	-1.21e-12
Natural Gas Prod.	Vinyl acetate	secondary	-1.14e-11	-1.27e-12
Natural Gas Prod.	Styrene	secondary	-1.17e-11	-1.31e-12
Fuel Oil #4 Prod.	2-Methylnaphthalene	secondary	-1.20e-11	-1.34e-12
LCD incineration	Chlorine	secondary	-1.26e-11	-1.40e-12
Fuel Oil #4 Prod.	Ethyl Chloride	secondary	-1.27e-11	-1.42e-12
LCD incineration	Copper (+1 & +2)	secondary	-1.34e-11	-1.49e-12
LCD incineration	Aromatic hydrocarbons	secondary	-1.43e-11	-1.60e-12
LCD incineration	Zinc (+2)	secondary	-1.45e-11	-1.62e-12
Natural Gas Prod.	Methyl tert-butyl ether	secondary	-1.60e-11	-1.79e-12
LCD incineration	3-Methylcholanthrene	secondary	-1.76e-11	-1.97e-12
Natural Gas Prod.	2-Methylnaphthalene	secondary	-1.79e-11	-2.00e-12
Fuel Oil #4 Prod.	1,1,1-Trichloroethane	secondary	-1.80e-11	-2.01e-12
Fuel Oil #4 Prod.	Ethylene dibromide	secondary	-1.91e-11	-2.13e-12
Fuel Oil #4 Prod.	Zinc (+2)	secondary	-2.12e-11	-2.37e-12
LCD incineration	5-Methyl chrysene	secondary	-2.12e-11	-2.37e-12
Natural Gas Prod.	Phenanthrene	secondary	-2.33e-11	-2.61e-12
LCD incineration	Benzo[g,h,i]perylene	secondary	-2.63e-11	-2.94e-12
Natural Gas Prod.	Aluminum (elemental)	secondary	-2.81e-11	-3.15e-12
LCD incineration	Dichlorobenzene (mixed isomers)	secondary	-3.18e-11	-3.55e-12
Natural Gas Prod.	Ethylbenzene	secondary	-3.20e-11	-3.58e-12
LCD incineration	Benzo[a]pyrene	secondary	-3.69e-11	-4.13e-12
Fuel Oil #4 Prod.	3-Methylcholanthrene	secondary	-3.74e-11	-4.18e-12
Fuel Oil #4 Prod.	Vinyl acetate	secondary	-4.71e-11	-5.27e-12
Fuel Oil #4 Prod.	Styrene	secondary	-4.83e-11	-5.40e-12
LCD incineration	Pyrene	secondary	-5.06e-11	-5.66e-12
Fuel Oil #4 Prod.	Phenanthrene	secondary	-5.20e-11	-5.81e-12
Natural Gas Prod.	Chromium (III)	secondary	-5.33e-11	-5.96e-12

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	3-Methylcholanthrene	secondary	-5.59e-11	-6.25e-12
LCD incineration	Indeno(1,2,3-cd)pyrene	secondary	-5.92e-11	-6.62e-12
Natural Gas Prod.	2,4-Dinitrotoluene	secondary	-6.40e-11	-7.16e-12
LCD incineration	Fluoranthene	secondary	-6.52e-11	-7.29e-12
Fuel Oil #4 Prod.	Methyl tert-butyl ether	secondary	-6.62e-11	-7.40e-12
LCD incineration	Benzo[a]anthracene	secondary	-7.75e-11	-8.67e-12
Natural Gas Prod.	Chlorobenzene	secondary	-8.05e-11	-9.00e-12
LCD incineration	Fluorene	secondary	-8.35e-11	-9.34e-12
Natural Gas Prod.	Dichloromethane	secondary	-9.62e-11	-1.08e-11
LCD incineration	Chrysene	secondary	-9.68e-11	-1.08e-11
Natural Gas Prod.	Bromoform	secondary	-9.96e-11	-1.11e-11
Natural Gas Prod.	1,2-Dichloroethane	secondary	-1.02e-10	-1.14e-11
LCD incineration	Benzo[b,j,k]fluoranthene	secondary	-1.06e-10	-1.19e-11
Natural Gas Prod.	Barium cmpds	secondary	-1.06e-10	-1.19e-11
Natural Gas Prod.	Methyl methacrylate	secondary	-1.22e-10	-1.36e-11
Natural Gas Prod.	Silicon	secondary	-1.23e-10	-1.37e-11
Fuel Oil #4 Prod.	Ethylbenzene	secondary	-1.32e-10	-1.47e-11
Natural Gas Prod.	Tetrachloroethylene	secondary	-1.40e-10	-1.57e-11
Natural Gas Prod.	Methyl ethyl ketone	secondary	-1.43e-10	-1.60e-11
Fuel Oil #4 Prod.	o-xylene	secondary	-1.43e-10	-1.60e-11
Natural Gas Prod.	Chlorine	secondary	-1.57e-10	-1.75e-11
LCD incineration	Acenaphthene	secondary	-1.67e-10	-1.87e-11
Natural Gas Prod.	Zinc (+2)	secondary	-1.74e-10	-1.94e-11
Natural Gas Prod.	Isophorone	secondary	-1.77e-10	-1.98e-11
Natural Gas Prod.	Dimethyl sulfate	secondary	-1.84e-10	-2.06e-11
Fuel Oil #4 Prod.	Chromium (III)	secondary	-2.04e-10	-2.29e-11
Fuel Oil #4 Prod.	Copper (+1 & +2)	secondary	-2.12e-10	-2.37e-11
Fuel Oil #4 Prod.	Aromatic hydrocarbons	secondary	-2.27e-10	-2.54e-11
LCD incineration	Acenaphthylene	secondary	-2.41e-10	-2.70e-11
Fuel Oil #4 Prod.	2,4-Dinitrotoluene	secondary	-2.65e-10	-2.96e-11
Fuel Oil #4 Prod.	Chlorobenzene	secondary	-3.33e-10	-3.72e-11
Natural Gas Prod.	Di(2-ethylhexyl)phthalate	secondary	-3.85e-10	-4.31e-11
LCD incineration	Biphenyl	secondary	-3.90e-10	-4.36e-11
Fuel Oil #4 Prod.	Dichloromethane	secondary	-3.98e-10	-4.45e-11
LCD incineration	Acetophenone	secondary	-4.07e-10	-4.55e-11
Fuel Oil #4 Prod.	Bromoform	secondary	-4.12e-10	-4.61e-11
Fuel Oil #4 Prod.	1,2-Dichloroethane	secondary	-4.20e-10	-4.70e-11
Natural Gas Prod.	Cadmium	secondary	-4.65e-10	-5.20e-11
Natural Gas Prod.	Propionaldehyde	secondary	-5.02e-10	-5.61e-11
Natural Gas Prod.	Acetaldehyde	secondary	-5.02e-10	-5.61e-11
Fuel Oil #4 Prod.	Methyl methacrylate	secondary	-5.04e-10	-5.64e-11
Fuel Oil #4 Prod.	Tetrachloroethylene	secondary	-5.81e-10	-6.50e-11
Fuel Oil #4 Prod.	Methyl ethyl ketone	secondary	-5.90e-10	-6.60e-11
Natural Gas Prod.	Mercury	secondary	-6.23e-10	-6.97e-11
Natural Gas Prod.	Methyl hydrazine	secondary	-6.53e-10	-7.31e-11
LCD incineration	Cumene	secondary	-6.53e-10	-7.31e-11
LCD incineration	Aluminum (elemental)	secondary	-7.02e-10	-7.85e-11
Fuel Oil #4 Prod.	1,4-Dichlorobenzene	secondary	-7.13e-10	-7.97e-11
Fuel Oil #4 Prod.	Isophorone	secondary	-7.31e-10	-8.18e-11

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	Dimethyl sulfate	secondary	-7.63e-10	-8.53e-11
LCD incineration	Ethyl Chloride	secondary	-7.72e-10	-8.64e-11
Natural Gas Prod.	Cobalt	secondary	-8.74e-10	-9.78e-11
Natural Gas Prod.	Methyl chloride	secondary	-9.03e-10	-1.01e-10
Natural Gas Prod.	Beryllium	secondary	-9.26e-10	-1.04e-10
Natural Gas Prod.	Aluminum (+3)	secondary	-9.48e-10	-1.06e-10
Natural Gas Prod.	1,4-Dichlorobenzene	secondary	-1.07e-09	-1.19e-10
LCD incineration	1,1,1-Trichloroethane	secondary	-1.09e-09	-1.22e-10
Natural Gas Prod.	Acrolein	secondary	-1.11e-09	-1.25e-10
Fuel Oil #4 Prod.	Cadmium cmpds	secondary	-1.12e-09	-1.26e-10
LCD incineration	Ethylene dibromide	secondary	-1.16e-09	-1.29e-10
Fuel Oil #4 Prod.	Toluene	secondary	-1.35e-09	-1.50e-10
Natural Gas Prod.	o-xylene	secondary	-1.52e-09	-1.70e-10
Fuel Oil #4 Prod.	Di(2-ethylhexyl)phthalate	secondary	-1.59e-09	-1.78e-10
Natural Gas Prod.	PM-10	secondary	-1.63e-09	-1.83e-10
Fuel Oil #4 Prod.	Cadmium	secondary	-1.90e-09	-2.12e-10
Fuel Oil #4 Prod.	Mercury	secondary	-2.05e-09	-2.30e-10
Fuel Oil #4 Prod.	Propionaldehyde	secondary	-2.07e-09	-2.32e-10
Fuel Oil #4 Prod.	Acetaldehyde	secondary	-2.07e-09	-2.32e-10
Natural Gas Prod.	Chloroform	secondary	-2.09e-09	-2.34e-10
LCD incineration	Xylene (mixed isomers)	secondary	-2.22e-09	-2.48e-10
LCD incineration	Phenanthrene	secondary	-2.61e-09	-2.91e-10
Natural Gas Prod.	Benzyl chloride	secondary	-2.69e-09	-3.01e-10
Fuel Oil #4 Prod.	Methyl hydrazine	secondary	-2.70e-09	-3.02e-10
Natural Gas Prod.	Toluene	secondary	-2.86e-09	-3.20e-10
LCD incineration	Vinyl acetate	secondary	-2.86e-09	-3.20e-10
LCD incineration	Styrene	secondary	-2.93e-09	-3.28e-10
LCD incineration	Silicon	secondary	-3.07e-09	-3.43e-10
Fuel Oil #4 Prod.	Beryllium	secondary	-3.31e-09	-3.71e-10
Natural Gas Prod.	Carbon disulfide	secondary	-3.43e-09	-3.84e-10
Fuel Oil #4 Prod.	Methyl chloride	secondary	-3.73e-09	-4.18e-10
LCD incineration	Methyl tert-butyl ether	secondary	-4.01e-09	-4.49e-10
Fuel Oil #4 Prod.	Acrolein	secondary	-4.61e-09	-5.15e-10
Natural Gas Prod.	Phenol	secondary	-4.83e-09	-5.40e-10
Natural Gas Prod.	Nitrate	secondary	-4.98e-09	-5.57e-10
Fuel Oil #4 Prod.	Cobalt	secondary	-6.12e-09	-6.85e-10
LCD incineration	Chloroacetophenone	secondary	-6.74e-09	-7.54e-10
Natural Gas Prod.	Lead	secondary	-7.17e-09	-8.02e-10
LCD incineration	Ethylbenzene	secondary	-7.87e-09	-8.80e-10
Fuel Oil #4 Prod.	Chloroform	secondary	-8.65e-09	-9.67e-10
Natural Gas Prod.	Cyanide (-1)	secondary	-9.61e-09	-1.07e-09
Fuel Oil #4 Prod.	Aluminum (elemental)	secondary	-1.06e-08	-1.19e-09
Fuel Oil #4 Prod.	Benzyl chloride	secondary	-1.11e-08	-1.24e-09
LCD incineration	Chromium (III)	secondary	-1.13e-08	-1.27e-09
Natural Gas Prod.	Manganese	secondary	-1.31e-08	-1.46e-09
Fuel Oil #4 Prod.	Carbon disulfide	secondary	-1.42e-08	-1.59e-09
LCD incineration	Aluminum (+3)	secondary	-1.44e-08	-1.61e-09
LCD incineration	2,4-Dinitrotoluene	secondary	-1.61e-08	-1.80e-09
Natural Gas Prod.	Copper	secondary	-1.75e-08	-1.95e-09
Natural Gas Prod.	Bromomethane	secondary	-1.83e-08	-2.05e-09
Natural Gas Prod.	2-Chloroacetophenone	secondary	-1.85e-08	-2.07e-09

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Barium	secondary	-1.95e-08	-2.18e-09
LCD incineration	Chlorobenzene	secondary	-2.02e-08	-2.26e-09
Natural Gas Prod.	Hydrogen sulfide	secondary	-2.23e-08	-2.49e-09
LCD incineration	Dichloromethane	secondary	-2.41e-08	-2.69e-09
LCD incineration	Bromoform	secondary	-2.50e-08	-2.79e-09
LCD incineration	1,2-Dichloroethane	secondary	-2.53e-08	-2.83e-09
Fuel Oil #4 Prod.	Barium cmpds	secondary	-2.57e-08	-2.87e-09
Fuel Oil #4 Prod.	Lead	secondary	-2.94e-08	-3.29e-09
LCD incineration	Methyl methacrylate	secondary	-3.06e-08	-3.42e-09
LCD incineration	Dimethylbenzanthracene	secondary	-3.12e-08	-3.49e-09
Natural Gas Prod.	Chromium (VI)	secondary	-3.13e-08	-3.50e-09
LCD incineration	Tetrachloroethylene	secondary	-3.50e-08	-3.91e-09
LCD incineration	Methyl ethyl ketone	secondary	-3.58e-08	-4.00e-09
Fuel Oil #4 Prod.	Barium	secondary	-3.61e-08	-4.04e-09
Fuel Oil #4 Prod.	Cyanide (-1)	secondary	-3.97e-08	-4.44e-09
Natural Gas Prod.	Nickel	secondary	-4.07e-08	-4.55e-09
LCD incineration	PM-10	secondary	-4.08e-08	-4.56e-09
Natural Gas Prod.	Naphthalene	secondary	-4.31e-08	-4.82e-09
LCD incineration	Isophorone	secondary	-4.43e-08	-4.96e-09
LCD incineration	Dimethyl sulfate	secondary	-4.62e-08	-5.17e-09
Fuel Oil #4 Prod.	Silicon	secondary	-4.64e-08	-5.19e-09
LCD incineration	Toluene	secondary	-4.73e-08	-5.29e-09
Fuel Oil #4 Prod.	Manganese	secondary	-5.28e-08	-5.91e-09
Fuel Oil #4 Prod.	Naphthalene	secondary	-5.29e-08	-5.91e-09
Fuel Oil #4 Prod.	Dimethylbenzanthracene	secondary	-6.37e-08	-7.12e-09
LCD incineration	Cadmium	secondary	-6.38e-08	-7.13e-09
Fuel Oil #4 Prod.	Bromomethane	secondary	-7.56e-08	-8.46e-09
LCD incineration	Phenol	secondary	-7.60e-08	-8.50e-09
Fuel Oil #4 Prod.	2-Chloroacetophenone	secondary	-7.64e-08	-8.55e-09
LCD incineration	Mercury	secondary	-8.42e-08	-9.42e-09
Fuel Oil #4 Prod.	Copper	secondary	-8.86e-08	-9.90e-09
Natural Gas Prod.	Dimethylbenzanthracene	secondary	-9.51e-08	-1.06e-08
LCD incineration	Di(2-ethylhexyl)phthalate	secondary	-9.66e-08	-1.08e-08
Fuel Oil #4 Prod.	Nitrate	secondary	-1.04e-07	-1.17e-08
Fuel Oil #4 Prod.	Chromium (VI)	secondary	-1.20e-07	-1.34e-08
LCD incineration	Cobalt	secondary	-1.24e-07	-1.39e-08
LCD incineration	Acetaldehyde	secondary	-1.26e-07	-1.41e-08
LCD incineration	Propionaldehyde	secondary	-1.26e-07	-1.41e-08
Natural Gas Prod.	Antimony	secondary	-1.47e-07	-1.65e-08
LCD incineration	Methyl hydrazine	secondary	-1.64e-07	-1.83e-08
LCD incineration	Beryllium	secondary	-1.94e-07	-2.18e-08
LCD incineration	Methyl chloride	secondary	-2.26e-07	-2.53e-08
Fuel Oil #4 Prod.	Aluminum (+3)	secondary	-2.29e-07	-2.56e-08
LCD incineration	Copper	secondary	-2.67e-07	-2.99e-08
LCD incineration	Acrolein	secondary	-2.79e-07	-3.12e-08
Fuel Oil #4 Prod.	Antimony	secondary	-4.21e-07	-4.70e-08
LCD incineration	Hexane	secondary	-4.88e-07	-5.46e-08
LCD incineration	Hydrogen sulfide	secondary	-5.13e-07	-5.74e-08
LCD incineration	Chloroform	secondary	-5.22e-07	-5.84e-08

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Natural Gas Prod.	Hydrofluoric acid	secondary	-5.77e-07	-6.45e-08
Natural Gas Prod.	Phosphorus (yellow or white)	secondary	-5.86e-07	-6.55e-08
LCD incineration	Pentane	secondary	-6.12e-07	-6.84e-08
Fuel Oil #4 Prod.	PM-10	secondary	-6.18e-07	-6.91e-08
LCD incineration	Benzyl chloride	secondary	-6.74e-07	-7.54e-08
LCD incineration	Ethane	secondary	-7.29e-07	-8.16e-08
Fuel Oil #4 Prod.	Nickel	secondary	-7.65e-07	-8.55e-08
Natural Gas Prod.	Molybdenum	secondary	-7.65e-07	-8.56e-08
LCD incineration	Carbon disulfide	secondary	-8.60e-07	-9.62e-08
LCD incineration	Barium	secondary	-8.87e-07	-9.92e-08
Fuel Oil #4 Prod.	Hexane	secondary	-9.00e-07	-1.01e-07
Fuel Oil #4 Prod.	Phenol	secondary	-1.16e-06	-1.30e-07
LCD incineration	Nitrate	secondary	-1.17e-06	-1.30e-07
Fuel Oil #4 Prod.	Pentane	secondary	-1.30e-06	-1.45e-07
LCD incineration	Naphthalene	secondary	-1.31e-06	-1.47e-07
Natural Gas Prod.	Hexane	secondary	-1.34e-06	-1.50e-07
Fuel Oil #4 Prod.	Ethane	secondary	-1.55e-06	-1.73e-07
Natural Gas Prod.	Pentane	secondary	-1.94e-06	-2.17e-07
Natural Gas Prod.	Ethane	secondary	-2.31e-06	-2.59e-07
Fuel Oil #4 Prod.	Zinc (elemental)	secondary	-2.35e-06	-2.63e-07
Fuel Oil #4 Prod.	Hydrofluoric acid	secondary	-2.38e-06	-2.67e-07
LCD incineration	Cyanide (-1)	secondary	-2.41e-06	-2.69e-07
Natural Gas Prod.	Zinc (elemental)	secondary	-2.81e-06	-3.15e-07
LCD incineration	Manganese	secondary	-3.17e-06	-3.55e-07
Natural Gas Prod.	Nitrous oxide	secondary	-3.82e-06	-4.28e-07
Natural Gas Prod.	Selenium	secondary	-4.02e-06	-4.49e-07
Fuel Oil #4 Prod.	Molybdenum	secondary	-4.28e-06	-4.79e-07
Natural Gas Prod.	Fluorides (F-)	secondary	-4.48e-06	-5.01e-07
LCD incineration	Bromomethane	secondary	-4.59e-06	-5.13e-07
LCD incineration	Nickel	secondary	-6.29e-06	-7.04e-07
LCD incineration	Molybdenum	secondary	-6.45e-06	-7.21e-07
LCD incineration	Chromium (VI)	secondary	-6.65e-06	-7.44e-07
Fuel Oil #4 Prod.	Ammonia	secondary	-7.26e-06	-8.12e-07
Fuel Oil #4 Prod.	Hydrogen sulfide	secondary	-8.41e-06	-9.41e-07
Natural Gas Prod.	Formaldehyde	secondary	-9.17e-06	-1.03e-06
LCD incineration	Antimony	secondary	-1.40e-05	-1.56e-06
LCD incineration	Zinc (elemental)	secondary	-1.65e-05	-1.84e-06
Fuel Oil #4 Prod.	Fluorides (F-)	secondary	-1.75e-05	-1.95e-06
Fuel Oil #4 Prod.	Selenium	secondary	-1.77e-05	-1.98e-06
Natural Gas Prod.	Hydrochloric acid	secondary	-2.11e-05	-2.37e-06
Natural Gas Prod.	Vanadium	secondary	-2.30e-05	-2.58e-06
Fuel Oil #4 Prod.	Phosphorus (yellow or white)	secondary	-2.63e-05	-2.94e-06
LCD incineration	Ammonia	secondary	-3.04e-05	-3.40e-06
LCD incineration	Phosphorus (yellow or white)	secondary	-3.56e-05	-3.98e-06
Fuel Oil #4 Prod.	Nitrous oxide	secondary	-4.08e-05	-4.56e-06
Fuel Oil #4 Prod.	Hydrochloric acid	secondary	-8.74e-05	-9.77e-06
Natural Gas Prod.	Ammonia	secondary	-8.90e-05	-9.96e-06
Natural Gas Prod.	Sulfur oxides	secondary	-9.13e-05	-1.02e-05
Natural Gas Prod.	Arsenic	secondary	-1.04e-04	-1.17e-05
Natural Gas Prod.	PM	secondary	-1.37e-04	-1.53e-05
LCD incineration	Hydrofluoric acid	secondary	-1.45e-04	-1.62e-05

Table M-40. LCD LCIA Results for the Terrestrial Ecotoxicity Impact Category

Process Group	Material	LCI Data Type	Terrestrial Toxicity (tox-kg)	% of Total
Fuel Oil #4 Prod.	PM	secondary	-2.87e-04	-3.21e-05
LCD incineration	Formaldehyde	secondary	-2.89e-04	-3.24e-05
Fuel Oil #4 Prod.	Formaldehyde	secondary	-3.65e-04	-4.08e-05
Fuel Oil #4 Prod.	Arsenic	secondary	-5.00e-04	-5.59e-05
LCD incineration	Nitrous oxide	secondary	-6.75e-04	-7.55e-05
LCD incineration	Vanadium	secondary	-7.59e-04	-8.49e-05
LCD incineration	Selenium	secondary	-9.94e-04	-1.11e-04
LCD incineration	Fluorides (F-)	secondary	-1.01e-03	-1.13e-04
Fuel Oil #4 Prod.	Nitrogen oxides	secondary	-1.27e-03	-1.43e-04
Fuel Oil #4 Prod.	Benzene	secondary	-1.71e-03	-1.91e-04
Fuel Oil #4 Prod.	Sulfur oxides	secondary	-1.74e-03	-1.94e-04
Fuel Oil #4 Prod.	Methane	secondary	-1.85e-03	-2.07e-04
LCD incineration	Benzene	secondary	-2.08e-03	-2.32e-04
Fuel Oil #4 Prod.	Vanadium	secondary	-2.86e-03	-3.20e-04
LCD incineration	Hydrochloric acid	secondary	-3.08e-03	-3.44e-04
Natural Gas Prod.	Nitrogen oxides	secondary	-3.09e-03	-3.45e-04
LCD incineration	Nitrogen oxides	secondary	-9.31e-03	-1.04e-03
LCD incineration	Methane	secondary	-9.85e-03	-1.10e-03
Fuel Oil #4 Prod.	Carbon monoxide	secondary	-9.96e-03	-1.11e-03
LCD incineration	PM	secondary	-1.20e-02	-1.34e-03
LCD incineration	Carbon monoxide	secondary	-1.44e-02	-1.61e-03
Natural Gas Prod.	Methane	secondary	-1.66e-02	-1.86e-03
LCD incineration	Sulfur oxides	secondary	-1.75e-02	-1.96e-03
Natural Gas Prod.	Carbon monoxide	secondary	-2.11e-02	-2.36e-03
LCD incineration	Arsenic	secondary	-2.50e-02	-2.80e-03
Natural Gas Prod.	Benzene	secondary	-2.50e-02	-2.80e-03
Total End-of-life			**1.46e-02**	**1.63e-03**
Total All Life-cycle Stages			**8.94e+02**	**1.00e+02**

APPENDIX N

CHAPTER 4 SUPPORTING TABLES

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Table N-1. CRT Lead Inputs by Life-cycle Stage

Life-cycle Stage	Process	Input	Quantity	Units	Type
Materials Processing	Aluminum Prod. (all virgin; EB)	Lead (Pb, ore)	6.30e-05	kg	Ancillary material
Materials Processing	Ferrite mfg. (EB)	Lead (Pb, ore)	5.70e-08	kg	Ancillary material
Materials Processing	Invar (DEAM mix)	Lead (Pb, ore)	5.84e-08	kg	Ancillary material
Materials Processing	Lead (EB)	Lead (Pb, ore)	4.96e-01	kg	Primary material
Materials Processing	Polycarbonate Production (PC; DEAM)	Lead (Pb, ore)	1.85e-06	kg	Ancillary material
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead (Pb, ore)	5.79e-08	kg	Ancillary material
Manufacturing	CRT tube mfg. (CDP)	Frit	6.67e-02	kg	Primary material
Manufacturing	CRT glass mfg. (CDP)	Lead	4.47e-01	kg	Primary material
Manufacturing	Frit manufacturing (CDP)	Lead	4.67e-02	kg	Primary material
Manufacturing	CRT monitor assembly (CDP)	Printed wiring board (PWB)	8.47e-01	kg	Direct to assembly
Manufacturing	PWB Mfg.	Solder (63% tin; 37% lead)	5.08e-02	kg	Primary material
Manufacturing	CRT monitor assembly (CDP)	Solder, unspecified	2.67e-02	kg	Direct to assembly
End-of-life	CRT Incineration (DEAM mix)	EOL CRT Monitor, incinerated	2.20e+01	kg	Primary material
End-of-life	CRT landfilling (CDP)	EOL CRT Monitor, landfilled	1.56e+01	kg	Primary material
End-of-life	CRT Recycling (CDP)	EOL CRT Monitor, recycled	2.42e+00	kg	Primary material

Table N-2. LCD Lead Inputs by Life-cycle Stage

Life-cycle Stage	Process	Input	Quantity	Units	Type
Materials Processing	Aluminum Prod. (all virgin; EB)	Lead (Pb, ore)	2.35e-05	kg	Ancillary material
Materials Processing	PET Resin Production (DEAM)	Lead (Pb, ore)	1.82e-07	kg	Ancillary material
Materials Processing	Polycarbonate Production (PC; DEAM)	Lead (Pb, ore)	1.03e-06	kg	Ancillary material
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead (Pb, ore)	2.84e-08	kg	Ancillary material
Manufacturing	LCD module mfg. (CDP)	Printed wiring board (PWB)	2.27e-02	kg	Direct to assembly
Manufacturing	LCD monitor assembly (CDP)	Printed wiring board (PWB)	3.51e-01	kg	Direct to assembly
Manufacturing	LCD monitor assembly (CDP)	Solder (60% tin, 40% lead)	3.81e-02	kg	Primary material
Manufacturing	PWB Mfg.	Solder (63% tin; 37% lead)	2.24e-02	kg	Primary material
Manufacturing	LCD module mfg. (CDP)	Solder, unspecified	7.35e-05	kg	Ancillary material
End-of-life	LCD incineration (DEAM mix)	EOL LCD Monitor, incinerated	6.50e+00	kg	Primary material
End-of-life	LCD landfilling (CDP)	EOL LCD Monitor, landfilled	3.57e+00	kg	Primary material
End-of-life	LCD recycling (CDP)	EOL LCD Monitor, recycled	9.75e-01	kg	Primary material

Table N-3. CRT Lead Outputs by Life-cycle Stage

Life-Cycle Stage	Process	Output	Quantity	Units	Type	Disposition
Materials Processing	ABS Production (DEAM)	Lead	2.12e-07	kg	Airborne	air
Materials Processing	Aluminum Prod. (all virgin; EB)	Lead	1.20e-06	kg	Airborne	air
Materials Processing	Aluminum Prod. (all virgin; EB)	Lead	1.45e-08	kg	Solid waste	landfill
Materials Processing	Aluminum Prod. (all virgin; EB)	Lead cmpds	8.72e-06	kg	Waterborne	surface water
Materials Processing	Ferrite mfg. (EB)	Lead	3.46e-05	kg	Airborne	air
Materials Processing	Ferrite mfg. (EB)	Lead	1.70e-10	kg	Solid waste	landfill
Materials Processing	Ferrite mfg. (EB)	Lead cmpds	5.19e-07	kg	Waterborne	surface water
Materials Processing	Ferrite mfg. (EB)	Lead-210 (isotope)	1.82e-01	Bq	Radioactivity	air
Materials Processing	Invar (DEAM mix)	Lead	3.62e-05	kg	Airborne	air
Materials Processing	Invar (DEAM mix)	Lead	5.49e-09	kg	Solid waste	landfill
Materials Processing	Invar (DEAM mix)	Lead cmpds	2.98e-06	kg	Waterborne	surface water
Materials Processing	Invar (DEAM mix)	Lead-210 (isotope)	1.87e-01	Bq	Radioactivity	air
Materials Processing	Lead (EB)	Lead	1.58e-03	kg	Airborne	air
Materials Processing	Lead (EB)	Lead	2.72e-09	kg	Solid waste	landfill
Materials Processing	Lead (EB)	Lead cmpds	2.75e-06	kg	Waterborne	surface water
Materials Processing	Polycarbonate Production (PC; DEAM)	Lead	4.62e-07	kg	Airborne	air
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead	1.10e-06	kg	Airborne	air
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead	1.02e-11	kg	Solid waste	landfill
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead cmpds	8.83e-07	kg	Waterborne	surface water
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead-210 (isotope)	6.54e-01	Bq	Radioactivity	air
Materials Processing	Styrene-butadiene Copolymer Prod. (DEAM mix)	Lead	2.07e-07	kg	Airborne	air
Manufacturing	CRT glass mfg. (CDP)	Broken CRT glass	1.88e-03	kg	Hazardous waste	landfill
Manufacturing	CRT glass mfg. (CDP)	cinders from CRT glass mfg (70% PbO)	8.26e-03	kg	Hazardous waste	landfill
Manufacturing	CRT glass mfg. (CDP)	CRT glass faceplate EP dust (Pb) (D008 waste)	1.03e-03	kg	Hazardous waste	landfill
Manufacturing	CRT glass mfg. (CDP)	CRT glass funnel EP dust (Pb) (D008 waste)	5.01e-03	kg	Hazardous waste	recycling/reuse

Table N-3. CRT Lead Outputs by Life-cycle Stage

Life-Cycle Stage	Process	Output	Quantity	Units	Type	Disposition
Manufacturing	CRT glass mfg. (CDP)	Hazardous sludge (Pb) (D008)	1.52e-03	kg	Hazardous waste	landfill
Manufacturing	CRT glass mfg. (CDP)	Lead	3.22e-07	kg	Airborne	air
Manufacturing	CRT glass mfg. (CDP)	Lead	4.34e-05	kg	Waterborne	surface water
Manufacturing	CRT glass mfg. (CDP)	Lead contaminated grit (D008 waste)	3.46e-05	kg	Hazardous waste	landfill
Manufacturing	CRT glass mfg. (CDP)	Lead debris (D008 waste)	2.14e-04	kg	Hazardous waste	landfill
Manufacturing	CRT glass mfg. (CDP)	sludge from CRT glass mfg (1% PbO)	8.78e-04	kg	Hazardous waste	landfill
Manufacturing	CRT glass mfg. (CDP)	Waste Batch (Ba, Pb) (D008 waste)	1.41e-03	kg	Hazardous waste	landfill
Manufacturing	CRT glass mfg. (CDP)	Waste finishing sludge (Pb) (D008 waste)	2.56e-04	kg	Hazardous waste	landfill
Manufacturing	CRT monitor assembly (CDP)	Broken CRT glass	3.82e-01	kg	Solid waste	recycling/reuse
Manufacturing	CRT monitor assembly (CDP)	Printed wiring board (PWB)	3.70e-02	kg	Solid waste	recycling/reuse
Manufacturing	CRT tube mfg. (CDP)	Broken CRT glass	6.94e-01	kg	Solid waste	recycling/reuse
Manufacturing	CRT tube mfg. (CDP)	Frit	2.99e-03	kg	Hazardous waste	landfill
Manufacturing	CRT tube mfg. (CDP)	Lead	3.01e-06	kg	Waterborne	surface water
Manufacturing	CRT tube mfg. (CDP)	Lead	1.03e-06	kg	Waterborne	treatment
Manufacturing	CRT tube mfg. (CDP)	Lead sulfate cake	2.67e-05	kg	Hazardous waste	landfill
Manufacturing	Frit manufacturing (CDP)	Lead	3.20e-10	kg	Airborne	air
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Lead	3.88e-08	kg	Airborne	air
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Lead cmpds	3.28e-12	kg	Waterborne	surface water
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Lead	4.14e-09	kg	Airborne	air
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Lead cmpds	2.66e-13	kg	Waterborne	surface water
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Lead	9.99e-08	kg	Airborne	air
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Lead cmpds	3.95e-12	kg	Waterborne	surface water
Manufacturing	Japanese Electric Grid	Lead (Pb, ore)	4.41e-07	kg	Airborne	air
Manufacturing	LPG Production (DEAM)	Lead	1.24e-05	kg	Airborne	air
Manufacturing	LPG Production (DEAM)	Lead cmpds	1.17e-09	kg	Waterborne	surface water

Table N-3. CRT Lead Outputs by Life-cycle Stage

Life-Cycle Stage	Process	Output	Quantity	Units	Type	Disposition
Manufacturing	Natural Gas Prod. (DEAM)	Lead	2.17e-08	kg	Airborne	air
Manufacturing	Natural Gas Prod. (DEAM)	Lead cmpds	2.36e-14	kg	Waterborne	surface water
Manufacturing	PWB Mfg.	Lead cmpds	1.62e-05	kg	Waterborne	treatment
Manufacturing	PWB Mfg.	PWB-Solder dross	6.70e-02	kg	Hazardous waste	recycling/reuse
Manufacturing	US electric grid	Lead	2.04e-07	kg	Airborne	air
Use	CRT monitor use (CDP)	EOL CRT Monitor, landfilled	1.01e+01	kg	Hazardous waste	treatment
Use	CRT monitor use (CDP)	EOL CRT Monitor, landfilled	2.12e+01	kg	Solid waste	treatment
Use	CRT monitor use (CDP)	EOL CRT Monitor, recycled	2.42e+00	kg	Solid waste	treatment
Use	CRT monitor use (CDP)	EOL CRT Monitor, remanufactured	6.60e-01	kg	Solid waste	recycling/reuse
Use	US electric grid	Lead	1.28e-05	kg	Airborne	air
End-of-life	CRT Incineration (DEAM mix)	Lead	1.43e-05	kg	Airborne	air
End-of-life	CRT Incineration (DEAM mix)	Lead cmpds	8.11e-10	kg	Waterborne	surface water
End-of-life	CRT landfilling (CDP)	EOL CRT Monitor, landfilled	3.91e+00	kg	Solid waste	landfill
End-of-life	CRT landfilling (CDP)	Lead cmpds	7.90e-10	kg	Waterborne	surface water
End-of-life	CRT Recycling (CDP)	Printed wiring board (PWB)	1.46e-01	kg	Hazardous waste	recycling/reuse
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Lead	-4.45e-08	kg	Airborne	air
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Lead cmpds	-2.86e-12	kg	Waterborne	surface water
End-of-life	LPG Production (DEAM)	Lead	1.07e-10	kg	Airborne	air
End-of-life	LPG Production (DEAM)	Lead cmpds	1.01e-14	kg	Waterborne	surface water
End-of-life	Natural Gas Prod. (DEAM)	Lead	-1.09e-08	kg	Airborne	air
End-of-life	Natural Gas Prod. (DEAM)	Lead cmpds	-1.18e-14	kg	Waterborne	surface water
End-of-life	US electric grid	Lead	1.28e-09	kg	Airborne	air

Table N-4. LCD Lead Outputs by Life-cycle Stage

Life-cycle Stage	Process	Output	Quantity	Units	Type	Disposition
Materials Processing	Aluminum Prod. (all virgin; EB)	Lead	4.47e-07	kg	Airborne	air
Materials Processing	Aluminum Prod. (all virgin; EB)	Lead	5.41e-09	kg	Solid waste	landfill
Materials Processing	Aluminum Prod. (all virgin; EB)	Lead cmpds	3.25e-06	kg	Waterborne	surface water
Materials Processing	Natural Gas Prod. (DEAM)	Lead	1.51e-06	kg	Airborne	air
Materials Processing	Natural Gas Prod. (DEAM)	Lead cmpds	1.65e-12	kg	Waterborne	surface water
Materials Processing	PET Resin Production (DEAM)	Lead	9.08e-08	kg	Airborne	air
Materials Processing	PMMA Sheet Prod. (DEAM)	Lead	1.92e-07	kg	Airborne	air
Materials Processing	Polycarbonate Production (PC; DEAM)	Lead	2.58e-07	kg	Airborne	air
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead	5.40e-07	kg	Airborne	air
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead	4.98e-12	kg	Solid waste	landfill
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead cmpds	4.33e-07	kg	Waterborne	surface water
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Lead-210 (isotope)	3.21e-01	Bq	Radioactivity	air
Materials Processing	Styrene-butadiene Copolymer Prod. (DEAM mix)	Lead	9.04e-08	kg	Airborne	air
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Lead	1.81e-09	kg	Airborne	air
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Lead cmpds	1.53e-13	kg	Waterborne	surface water
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Lead	6.38e-09	kg	Airborne	air
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Lead cmpds	4.10e-13	kg	Waterborne	surface water
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Lead	3.40e-09	kg	Airborne	air
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Lead cmpds	1.34e-13	kg	Waterborne	surface water
Manufacturing	Japanese Electric Grid	Lead (Pb, ore)	1.48e-06	kg	Airborne	air
Manufacturing	LCD backlight unit assembly (CDP)	Waste CCFL, with lead	8.17e-08	kg	Hazardous waste	treatment
Manufacturing	LCD CCFL mfg. (CDP)	Lead	8.33e-07	kg	Waterborne	treatment
Manufacturing	LCD glass mfg. (CDP)	Lead	2.01e-06	kg	Waterborne	surface water
Manufacturing	LCD glass mfg. (CDP)	Waste Batch (Ba, Pb) (D008 waste)	6.55e-05	kg	Hazardous waste	landfill

Table N-4. LCD Lead Outputs by Life-cycle Stage

Life-cycle Stage	Process	Output	Quantity	Units	Type	Disposition
Manufacturing	LCD module mfg. (CDP)	Lead	6.17e-06	kg	Waterborne	surface water
Manufacturing	LCD monitor assembly (CDP)	Printed wiring board (PWB)	7.50e-03	kg	Solid waste	landfill
Manufacturing	LPG Production (DEAM)	Lead	5.93e-07	kg	Airborne	air
Manufacturing	LPG Production (DEAM)	Lead cmpds	5.60e-11	kg	Waterborne	surface water
Manufacturing	Natural Gas Prod. (DEAM)	Lead	3.42e-08	kg	Airborne	air
Manufacturing	Natural Gas Prod. (DEAM)	Lead cmpds	3.72e-14	kg	Waterborne	surface water
Manufacturing	PWB Mfg.	Lead cmpds	7.14e-06	kg	Waterborne	treatment
Manufacturing	PWB Mfg.	PWB-Lead contaminated waste oil	5.14e-03	kg	Hazardous waste	treatment
Manufacturing	PWB Mfg.	PWB-Solder dross	2.96e-02	kg	Hazardous waste	recycling/reuse
Manufacturing	US electric grid	Lead	2.47e-08	kg	Airborne	air
Use	LCD monitor use (CDP)	EOL LCD Monitor, incinerated	9.75e-01	kg	Solid waste	treatment
Use	LCD monitor use (CDP)	EOL LCD Monitor, landfilled	3.25e-01	kg	Hazardous waste	treatment
Use	LCD monitor use (CDP)	EOL LCD Monitor, landfilled	6.82e+00	kg	Solid waste	treatment
Use	LCD monitor use (CDP)	EOL LCD Monitor, recycled	9.75e-01	kg	Solid waste	treatment
Use	LCD monitor use (CDP)	EOL LCD Monitor, remanufactured	9.75e-01	kg	Solid waste	recycling/reuse
Use	US electric grid	Lead	4.76e-06	kg	Airborne	air
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Lead	-2.90e-08	kg	Airborne	air
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Lead cmpds	-1.90e-12	kg	Waterborne	surface water
End-of-life	LCD incineration (DEAM mix)	Lead	4.80e-06	kg	Airborne	air
End-of-life	LCD incineration (DEAM mix)	Lead cmpds	2.59e-10	kg	Waterborne	surface water
End-of-life	LCD landfilling (CDP)	EOL LCD Monitor, landfilled	8.94e-01	kg	Solid waste	landfill
End-of-life	LCD landfilling (CDP)	EOL LCD Monitor, landfilled	1.64e+00	kg	Hazardous waste	landfill
End-of-life	LCD landfilling (CDP)	Lead cmpds	2.40e-10	kg	Waterborne	surface water
End-of-life	LPG Production (DEAM)	Lead	4.87e-11	kg	Airborne	air
End-of-life	LPG Production (DEAM)	Lead cmpds	4.60e-15	kg	Waterborne	surface water

Table N-4. LCD Lead Outputs by Life-cycle Stage

Life-cycle Stage	Process	Output	Quantity	Units	Type	Disposition
End-of-life	Natural Gas Prod. (DEAM)	Lead	-7.20e-09	kg	Airborne	air
End-of-life	Natural Gas Prod. (DEAM)	Lead cmpds	-7.80e-15	kg	Waterborne	surface water
End-of-life	US electric grid	Lead	9.03e-10	kg	Airborne	air

Table N-5. CRT Life-Cycle Impacts Scores from Lead-based Materials

Life-cycle Stage	Process	Input/Output	Impact Scores by Category						
			Nonrenew.	Haz. Waste	Rad	ChrTox-pub	ChrTox- occ	Aq. Tox.	Terr. Tox.
MP	ABS Production (DEAM)	Lead				4.24e-07			2.12e-07
MP	Aluminum Prod. (all virgin; EB)	Lead				2.40e-06			1.20e-06
MP	Ferrite mfg. (EB)	Lead				6.92e-05			3.46e-05
MP	Invar (DEAM mix)	Lead				7.24e-05			3.62e-05
MP	Lead (EB)	Lead				3.16e-03			1.58e-03
MP	Polycarbonate Production (PC; DEAM)	Lead				9.23e-07			4.62e-07
MP	Steel Prod., cold-rolled, semi-finished (EB)	Lead				2.20e-06			1.10e-06
MP	Styrene-butadiene Copolymer Prod. (DEAM	Lead				4.14e-07			2.07e-07
MP	Aluminum Prod. (all virgin; EB)	Lead (Pb, ore)	6.30e-05						
MP	Ferrite mfg. (EB)	Lead (Pb, ore)	5.70e-08						
MP	Invar (DEAM mix)	Lead (Pb, ore)	5.84e-08						
MP	Lead (EB)	Lead (Pb, ore)	4.96e-01						
MP	Polycarbonate Production (PC; DEAM)	Lead (Pb, ore)	1.85e-06						
MP	Steel Prod., cold-rolled, semi-finished (EB)	Lead (Pb, ore)	5.79e-08						
MP	Aluminum Prod. (all virgin; EB)	Lead cmpds				1.74e-05		1.70e-04	8.72e-06
MP	Ferrite mfg. (EB)	Lead cmpds	1.04e-06	1.00e-05	5.19e-07				
MP	Invar (DEAM mix)	Lead cmpds				5.96e-06		5.90e-05	2.98e-06

Table N-5. CRT Life-Cycle Impacts Scores from Lead-based Materials

Life-cycle Stage	Process	Input/Output	Impact Scores by Category						
			Nonrenew.	Haz. Waste	Rad	ChrTox-pub	ChrTox- occ	Aq. Tox.	Terr. Tox.
MP	Lead (EB)	Lead cmpds				5.50e-06		5.40e-05	2.75e-06
MP	Steel Prod., cold-rolled, semi-finished (EB)	Lead cmpds				1.77e-06		1.70e-05	8.83e-07
MP	Ferrite mfg. (EB)	Lead-210 (isotope)			1.82e-01				
MP	Invar (DEAM mix)	Lead-210 (isotope)			1.87e-01				
MP	Steel Prod., cold-rolled, semi-finished (EB)	Lead-210 (isotope)			6.54e-01				
Manufacturing	CRT glass mfg. (CDP)	Broken CRT glass		6.22e-07					
Manufacturing	CRT glass mfg. (CDP)	cinders from CRT glass mfg (70% PbO)		6.88e-06					
Manufacturing	CRT glass mfg. (CDP)	CRT glass faceplate EP dust (Pb) (D008 waste)		2.15e-06					
Manufacturing	CRT tube mfg. (CDP)	Frit		3.04e-06					
Manufacturing	CRT glass mfg. (CDP)	Hazardous sludge (Pb)		1.38e-06					
Manufacturing	CRT glass mfg. (CDP)	Lead	4.47e-01			8.74e-05	8.95e-01	8.70e-05	4.37e-05
Manufacturing	CRT tube mfg. (CDP)	Lead				6.03e-06		6.00e-06	3.01e-06
Manufacturing	Frit manufacturing (CDP)	Lead	4.67e-02			6.40e-10	9.33e-02		3.20e-10
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Lead				7.76e-08			3.88e-08
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Lead				8.28e-09			4.14e-09
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Lead				2.00e-07			9.99e-08
Manufacturing	LPG Production (DEAM)	Lead				2.47e-05			1.24e-05
Manufacturing	Natural Gas Prod. (DEAM)	Lead				4.33e-08			2.17e-08
Manufacturing	US electric grid	Lead				4.07e-07			2.04e-07
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Lead cmpds				6.55e-12		6.50e-11	3.27e-12
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Lead cmpds		5.32e-13	5.2E-				
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Lead cmpds				7.89e-12		7.80e-11	3.95e-12
Manufacturing	LPG Production (DEAM)	Lead cmpds				2.33e-09		2.30e-08	1.17e-09

Table N-5. CRT Life-Cycle Impacts Scores from Lead-based Materials

Life-cycle Stage	Process	Input/Output	Impact Scores by Category						
			Nonrenew.	Haz. Waste	Rad	ChrTox-pub	ChrTox- occ	Aq. Tox.	Terr. Tox.
Manufacturing	Natural Gas Prod. (DEAM)	Lead cmpds				4.72e-14		4.60e-13	2.36e-14
Manufacturing	CRT glass mfg. (CDP)	Lead contaminated grit (D008 waste)		2.99e-09					
Manufacturing	CRT glass mfg. (CDP)	Lead debris (D008 waste)		1.85e-08					
Manufacturing	CRT tube mfg. (CDP)	Lead sulfate cake		3.03e-08					
Manufacturing	CRT glass mfg. (CDP)	sludge from CRT glass mfg (1% PbO)		6.45e-07					
Manufacturing	CRT glass mfg. (CDP)	Waste Batch (Ba, Pb) (D008 waste)		1.22e-07					
Manufacturing	CRT glass mfg. (CDP)	Waste finishing sludge (Pb) (D008 waste)		2.32e-07					
Use	US electric grid	Lead				2.55e-05			1.27e-05
End-of-life	CRT Incineration (DEAM mix)	Lead		2.86e-05	1.43e-05				
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Lead				-8.90e-08			-4.40e-08
End-of-life	LPG Production (DEAM)	Lead				2.13e-10			1.07e-10
End-of-life	Natural Gas Prod. (DEAM)	Lead				-2.17e-08			-1.10e-08
End-of-life	US electric grid	Lead				2.55e-09			1.28e-09
End-of-life	CRT Incineration (DEAM mix)	Lead cmpds				1.62e-09		1.60e-08	8.10e-10
End-of-life	CRT landfilling (CDP)	Lead cmpds				1.58e-09		1.60e-08	7.89e-10
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Lead cmpds				-5.72e-12		-5.60e-11	-2.90e-12
End-of-life	LPG Production (DEAM)	Lead cmpds				2.01e-14		2.00e-13	1.01e-14
End-of-life	Natural Gas Prod. (DEAM)	Lead cmpds				-2.37e-14		-2.30e-13	-1.20e-14

MP = Materials processing.
Blank = not applicable.

Table N-6. LCD Life-Cycle Impact Scores from Lead-based Materials

Life-cycle Stage	Process	Input/Output	Impact Scores by Category						
			Nonrenew	Haz. Waste	Solid Waste	Rad	ChrTox-pub	Aq. Tox.	Terr. Tox.
MP	Aluminum Prod. (all virgin; EB)	Lead					8.94e-07		4.47e-07
MP	Natural Gas Prod. (DEAM)	Lead					3.03e-06		1.51e-06
MP	PET Resin Production (DEAM)	Lead					1.82e-07		9.08e-08
MP	PMMA Sheet Prod. (DEAM)	Lead					3.83e-07		1.92e-07
MP	Polycarbonate Production (PC; DEAM)	Lead					5.16e-07		2.58e-07
MP	Steel Prod., cold-rolled, semi-finished (EB)	Lead					1.08e-06		5.40e-07
MP	Styrene-butadiene Copolymer Prod. (DEAM mix)	Lead					1.81e-07		9.04e-08
MP	Aluminum Prod. (all virgin; EB)	Lead (Pb, ore)	2.35e-05						
MP	PET Resin Production (DEAM)	Lead (Pb, ore)	1.82e-07						
MP	Polycarbonate Production (PC; DEAM)	Lead (Pb, ore)	1.03e-06						
MP	Steel Prod., cold-rolled, semi-finished (EB)	Lead (Pb, ore)	2.84e-08						
MP	Aluminum Prod. (all virgin; EB)	Lead cmpds					6.49e-06	6.40e-05	3.25e-06
MP	Natural Gas Prod. (DEAM)	Lead cmpds					3.30e-12	3.25e-11	1.65e-12
MP	Steel Prod., cold-rolled, semi-finished (EB)	Lead cmpds					8.65e-07	8.52e-06	4.33e-07
MP	Steel Prod., cold-rolled, semi-finished (EB)	Lead-210 (isotope)				3.21e-01			
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Lead					3.62e-09		1.81e-09
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Lead					1.28e-08		6.38e-09
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Lead					6.80e-09		3.40e-09
Manufacturing	LCD glass mfg. (CDP)	Lead					4.02e-06	4.02e-06	2.01e-06
Manufacturing	LCD module mfg. (CDP)	Lead					1.23e-05	1.23e-05	6.17e-06
Manufacturing	LPG Production (DEAM)	Lead					1.19e-06		5.93e-07
Manufacturing	Natural Gas Prod. (DEAM)	Lead					6.83e-08		3.42e-08
Manufacturing	US electric grid	Lead					4.94e-08		2.47e-08
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Lead cmpds					3.06e-13	3.01e-12	1.53e-13

Table N-6. LCD Life-Cycle Impact Scores from Lead-based Materials

Life-cycle Stage	Process	Input/Output	Impact Scores by Category						
			Nonrenew	Haz. Waste	Solid Waste	Rad	ChrTox-pub	Aq. Tox.	Terr. Tox.
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Lead cmpds					8.20e-13	8.08e-12	4.10e-13
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Lead cmpds					2.69e-13	2.65e-12	1.34e-13
Manufacturing	LPG Production (DEAM)	Lead cmpds					1.12e-10	1.10e-09	5.60e-11
Manufacturing	Natural Gas Prod. (DEAM)	Lead cmpds					7.44e-14	7.33e-13	3.72e-14
Manufacturing	LCD monitor assembly (CDP)	Printed wiring board			9.38e-06				
Manufacturing	LCD glass mfg. (CDP)	Waste batch (Ba, Pb) (D008 waste)		5.67e-09					
Use	US electric grid	Lead					9.52e-06		4.76e-06
End-of Life	Fuel Oil #4 Prod. (DEAM mix)	Lead					-5.88e-08		-2.94e-08
End-of Life	LCD incineration (DEAM mix)	Lead					9.60e-06		4.80e-06
End-of Life	LPG Production (DEAM)	Lead					9.74e-11		4.87e-11
End-of Life	Natural Gas Prod. (DEAM)	Lead					-1.43e-08		-7.17e-09
End-of Life	US electric grid	Lead					1.81e-09		9.03e-10
End-of Life	Fuel Oil #4 Prod. (DEAM mix)	Lead cmpds					-3.78e-12	-3.72e-11	-1.89e-12
End-of Life	LCD incineration (DEAM mix)	Lead cmpds					5.19e-10	5.11e-09	2.59e-10
End-of Life	LCD landfilling (CDP)	Lead cmpds					4.80e-10	4.73e-09	2.40e-10
End-of Life	LPG Production (DEAM)	Lead cmpds					9.19e-15	9.06e-14	4.60e-15
End-of Life	Natural Gas Prod. (DEAM)	Lead cmpds					-1.56e-14	-1.54e-13	-7.81e-15

MP = Materials processing.
Blank = not applicable.

Table N-7. LCD Mercury Inputs by Life-cycle Stage

Life-cycle Stage	Process	Input	Quantity	Units	Type
Manufacturing	LCD CCFL mfg. (CDP)	Mercury	3.99e-06	kg	Primary material
Manufacturing	LCD backlight unit assembly (CDP)	Backlight lamp (CCFL)	1.94e-03	kg	Direct to assembly

Table N-8. CRT Mercury Outputs by Life-cycle Stage

Life-cycle Stage	Process	Output	Quantity	Units	Type	Disposition
Materials Processing	ABS Production (DEAM)	Mercury	2.12e-07	kg	Airborne	air
Materials Processing	ABS Production (DEAM)	Mercury compounds	2.12e-07	kg	Waterborne	surface water
Materials Processing	Aluminum Prod. (all virgin; EB)	Mercury	2.02e-07	kg	Airborne	air
Materials Processing	Aluminum Prod. (all virgin; EB)	Mercury	8.93e-11	kg	Solid waste	landfill
Materials Processing	Ferrite mfg. (EB)	Mercury	1.62e-07	kg	Airborne	air
Materials Processing	Ferrite mfg. (EB)	Mercury	1.11e-12	kg	Solid waste	landfill
Materials Processing	Ferrite mfg. (EB)	Mercury compounds	1.03e-10	kg	Waterborne	surface water
Materials Processing	Invar (DEAM mix)	Mercury	2.12e-07	kg	Airborne	air
Materials Processing	Invar (DEAM mix)	Mercury	3.39e-11	kg	Solid waste	landfill
Materials Processing	Invar (DEAM mix)	Mercury compounds	1.06e-10	kg	Waterborne	surface water
Materials Processing	Lead (EB)	Mercury	1.51e-06	kg	Airborne	air
Materials Processing	Lead (EB)	Mercury	1.72e-11	kg	Solid waste	landfill
Materials Processing	Lead (EB)	Mercury compounds	1.50e-09	kg	Waterborne	surface water
Materials Processing	Polycarbonate Production (PC; DEAM)	Mercury	4.62e-07	kg	Airborne	air
Materials Processing	Polycarbonate Production (PC; DEAM)	Mercury compounds	4.62e-07	kg	Waterborne	surface water
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Mercury	3.26e-08	kg	Airborne	air
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Mercury	8.26e-14	kg	Solid waste	landfill
Materials Processing	Steel Prod., cold-rolled, semi-finished (EB)	Mercury compounds	8.58e-08	kg	Waterborne	surface water
Materials Processing	Styrene-butadiene Copolymer Prod. (DEAM mix)	Mercury	2.07e-07	kg	Airborne	air
Materials Processing	Styrene-butadiene Copolymer Prod. (DEAM mix)	Mercury compounds	2.07e-07	kg	Waterborne	surface water
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Mercury	2.72e-09	kg	Airborne	air
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Mercury compounds	3.77e-15	kg	Waterborne	surface water
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Mercury	2.89e-10	kg	Airborne	air
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Mercury compounds	3.06e-16	kg	Waterborne	surface water
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Mercury	6.94e-09	kg	Airborne	air

Table N-8. CRT Mercury Outputs by Life-cycle Stage

Life-cycle Stage	Process	Output	Quantity	Units	Type	Disposition
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Mercury compounds	4.54e-15	kg	Waterborne	surface water
Manufacturing	Japanese Electric Grid	Mercury	1.18e-07	kg	Airborne	air
Manufacturing	LPG Production (DEAM)	Mercury	8.69e-07	kg	Airborne	air
Manufacturing	LPG Production (DEAM)	Mercury compounds	1.34e-12	kg	Waterborne	surface water
Manufacturing	Natural Gas Prod. (DEAM)	Mercury	1.88e-09	kg	Airborne	air
Manufacturing	Natural Gas Prod. (DEAM)	Mercury compounds	2.71e-17	kg	Waterborne	surface water
Manufacturing	US electric grid	Mercury	1.20e-07	kg	Airborne	air
Use	US electric grid	Mercury	7.51e-06	kg	Airborne	air
End-of-life	CRT Incineration (DEAM mix)	Mercury	-1.12e-07	kg	Airborne	air
End-of-life	CRT Incineration (DEAM mix)	Mercury compounds	2.15e-11	kg	Waterborne	surface water
End-of-life	CRT landfilling (CDP)	Mercury compounds	2.19e-11	kg	Waterborne	surface water
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Mercury	-3.11e-09	kg	Airborne	air
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Mercury compounds	-3.29e-15	kg	Waterborne	surface water
End-of-life	LPG Production (DEAM)	Mercury	7.50e-12	kg	Airborne	air
End-of-life	LPG Production (DEAM)	Mercury compounds	1.16e-17	kg	Waterborne	surface water
End-of-life	Natural Gas Prod. (DEAM)	Mercury	-9.44e-10	kg	Airborne	air
End-of-life	Natural Gas Prod. (DEAM)	Mercury compounds	-1.36e-17	kg	Waterborne	surface water
End-of-life	US electric grid	Mercury	7.52e-10	kg	Airborne	air

Table N-9. LCD Mercury Outputs by Life-cycle Stage

Life-Cycle Stage	Process	Output	Quantity	Units	Type	Disposition
MP	Aluminum Prod. (all virgin; EB)	Mercury	7.51e-08	kg	Airborne	air
MP	Natural Gas Prod. (DEAM)	Mercury	1.32e-07	kg	Airborne	air
MP	PET Resin Production (DEAM)	Mercury	9.08e-08	kg	Airborne	air
MP	PMMA Sheet Prod. (DEAM)	Mercury	1.92e-07	kg	Airborne	air
MP	Polycarbonate Production (PC; DEAM)	Mercury	2.58e-07	kg	Airborne	air
MP	Steel Prod., cold-rolled, semi-finished (EB)	Mercury	1.60e-08	kg	Airborne	air
MP	Styrene-butadiene Copolymer Prod. (DEAM mix)	Mercury	9.04e-08	kg	Airborne	air
MP	Aluminum Prod. (all virgin; EB)	Mercury	3.32e-11	kg	Solid waste	landfill
MP	Steel Prod., cold-rolled, semi-finished (EB)	Mercury	4.05e-14	kg	Solid waste	landfill
MP	PET Resin Production (DEAM)	Mercury	9.08e-08	kg	Waterborne	surface water
MP	Natural Gas Prod. (DEAM)	Mercury compounds	1.89e-15	kg	Waterborne	surface water
MP	PMMA Sheet Prod. (DEAM)	Mercury compounds	1.92e-07	kg	Waterborne	surface water
MP	Polycarbonate Production (PC; DEAM)	Mercury compounds	2.58e-07	kg	Waterborne	surface water
MP	Steel Prod., cold-rolled, semi-finished (EB)	Mercury compounds	4.21e-08	kg	Waterborne	surface water
MP	Styrene-butadiene Copolymer Prod. (DEAM mix)	Mercury compounds	9.04e-08	kg	Waterborne	surface water
Manufacturing	LCD CCFL mfg. (CDP)	Backlight lamp (CCFL)	1.94e-03	kg	Product	
Manufacturing	LCD backlight unit assembly (CDP)	Broken CCFL	2.69e-07	kg	Solid waste	landfill
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Mercury	1.27e-10	kg	Airborne	air
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Mercury	4.46e-10	kg	Airborne	air
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Mercury	2.36e-10	kg	Airborne	air
Manufacturing	Japanese Electric Grid	Mercury	3.97e-07	kg	Airborne	air
Manufacturing	LPG Production (DEAM)	Mercury	4.17e-08	kg	Airborne	air
Manufacturing	Natural Gas Prod. (DEAM)	Mercury	2.97e-09	kg	Airborne	air
Manufacturing	US electric grid	Mercury	1.45e-08	kg	Airborne	air
Manufacturing	LCD monitor assembly (CDP)	Mercury	2.00e-06	kg	Hazardous waste	recycling/reuse

Table N-9. LCD Mercury Outputs by Life-cycle Stage

Life-Cycle Stage	Process	Output	Quantity	Units	Type	Disposition
Manufacturing	LCD module mfg. (CDP)	Mercury	9.69e-08	kg	Waterborne	surface water
Manufacturing	LCD CCFL mfg. (CDP)	Mercury	8.33e-08	kg	Waterborne	treatment
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Mercury compounds	1.76e-16	kg	Waterborne	surface water
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Mercury compounds	4.71e-16	kg	Waterborne	surface water
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Mercury compounds	1.55e-16	kg	Waterborne	surface water
Manufacturing	LPG Production (DEAM)	Mercury compounds	6.44e-14	kg	Waterborne	surface water
Manufacturing	Natural Gas Prod. (DEAM)	Mercury compounds	4.28e-17	kg	Waterborne	surface water
Manufacturing	LCD backlight unit assembly (CDP)	Waste CCFL, with mercury	8.17e-10	kg	Hazardous waste	treatment
Manufacturing	LCD backlight unit assembly (CDP)	Waste glass, with mercury	1.05e-10	kg	Hazardous waste	landfill
Manufacturing	LCD CCFL mfg. (CDP)	Wastewater stream, from CCFL mfg.	1.67e+02	kg	Waterborne	treatment
Use	US electric grid	Mercury	2.80e-06	kg	Airborne	air
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Mercury	-2.05e-09	kg	Airborne	air
End-of-life	LCD incineration (DEAM mix)	Mercury	-8.42e-08	kg	Airborne	air
End-of-life	LPG Production (DEAM)	Mercury	3.42e-12	kg	Airborne	air
End-of-life	Natural Gas Prod. (DEAM)	Mercury	-6.23e-10	kg	Airborne	air
End-of-life	US electric grid	Mercury	5.32e-10	kg	Airborne	air
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Mercury compounds	-2.17e-15	kg	Waterborne	surface water
End-of-life	LCD incineration (DEAM mix)	Mercury compounds	8.67e-12	kg	Waterborne	surface water
End-of-life	LCD landfilling (CDP)	Mercury compounds	7.50e-12	kg	Waterborne	surface water
End-of-life	LPG Production (DEAM)	Mercury compounds	5.29e-18	kg	Waterborne	surface water
End-of-life	Natural Gas Prod. (DEAM)	Mercury compounds	-8.98e-18	kg	Waterborne	surface water

MP = Materials processing

Table N-10. CRT Life-Cycle Impact Scores from Mercury-based Materials

Life-cycle Stage	Process	Input/Output	Impact Scores by Category					
			Haz. Waste	Solid Waste	ChrTox-pub	ChrTox-occ	Aq. Tox.	Terr. Tox.
MP	ABS Production (DEAM)	Mercury			2.12e-07			2.12e-07
MP	Aluminum Prod. (all virgin; EB)	Mercury			2.02e-07			2.02e-07
MP	Ferrite mfg. (EB)	Mercury			1.62e-07			1.62e-07
MP	Invar (DEAM mix)	Mercury			2.12e-07			2.12e-07
MP	Lead (EB)	Mercury			1.51e-06			1.51e-06
MP	Polycarbonate Production (PC; DEAM)	Mercury			4.62e-07			4.62e-07
MP	Steel Prod., cold-rolled, semi-finished (EB)	Mercury			3.26e-08			3.26e-08
MP	Styrene-butadiene Copolymer Prod. (DEAM mix)	Mercury			2.07e-07			2.07e-07
MP	ABS Production (DEAM)	Mercury compounds			1.12e-04		1.97e-04	1.11e-04
MP	Ferrite mfg. (EB)	Mercury compounds			5.45e-08		9.63e-08	5.44e-08
MP	Invar (DEAM mix)	Mercury compounds			5.58e-08		9.86e-08	5.57e-08
MP	Lead (EB)	Mercury compounds			7.89e-07		1.39e-06	7.88e-07
MP	Polycarbonate Production (PC; DEAM)	Mercury compounds			2.44e-04		4.30e-04	2.43e-04
MP	Steel Prod., cold-rolled, semi-finished (EB)	Mercury compounds			4.53e-05		8.00e-05	4.52e-05
MP	Styrene-butadiene Copolymer Prod. (DEAM mix)	Mercury compounds			1.09e-04		1.93e-04	1.09e-04
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Mercury			2.72e-09			2.72e-09
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Mercury			2.89e-10			2.89e-10
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Mercury			6.94e-09			6.94e-09
Manufacturing	Japanese Electric Grid	Mercury			1.18e-07			1.18e-07
Manufacturing	LPG Production (DEAM)	Mercury			8.69e-07			8.69e-07
Manufacturing	Natural Gas Prod. (DEAM)	Mercury			1.88e-09			1.88e-09
Manufacturing	US electric grid	Mercury			1.20e-07			1.20e-07
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Mercury compounds			1.99e-12		3.51e-12	1.98e-12
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Mercury compounds			1.61e-13		2.85e-13	1.61e-13

Table N-10. CRT Life-Cycle Impact Scores from Mercury-based Materials

Life-cycle Stage	Process	Input/Output	Impact Scores by Category					
			Haz. Waste	Solid Waste	ChrTox-pub	ChrTox-occ	Aq. Tox.	Terr. Tox.
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Mercury compounds			2.39e-12		4.23e-12	2.39e-12
Manufacturing	LPG Production (DEAM)	Mercury compounds			7.08e-10		1.25e-09	7.07e-10
Manufacturing	Natural Gas Prod. (DEAM)	Mercury compounds			1.43e-14		2.53e-14	1.43e-14
Use	US electric grid	Mercury			7.51e-06			7.51e-06
End-of-life	CRT Incineration (DEAM mix)	Mercury			-1.12e-07			-1.12e-07
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Mercury			-3.11e-09			-3.11e-09
End-of-life	LPG Production (DEAM)	Mercury			7.50e-12			7.50e-12
End-of-life	Natural Gas Prod. (DEAM)	Mercury			-9.44e-10			-9.44e-10
End-of-life	US electric grid	Mercury			7.52e-10			7.52e-10
End-of-life	CRT Incineration (DEAM mix)	Mercury compounds			1.13e-08		2.00e-08	1.13e-08
End-of-life	CRT landfilling (CDP)	Mercury compounds			1.15e-08		2.04e-08	1.15e-08
End-of-life	Fuel Oil #4 Prod. (DEAM mix)	Mercury compounds			-1.74e-12		-3.06e-12	-1.73e-12
End-of-life	LPG Production (DEAM)	Mercury compounds			6.11e-15		1.08e-14	6.10e-15
End-of-life	Natural Gas Prod. (DEAM)	Mercury compounds			-7.18e-15		-1.27e-14	-7.16e-15

MP = Materials processing.
Blank = not applicable.

Table N-11. LCD Life-Cycle Impact Scores from Mercury-based Materials

Life-cycle Stage	Process	Input/Output	Impact Scores by Category					
			Haz. Waste	Solid Waste	ChrTox-pub	ChrTox- occ	Aq. Tox.	Terr. Tox.
MP	Aluminum Prod. (all virgin; EB)	Mercury			7.51e-08			7.51e-08
MP	Natural Gas Prod. (DEAM)	Mercury			1.32e-07			1.32e-07
MP	PET Resin Production (DEAM)	Mercury			1.82e-07		1.82e-07	1.82e-07
MP	PMMA Sheet Prod. (DEAM)	Mercury			1.92e-07			1.92e-07
MP	Polycarbonate Production (PC; DEAM)	Mercury			2.58e-07			2.58e-07
MP	Steel Prod., cold-rolled, semi-finished (EB)	Mercury			1.60e-08			1.60e-08
MP	Styrene-butadiene Copolymer Prod. (DEAM mix)	Mercury			9.04e-08			9.04e-08
MP	Natural Gas Prod. (DEAM)	Mercury compounds			1.00e-12		1.77e-12	9.98e-13
MP	PMMA Sheet Prod. (DEAM)	Mercury compounds			1.01e-04		1.79e-04	1.01e-04
MP	Polycarbonate Production (PC; DEAM)	Mercury compounds			1.36e-04		2.40e-04	1.36e-04
MP	Steel Prod., cold-rolled, semi-finished (EB)	Mercury compounds			2.22e-05		3.92e-05	2.22e-05
MP	Styrene-butadiene Copolymer Prod. (DEAM mix)	Mercury compounds			4.77e-05		8.42e-05	4.76e-05
Manufacturing	LCD backlight unit assembly (CDP)	Broken CCFL		1.98e-11				
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Mercury			1.27e-10			1.27e-10
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Mercury			4.46e-10			4.46e-10
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Mercury			2.36e-10			2.36e-10
Manufacturing	Japanese Electric Grid	Mercury			3.97e-07			3.97e-07
Manufacturing	LCD CCFL mfg. (CDP)	Mercury				3.99e-06		
Manufacturing	LCD module mfg. (CDP)	Mercury			9.69e-08		1.94e-07	9.69e-08
Manufacturing	LPG Production (DEAM)	Mercury			4.17e-08			4.17e-08
Manufacturing	Natural Gas Prod. (DEAM)	Mercury			2.97e-09			2.97e-09
Manufacturing	US electric grid	Mercury			1.45e-08			1.45e-08
Manufacturing	Fuel Oil #2 Prod. (DEAM)	Mercury compounds			9.27e-14		1.64e-13	9.25e-14

Table N-11. LCD Life-Cycle Impact Scores from Mercury-based Materials

Life-cycle Stage	Process	Input/Output	Impact Scores by Category					
			Haz. Waste	Solid Waste	ChrTox-pub	ChrTox- occ	Aq. Tox.	Terr. Tox.
Manufacturing	Fuel Oil #4 Prod. (DEAM mix)	Mercury compounds			2.49e-13		4.39e-13	2.48e-13
Manufacturing	Fuel Oil #6 Prod. (DEAM)	Mercury compounds			8.15e-14		1.44e-13	8.14e-14
Manufacturing	LPG Production (DEAM)	Mercury compounds			3.40e-11		6.00e-11	3.39e-11
Manufacturing	Natural Gas Prod. (DEAM)	Mercury compounds			2.26e-14		3.98e-14	2.25e-14
Manufacturing	LCD backlight unit assembly (CDP)	Waste glass, with mercury	7.73e-15					
Use	US electric grid	Mercury			2.80e-06			2.80e-06
End of Life	Fuel Oil #4 Prod. (DEAM mix)	Mercury			-2.05e-09			-2.05e-09
End of Life	LCD incineration (DEAM mix)	Mercury			-8.42e-08			-8.42e-08
End of Life	LPG Production (DEAM)	Mercury			3.42e-12			3.42e-12
End of Life	Natural Gas Prod. (DEAM)	Mercury			-6.23e-10			-6.23e-10
End of Life	US electric grid	Mercury			5.32e-10			5.32e-10
End of Life	Fuel Oil #4 Prod. (DEAM mix)	Mercury compounds			-1.15e-12		-2.02e-12	-1.14e-12
End of Life	LCD incineration (DEAM mix)	Mercury compounds			4.57e-09		8.08e-09	4.57e-09
End of Life	LCD landfilling (CDP)	Mercury compounds			3.96e-09		6.99e-09	3.95e-09
End of Life	LPG Production (DEAM)	Mercury compounds			2.79e-15		4.93e-15	2.78e-15
End of Life	Natural Gas Prod. (DEAM)	Mercury compounds			-4.74e-15		-8.37e-15	-4.73e-15

MP = Materials processing.
Blank = not applicable.

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