

F-GHG Emissions Reduction Efforts: Flat Panel Display Supplier Profiles

Introduction

U.S. Environmental Protection Agency
Office of Air and Radiation
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Fluorinated greenhouse gases (F-GHGs) are among the most potent and persistent greenhouse gases (GHGs) contributing to global climate change. These gases play a vital role in the manufacture of flat panel displays--most commonly liquid crystal display (LCD) panels-- that go into televisions, computer monitors, and many other display products. The overall climate impact of the millions of display products Americans use can be greatly reduced if suppliers of these components take steps to mitigate releases of these F-GHGs to the atmosphere.

Over the last decade, many key flat panel display manufacturers have undertaken commendable voluntary efforts to reduce their F-GHG emissions. In the interest of encouraging further emissions reductions, the U.S. Environmental Protection Agency (EPA) is profiling efforts by flat panel display suppliers to reduce their F-GHG emissions, consistent with its purpose of sharing industry best practices and emerging efforts to reduce corporate GHG emissions through its Center for Corporate Climate Leadership. Additionally, in late 2013, leading electronics brands and retailers Walmart, Dell, HP, Lenovo and Best Buy began taking steps to foster further voluntary F-GHG reductions among their LCD suppliers. Consistent with the mission of the Center, EPA commends these companies for having submitted a proposal to their suppliers calling for them to 1) develop a standard method for measuring and recording F-GHG emissions for the industry, 2) establish a voluntary long-term F-GHG emissions reduction goal with public timelines for demonstrating progress, and 3) develop an annual progress report that can be shared with them and/or other supporting organizations.

EPA assembled the information presented in each profile from publicly available sources, including suppliers' corporate sustainability reports and their responses to the Carbon Disclosure Project's Investor or Supply Chain questionnaire, and from information provided by the suppliers themselves or by trade associations representing the flat panel display industry. Where information on suppliers' F-GHG emissions reduction efforts was assembled, suppliers then had the opportunity to review their draft profiles and provide feedback before profiles were completed. EPA intends to update the following profiles from all flat panel suppliers on an as-needed basis when new information or updates to existing information become available.

To better understand the information presented, below are some key points to consider.

Definitions:

- Flat Panel Displays: Today flat panel displays that use F-GHGs during manufacturing are mostly liquid crystal display (LCD) panels. Some suppliers refer specifically to LCD manufacturing when describing their efforts to reduce F-GHG use in production. For purposes of capturing future products or other displays that may use F-GHGs in production, EPA has opted to use the broader term of 'flat panel displays' instead of 'LCDs.' To EPA's knowledge, production of OLEDs uses F-GHGs but production of plasma displays does not use them.
- F-GHGs and PFCs: The F-GHG emissions of primary concern are from perfluorocarbons (PFCs), trifluoromethane (CHF₃ or HFCs), nitrogen trifluoride (NF₃), and sulfur hexafluoride (SF₆); these are sometimes collectively called perfluorocompounds (also termed PFCs). In some publicly available information, suppliers use the term 'PFCs' instead of 'F-GHGs' to refer to all of their F-GHGs used. EPA has chosen to use the term 'F-GHGs' instead of 'PFCs' (for perfluorocompounds) to address all known F-GHGs used in flat panel display manufacturing.
- Fab: Fabrication facility for panel production.

F-GHGs in the Context of Corporate GHG Inventories and Reporting:

Many flat panel display suppliers have implemented corporate-wide GHG emissions reduction goals and developed GHG inventories, encompassing both Scope 1 emissions, namely those from on-site combustion and processes, and Scope 2 emissions, those from purchased electricity and/or steam. The F-GHG emissions used in flat panel manufacturing reflect a subset of suppliers' Scope 1 emissions and are usually referenced in terms of CO₂ equivalent (CO₂e).

Key Manufacturing Processes to Consider

Panel etching and CVD chamber cleaning are the key processes that use F-GHGs in manufacturing flat panel displays.

Fluorinated heat transfer fluids (HTFs) are often used to cool equipment, resulting in emissions due to evaporative losses. Some manufacturers indicate that they do not use such fluorinated HTFs, or that emissions from fluorinated HTFs are minimal compared to those from etching and chamber cleaning processes. EPA is interested in understanding the extent to which such HTFs are used, how their potential emissions compare to those resulting from other key processes, and options for reducing F-GHG emissions from their use. EPA has also learned that N₂O (not an F-GHG, but another GHG which has a GWP of nearly 300) is also used in flat panel display manufacturing in the CVD process and in it is emitted from onsite stationary combustion. EPA is also interested in understanding the role of N₂O in flat panel display manufacturing and current and emerging opportunities to reduce N₂O emissions from manufacturing, alongside reducing F-GHG emissions.

Reducing F-GHG Emissions

Over the last decade, electronics manufacturers have made significant progress in identifying effective technological solutions to reducing F-GHG emissions. The following approaches to reducing F-GHG emissions from the manufacture of flat panels are in use today or are being explored:

- 1. Process improvements/source reduction:** Manufacturers optimize their processes to use F-GHGs more efficiently, especially in CVD clean processes, resulting in smaller amounts of gas that are unreacted and emitted.
- 2. Alternative chemicals:** Manufacturers use alternative gases that are more efficient (more of the applied gas served its intended purpose versus being left unreacted) with a lower global warming potential (GWP) to accomplish the same result. For example, many manufacturers have modified certain key processes to use NF_3 instead of SF_6 ; NF_3 is a replacement gas for in-situ use for CVD and is also used in CVD remote plasma chamber cleaning. Though NF_3 still has very high GWP of 17,200, it is lower than that of SF_6 (which has a GWP of nearly 23,000) and is used more efficiently. Some companies are piloting the use of F_2 to replace NF_3 in the remote plasma chamber cleaning process and are seeking to surmount some of challenges associated with transport, storage and use of F_2 .
- 3. Capture and beneficial reuse:** Manufacturers capture F-GHGs and process them to remove impurities and refine them for reuse. Some suppliers are evaluating the opportunities; however, reuse/recycling has so far not been implemented widely due to limitations on the effectiveness and cost of available recycling technologies.
- 4. Abatement via gas destruction technologies:** Both point-of-use abatement, where the abatement system is attached to a process tool(s), and centralized abatement systems, where gases are sent to, and destroyed in, a centralized system, are being used by major panel suppliers. Abatement remains one of the most effective ways to reduce the majority of F-GHG emissions. There are many different types of destruction technologies that are used to abate F-GHGs, however, most abatement systems today use combustion.

Measuring Emissions and Monitoring Abatement Systems:

Measuring the efficiency of an installed abatement system to destroy or remove gases such as F-GHGs--known as the destruction or removal efficiency (DRE)-- directly relates to how suppliers can account for their annual F-GHG emissions and subsequent reductions. Most suppliers today use default factors from the 2006 IPCC Guidelines to account for the DRE of abatement systems. However, suppliers may also directly measure DREs using measurement guidelines or protocols. An example of such a protocol is EPA's "Protocol for Measuring Destruction or Removal Efficiency (DRE) of Fluorinated Greenhouse Gas Abatement Equipment in Electronics Manufacturing" (EPA's DRE Protocol). Published in 2010 and internationally peer-reviewed, EPA's DRE Protocol provides a reliable method for measuring DRE's of

point-of-use abatement systems for F-GHG used during the manufacture of electronics. In other cases, for both point of use and centralized abatement systems, suppliers may monitor their systems on an ongoing basis, especially in the case of Clean Development Mechanism (CDM) projects, to acquire on-site real-time data. Suppliers may also test their abatement systems by monitoring specific parameters such as temperature, process gas and exhaust gas flow rate. Going forward, EPA anticipates that this effort will enable sharing of best practices regarding measurement and move the industry to produce reliable estimates of abatement systems' DREs.

Voluntary F-GHG reduction efforts:

Flat panel display suppliers are to be commended for undertaking F-GHG reductions voluntarily, as many companies have been implementing F-GHG emissions reductions for over a decade. Most suppliers represented in the following profiles have been participating, through their respective trade associations, in the World LCD Industry Cooperation Committee (WLICC), which agreed to voluntary reduction activities in 2001-2010 that would reduce 2000 baseline levels by approximately 90 percent down to 0.82 MMTCE. To meet the reduction goal, many suppliers in participating countries implemented strategies to address their emissions including installing abatement technologies on production lines in their newer generation fabs, namely those built within the last decade. As a result, F-GHG emissions were reduced by 10.1 MMTCE, to where aggregate emissions totaled 1.75 MMTCE. Though these reductions demonstrated significant accomplishments, the WLICC fell short of its goal due to a rise in emissions resulting from a rapid increase in production for LCD panels that were integrated into products such as televisions faster than initially anticipated.

Since the WLICC set its goals, newer suppliers with growing market share—those who have not participated in the WLICC's F-GHG reduction efforts to date-- have also emerged and information on their F-GHG emissions reductions efforts is currently unknown. In addition, it appears that some key suppliers, are still in varying stages of implementing comprehensive F-GHG emission reductions efforts across their fabs. As worldwide demand for flat panels continue to increase, F-GHG emissions are also projected to rise. To mitigate those emissions, it is important that reduction efforts across all major panel suppliers are implemented.

Suppliers:

Currently, twelve suppliers (listed below) are the major producers of large-area flat panel displays used to make TVs and display products. The profiles that follow highlight efforts of these suppliers to reduce their F-GHG emissions in flat panel manufacturing across key areas covering mitigation measures and goals, the extent of their reduction efforts (whether they include all processes and gases used), the extent to which abatement technologies are installed on newer fabs, and public disclosure of F-GHG emissions and/or emissions reductions. Profiles were only developed for suppliers where information on their F-GHG emissions reduction efforts in flat panel manufacturing was publicly available. The emissions data are reported in either tons or metric tons to reflect how suppliers reported on their emissions.

AU Optronics (AUO)

BOE Technology

CEC-Panda

ChinaStar

Chunghwa Picture Tubes (CPT)

HannStar

Infovision

INX (Innolux)

LG Display

Panasonic

Samsung Display

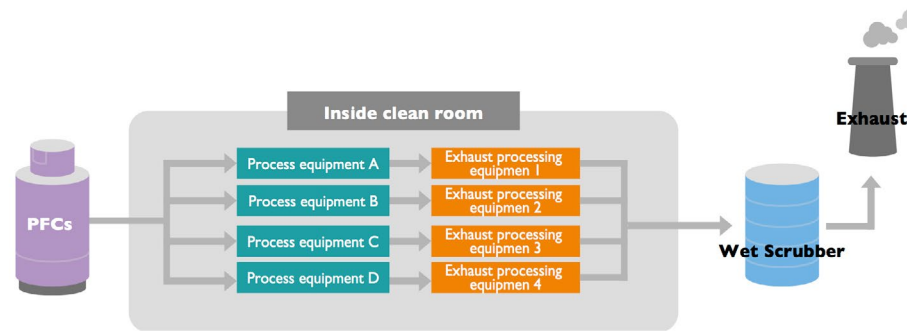
Sharp

AUO (AU Optronics)

Specific F-GHG emissions reduction efforts and/or goals

AUO reduced F-GHGs emissions, namely NF_3 , SF_6 and CF_4 (PFCs), by 9.34 million metric tons of CO_2e from 2003-2013. AUO considers itself a pioneer of F-GHG abatement in Taiwan. Since 2003, AUO voluntarily installed IPCC-recognized F-GHG abatement devices with destruction removal efficiencies (DRE) over 90 percent in dry etching and chemical vapor deposition (CVD) processes for all newly built fabs to reduce F-GHG emissions from gases such as SF_6 and NF_3 . Over the past two years, AUO also installed local scrubbers to remove F-GHG emissions at older fabs built before 2003. Currently the installation rate of F-GHG abatement equipment at older, lower-generation fabs, is approaching 100 percent.

PFCs Scrubbing Process



Sources:

AUO 2013 Corporate Social Responsibility Report (Section 4.2.1, page 61)
http://www.auo.com/upload/download/1/AUO_2013_CSR_EN_All.pdf

AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.

Overview

+ F-GHG emissions reduction efforts/goals target the following key processes that emit F-GHGs

Etch and clean processes.

On fluorinated heat transfer fluids (HTFs): AUO follows the "Guidance for Greenhouse Gas Accounting and Reporting for GHG inventory" published by the Taiwanese EPA. In the guidance, HTFs are listed as emission sources for semiconductor industry, but not for optoelectronics industry, meaning that emissions from HTFs are too minor in AUO's process.

Sources:

AUO
 TTLA presentation at APEC meeting, August 2012, Taiwan.

+ F-GHG emissions reduction efforts/goals target the following F-GHGs emitted

SF₆, PFCs, HFCs, NF₃.

Source:

AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.

Participation in national and/or international mandatory and/or voluntary efforts to reduce F-GHG emissions from flat panel display manufacturing

AUO is a member of the Taiwanese TFT-LCD Association (TTLA). TTLA participates on behalf of Taiwan's LCD suppliers in the World Display device Industry Cooperation Committee (WDICC), an international industry initiative that previously set goals to reduce F-GHG emissions (formerly the World LCD Industry Cooperation Committee).

In 2004, TTLA and Taiwan's Environmental Protection Agency signed an MOU where TTLA agreed to choose 2002 as the base year for reducing F-GHG emissions and to reduce F-GHGs emissions intensity to 0.0335 tons of CO₂e/m² of glass substrate area by 2010 (this target is TTLA's collective goal and does not necessarily reflect each individual supplier's goal).

The TTLA and Taiwan's Industrial Development Bureau, Ministry of Economic Affairs signed a "Voluntary GHG Reduction Agreement," for 2011-2015, which aims to achieve additional GHG reductions by 12 million metric tons of CO₂e within 5 years. In Taiwan, F-GHG emission reductions by flat panel display manufacturers are still voluntary. However, as of 2012, Taiwan's EPA listed PFCs, HFCs, and SF₆ (including non-F-GHGs CO₂, CH₄, and N₂O) as air pollutants and has indicated that it will implement emissions control measures under the Air Pollution Control Act in the future. Taiwan's government has launched the Principles for Promoting Greenhouse Gas Early Action and Offset Program to encourage carbon reduction. AUO has engaged in developing the SF₆ abatement verification methodology for LCD industries, and received 9.11 million tons of tradable carbon credits base on the amount of PFCs reduced in the past. No trading occurred in 2013.

Sources:

AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.

"SF₆ Abatement Strategy in Taiwan." Presentation by Taiwan's Industrial Technology Research Institute (ITRI) (www.epa.gov/electricpower-sf6/documents/conf04_lu.pdf)

TTLA

Overview	Corporate-wide GHG emissions reduction goals and reduction initiatives	<p>AUO set an intensity goal to reduce its Scope 1 and Scope 2 GHG emissions in all its fabs worldwide by 25 percent from 2010 to 2015, where its most recent base year GHG emissions, based on the 2010 national electricity emission factor, were reported as 69 kg CO₂e/m². AUO updates its GHG inventory based on the latest national electricity factors published by the Bureau of Energy.</p> <p>AUO's "Green Solutions" initiative addresses emissions reductions from all of its manufacturing and other operations, from within its supply chain, and via improved product design to create lower-carbon products. In 2011, AUO initiated a carbon footprint management system to assist its global customers in calculating the carbon footprint of individual products as they seek PAS 2050 third party verification.</p> <p>AUO also participated in the Product Attribute to Impact Algorithm (PAIA) Project to develop calculation models for LCD-related products.</p> <p><i>Sources:</i> AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.</p>
	F-GHG Reduction Efforts	Process optimization
Use of alternatives		<p>Though it is more expensive, AUO uses NF₃, which has a lower global warming potential, instead of SF₆ in clean vapor deposition (CVD) chambers. AUO also started using NF₃ when fabs were newly built. AUO continues to research the possibilities of using alternative gases with lower or no GWP in conjunction with optimizing process efficiencies and implementing abatement systems.</p> <p><i>Source:</i> AUO</p>

Capture and recycling

In 2012, AUO tested gas recycling technologies and recycling efficiency at one fab, where the utilization efficiency of the recycling system was measured directly by monitoring the recycled gas flow. In 2013, AUO's Longtan site introduced a membrane separation method, previously approved by the IPCC, which purifies SF₆ so that it can be re-used in the manufacturing process. This recycling technology reduced F-GHG emissions and saved on operating and material costs. However, due to a higher maintenance demand and lower efficiency in general, the recycling system has been replaced by the abatement system.

Sources:
AUO

AUO 2013 Corporate Social Responsibility Report (Section 4.2.1, page 61)
http://www.auo.com/upload/download/1/AUO_2013_CSR_EN_All.pdf

AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.

Abatement

- + Full or partial installation of abatement systems across all new generation fabs

AUO has installed abatement systems in all newer generation fabs. CVD processes in all fabs are equipped with abatement systems. For dry etching processes, abatement systems have been gradually installed since 2003 on new production lines. Types of abatement technologies being employed include combustion (for CVD, dry etching) and membrane separation technology (for dry etching and is regarded as a recycling technology). AUO uses localized, point of use (POU) abatement systems.

Sources:
AUO

Taiwan Environmental Protection Administration. "The Initiative and Efforts from Electronic Corporations in Taiwan- Semiconductor and TFT-LCD."
http://unfccc.epa.gov.tw/unfccc/english/_uploads/downloads/05_The_Initiative_and_Efforts_form_Electronic_Industry_in_Taiwan.pdf

TTLA presentation at APEC meeting, August 2012, Taiwan.

AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.

F-GHG Reduction Efforts

<p>+ Ensured that abatement systems are installed, operated, and maintained according to manufacturer specifications</p>	<p>For abatement systems, the destruction or removal efficiency was checked once first installed.</p> <p><i>Source: AUO</i></p>
<p>+ Indicate whether default factors or actual measurements were used to estimate the DRE</p> <p>Reported destruction or removal efficiency (DRE)</p>	<p>Default factors used.</p> <p>AUO applies the 90 percent default DRE value for SF₆, HFCs and PFCs abatement technologies and the 95 percent default DRE value for NF₃ abatement technologies, taken from the 2006 IPCC Tier 2b Guidelines for National Greenhouse Gas Inventories for electronics industry emissions.</p> <p><i>Source: AUO</i></p>
<p>+ Practices for monitoring abatement systems</p>	<p>When abatement systems were first installed, AUO randomly selected devices from each machine type per site, and measured their utilization efficiencies and DRE using Fourier Transform Infra Red (FTIR). To ensure the effectiveness of the CVD and dry etching abatement systems, both systems were measured even if they were located in the same site. The outcomes of the FTIR measurements were verified by a third party, the Industrial Technology Research Institute of Taiwan (ITRI). However, due to the high cost of FTIR testing, AUO uses an operation recipe instead as a method to monitor abatement devices after installation. Engineers check and record the operation recipe. Parameters include temperature, process gas, and exhaust gas flow rate. By types of devices, different parameters are monitored. For most devices, AUO found that air fuel ratio is a key indicator to determine if more fuel is needed. If the abatement system does not have a thermometer, then the volume of gas flow will become an important indicator.</p> <p><i>Sources:</i> <i>AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire (see section ICT3.6)</i></p>

Total annual F-GHG emissions in CO₂e, emitted across all flat panel display manufacturing fabs (2014)

The total amount of F-GHG emissions attributed to panel manufacturing is not publicly available.

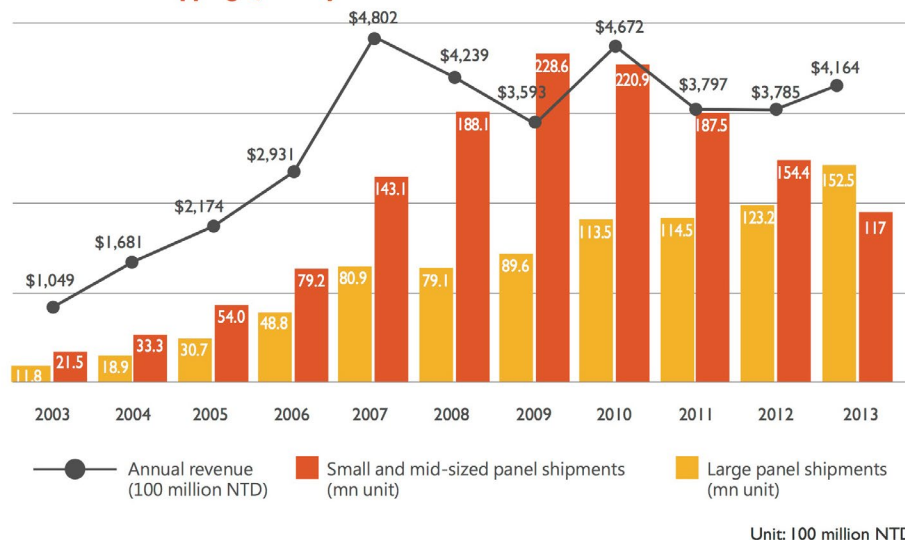
As part of its **2014** disclosure to the Carbon Disclosure Project, which discloses GHG emissions from **Jan 1, 2013 to Dec 31, 2013**, AUO lists its total Scope 1 emissions. These Scope 1 emissions represent its organizational boundary, using an operational control approach that includes facilities within Taiwan and in other countries. Its F-GHG emissions, as reported, are as follows, in metric tons of CO₂e:

- HFCs: 4,487.30 (decrease compared to 8,139.39 in CY 2012)
- PFCs: 21,285.95 (decrease compared to 34,071.44 in CY 2012)
- SF₆: 212,597.60 (increase compared to 205,468.08 in CY 2012)

Context:

AUO's large panel shipments increased from 123.2 million units in 2012 to 152.5 million units, and small and medium panel shipments decreased from 154.4 million units in 2012 to 117 million units in 2013.

Revenue and Shipping Quantity



Important: The emissions listed cannot be compared to the emissions from other suppliers because they may use different estimation methods and monitoring practices to calculate their emissions. These process emissions may also reflect manufacturing processes that create additional products other than large-area flat panel displays.

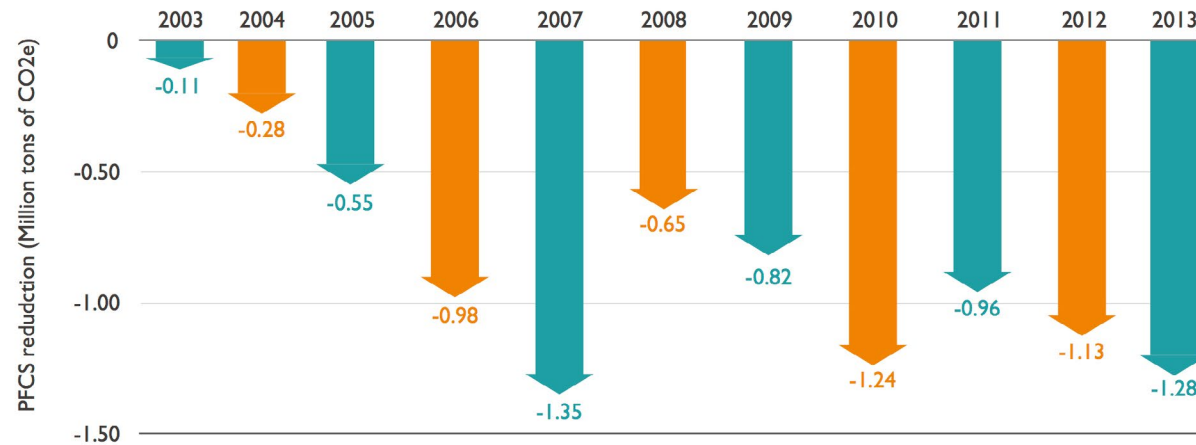
Source:

AUO 2013 Corporate Social Responsibility Report (Section 2.1.1, page 22)
http://www.auo.com/upload/download/1/AUO_2013_CSR_EN_All.pdf

AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.

Total annual F-GHG emissions reductions and/or rate of emissions reductions

PFCs Emissions Reduction Performance



Sources:

AUO 2013 Corporate Social Responsibility Report

http://www.auo.com/upload/download/1/AUO_2013_CSR_EN_All.pdf

AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire (see page 8 of 35).

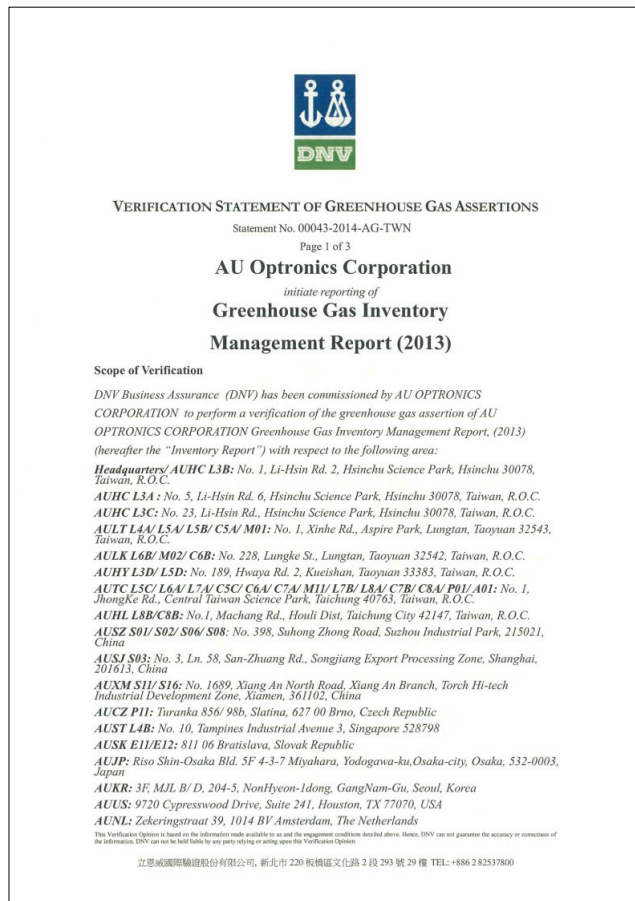
Methodology used to estimate F-GHG emissions

AUO estimates its F-GHG emissions based on the Tier 2b method provided by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for electronics industry emissions. AUO's raw data is verified by a third party each year. The page below is part of AUO's "Verification Statement of Greenhouse Gas Assertions" for 2013.

Source: AUO

Third party assurance for F-GHG emissions estimates

AUO's raw data is verified by a third party each year. The pages below are part of AUO's "Verification Statement of Greenhouse Gas Assertions" for 2013.



Source: AUO



Chunghwa Picture Tubes (CPT)

Overview

Specific F-GHG emissions reduction efforts and/or goals

As part of the memorandum of understanding (MOU) in 2004 with the Taiwan TFT-LCD Association (TTLA) and Taiwan's Environmental Protection Administration, CPT promised to install abatement equipment with over 90 percent destruction and removal efficiency (DRE) in all new fabs designed after 2003 and to reduce F-GHGs emissions intensity to 0.0335 tons of CO₂e/m² of glass substrate area by 2010.

To reduce F-GHG emissions of SF₆ and NF₃ at its Taoyuan and Lungtan TFT-LCD fabs, CPT uses high-temperature, point-of-use abatement, augmented by particle accumulation filter bags to capture silicon dioxide, the secondary solid pollutant that results from the burning process. Lastly, the cleaning tower is used to clean out special gas molecules in the waste gas. Currently, efficiency is at 90 percent or above.

Sources:

CPT Website: Environmental Management
 (www.cptt.com.tw/index.php?option=com_content&task=view&id=447&Itemid=180)

CPT's responses to the 2009 Carbon Disclosure Project Supply Chain Questionnaire.

"SF₆ Abatement Strategy in Taiwan." Presentation by Taiwan's Industrial Technology Research Institute (ITRI), 2004.
 (www.epa.gov/electricpower-sf6/documents/conf04_lu.pdf).

+ F-GHG emissions reduction efforts/goals target the following key processes that emit F-GHGs

Etching and cleaning processes.
 Information on fluorinated heat transfer fluids not available.

Sources:

CPT Website: Environmental Management
 (www.cptt.com.tw/index.php?option=com_content&task=view&id=447&Itemid=180)

TTLA presentation at APEC meeting, August 2012, Taiwan.

+ F-GHG emissions reduction efforts/goals target the following F-GHGs emitted

SF₆, PFCs, HFCs, NF₃.

Sources:

CPT Website: Environmental Management
 (www.cptt.com.tw/index.php?option=com_content&task=view&id=447&Itemid=180)

TTLA presentation at APEC meeting, August 2012, Taiwan.

Participation in national and/or international mandatory and/or voluntary efforts to reduce F-GHG emissions from flat panel display manufacturing

CPT is a member of the Taiwan TFT-LCD Association (TTLA). TTLA participates on behalf of Taiwan's LCD suppliers in the World Display device Industry Cooperation Committee (WDICC), an international industry initiative that previously set goals to reduce F-GHG emissions (formerly the World LCD Industry Cooperation Committee).

In 2004, TTLA and Taiwan's Environmental Protection Administration signed an MOU where TTLA agreed to choose 2002 as the base year for reducing F-GHG emissions and to reduce F-GHG emissions intensity to 0.0335 tons of CO₂e/m² of glass substrate area by 2010 (this target is TTLA's collective goal and does not necessarily reflect each individual supplier's goal).

Recently, the TTLA and Taiwan's Industrial Development Bureau, Ministry of Economic Affairs signed a "Voluntary GHG Reduction Agreement" for 2011-2015, which aims to achieve additional GHG reductions by 12 million metric tons of CO₂e within 5 years. In Taiwan, F-GHG emission reductions by flat panel display manufacturers are still voluntary. However, as of 2012, Taiwan's EPA listed PFCs, HFCs, and SF₆ (including non-F-GHG CO₂, CH₄, and N₂O) as air pollutants and has indicated that it will implement emissions control measures under the Air Pollution Control Act in the future.

According to CPT's website, TTLA signed its first cooperative memorandum for voluntary reductions with the Environmental Protection Administration in 2004. In 2007, it signed the "Voluntary Greenhouse Gas Reduction Agreement" with the Ministry of Economic Affairs. CPT will also work with TTLA to provide regular emissions information on fluorinated compounds, and engage in reductions of fluorinated compounds. Its management procedures include:

1. Reconstruction of the chemical vapor deposition (CVD) process in the Taoyuan and Longtan plants, now completed. This has reduced emissions of carbon dioxide.
2. Processes for end gases from machines, including increasing the production usage rate and adding local scrubbers (LS).

Sources:

CPT Website: Environmental Management

(www.cptt.com.tw/index.php?option=com_content&task=view&id=447&Itemid=180)

"SF₆ Abatement Strategy in Taiwan." Presentation by Taiwan's Industrial Technology Research Institute (ITRI), 2004. (www.epa.gov/electricpower-sf6/documents/conf04_lu.pdf).

TTLA

Overview	Corporate-wide GHG emissions reduction goals and reduction initiatives	<p>Currently, CPT's goal is to reduce GHG emissions by 280,000 tons of CO₂e by 2016 through process optimization and adoption of dry etch machinery and tail gas incinerator facilities.</p> <p><i>Source:</i> CPT 2013 Corporate Social Responsibility Report (page 30).</p>
	F-GHG Reduction Efforts	Process optimization
Use of alternatives		<p>CPT is using lower GWP gases, where possible. Additional details not available.</p> <p><i>Sources:</i> CPT TTLA presentation at APEC meeting, August 2012, Taiwan.</p>
Capture and recycling		<p>Information not available.</p>

Abatement

- + Full or partial installation of abatement systems across all new generation fabs

CPT has installed abatement systems in all newer generation fabs. CPT committed to install abatement systems in all fabs established after 2003 to reduce more than 90 percent of its F-GHG emissions.

According to CPT, its “Taoyuan and Lungtan plants’ TFT manufacturing process involve membrane molding and dry etching procedures that use SF₆ and NF₃ gases for the manufacturing process. Therefore, fluoride gases that have not reacted completely would be emitted from the end gas emissions. Because SF₆ and NF₃ are greenhouse gases with high global warming potential (GWP), CPT uses high temperature burning to break down the gases’ molecules, augmented by particle accumulation filter bags to capture the secondary solid pollutant that results from the burning process – silicon dioxide. Lastly, the cleaning tower is used to clean out special gas molecules in the waste gas. Currently, efficiency is at 90 percent or above.”

Sources:

CPT Website: Environmental Management

(www.cpt.com.tw/index.php?option=com_content&task=view&id=447&Itemid=180)

CPT’s responses to the 2009 Carbon Disclosure Project Supply Chain Questionnaire.

Taiwan Environmental Protection Administration. “The Initiative and Efforts from Electronic Corporations in Taiwan-Semiconductor and TFT-LCD.”

(http://unfccc.epa.gov.tw/unfccc/english/_uploads/downloads/05_The_Initiative_and_Efforts_form_Electronic_Industry_in_Taiwan.pdf)

TTLA presentation at APEC meeting, August 2012, Taiwan.

- + Ensured that abatement systems are installed, operated, and maintained according to manufacturer specifications

Upon installation at the facility and before CPT begins operating the abatement system, the abatement equipment manufacturer verifies that the system can meet the default DRE.

Sources:

CPT

TTLA

F-GHG Reduction Efforts	<p>+ Indicate whether default factors or actual measurements were used to estimate the DRE</p> <p>Reported destruction or removal efficiency (DRE)</p>	<p>Default factors used.</p> <p>CPT applies the 90 percent default DRE value for SF₆, HFCs and PFCs abatement technologies and the 95 percent default DRE value for NF₃ abatement technologies, taken from the 2006 IPCC Tier 2b Guidelines for National Greenhouse Gas Inventories for electronics industry emissions.</p> <p>CPT reports the DRE of its abatement systems at 90 percent or higher.</p> <p><i>Sources:</i> CPT</p>
	<p>+ Practices for monitoring abatement systems</p>	<p>Information not available.</p>
F-GHG Emissions Measurements	<p>Total annual F-GHG emissions in CO₂e, emitted across all flat panel display manufacturing fabs (2013)</p>	<p>In 2008, its base year, CPT's F-GHG emissions amounted to 505,000 tons of CO₂e. In 2013 emissions equaled 483,000 tons of CO₂e, a decrease from base year emissions, but an increase over F-GHG emissions in 2012. CPT attributes the increase to improved production capacities that led to higher F-GHG consumption and process yield issues required a switch back to SF₆ from NF₃ for certain machinery (SF₆ has a higher global warming potential). In 2012, CPT's F-GHG emissions accounted for 30.17 percent of the company's total GHG emissions. In 2011, CPT's F-GHG emissions accounted for 24 percent of the company's total GHG emissions.*</p> <p>Important: The emissions cannot be compared to the emissions from other suppliers because they may use different estimation methods and monitoring practices to calculate their emissions. These process emissions may also reflect manufacturing processes that create additional products other than large-area flat panel displays.</p> <p><i>Source:</i> CPT 2013 Corporate Social Responsibility Report (page 30) *Information available on CPT's website in prior years.</p>

Total annual F-GHG emissions reductions and/or rate of emissions reductions

CPT estimates reducing F-GHG emissions by approximately 23.8 million tons of CO₂e between 2002 and 2012.
CPT estimates reducing F-GHG emissions by approximately 21.8 million tons of CO₂e between 2002 and 2011.

Source:
CPT Website: Environmental Management
(www.cptt.com.tw/index.php?option=com_content&task=view&id=447&Itemid=180)

Methodology used to estimate F-GHG emissions

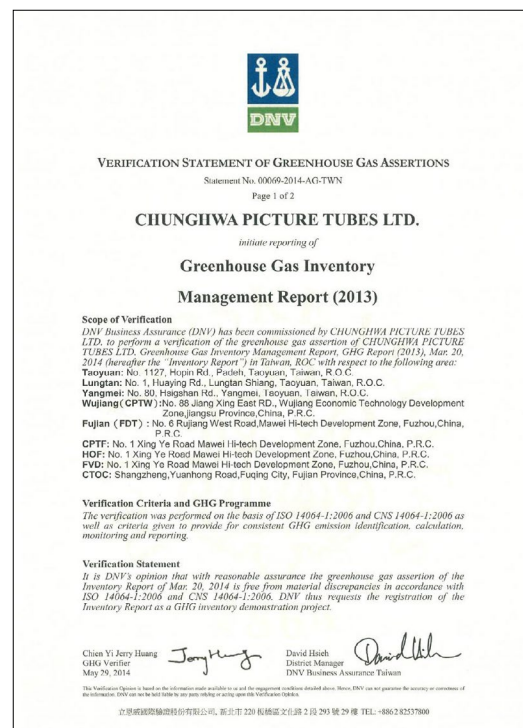
CPT estimates its F-GHG emissions based on the Tier 2b method provided by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for electronics industry emissions.

Source:
CPT

Third party assurance for F-GHG emissions estimates

CPT's annual total GHG inventory undergoes third party verification.

Source:
CPT Website: Environmental Management
(www.cptt.com.tw/index.php?option=com_content&task=view&id=447&Itemid=180)



Specific F-GHG emissions reduction efforts and/or goals

As part of the memorandum of understanding (MOU) in 2004 with the Taiwan TFT-LCD Association (TTLA) and Taiwan's Environmental Protection Administration, HannStar promised to install abatement equipment with over 90 percent destruction and removal efficiency (DRE) in all new fabs designed after 2003. HannStar reduced approximately 1.33 million tons of F-GHG emissions in CO₂e from 2007-2012. In 2013, HannStar reduced 89,000 tons of CO₂e by voluntarily installing high-efficiency burning local scrubbers to reduce F-GHG emissions, namely SF₆ and NF₃ emissions.

Sources:
HannStar

HannStar 2013 Corporate Social Responsibility Report (page 25)
(http://www.hannstar.com/HannStarUserFile/files/Quality/HannStar_2013CSR_en.pdf)

"SF₆ Abatement Strategy in Taiwan". Presentation by Taiwan's Industrial Technology Research Institute (ITRI), 2004.
(www.epa.gov/electricpower-sf6/documents/conf04_lu.pdf)

+ F-GHG emissions reduction efforts/goals target the following key processes that emit F-GHGs

Etch and clean processes.
HannStar does not use fluorinated heat transfer fluids.

Source:
HannStar

TTLA presentation at APEC meeting, August 2012, Taiwan.

+ F-GHG emissions reduction efforts/goals target the following F-GHGs emitted

SF₆, PFCs, HFCs, NF₃

Sources:
HannStar 2013 Corporate Social Responsibility Report
(http://www.hannstar.com/HannStarUserFile/files/Quality/HannStar_2013CSR_en.pdf)

Participation in national and/or international mandatory and/or voluntary efforts to reduce F-GHG emissions from flat panel display manufacturing

HannStar is a member of the Taiwan TFT-LCD Association (TTLA). TTLA participates on behalf of Taiwan's LCD suppliers in the World Display device Industry Cooperation Committee (WDICC), an international industry initiative that previously set goals to reduce F-GHG emissions (formerly the World LCD Industry Cooperation Committee).

In 2004, TTLA and Taiwan's Environmental Protection Administration signed an MOU where TTLA agreed to choose 2002 as the base year for reducing F-GHG emissions and to reduce F-GHG emissions intensity to 0.0335 tons of CO₂e/m₂ of glass substrate area by 2010 (this target is TTLA's collective goal and does not necessarily reflect each individual supplier's goal).

Recently, the TTLA and Taiwan's Industrial Development Bureau, Ministry of Economic Affairs signed a "Voluntary GHG Reduction Agreement" for 2011-2015, which aims to achieve additional GHG reductions by 12 million metric tons of CO₂e within 5 years. In Taiwan, F-GHG emission reductions by flat panel display manufacturers are still voluntary. However, as of 2012, Taiwan's EPA listed PFCs, HFCs, and SF₆ (including non-F-GHGs CO₂, CH₄, and N₂O) as air pollutants and has indicated that it will implement emissions control measures under the Air Pollution Control Act in the future.

Sources:

"SF₆ Abatement Strategy in Taiwan." Presentation by Taiwan's Industrial Technology Research Institute (ITRI), 2004. (www.epa.gov/electricpower-sf6/documents/conf04_lu.pdf)

TTLA

Corporate-wide GHG emissions reduction goals and reduction initiatives

Since HannStar's GHG emissions are mostly due to electricity consumption and the use of F-GHGs in flat panel display manufacturing, the company has focused its efforts on reducing energy use and F-GHG emissions. HannStar lowered its overall GHG emissions intensity by 61 percent from 2005 to 2012 down to 0.069 tons of CO₂e/m² of glass input. In 2013, it lowered overall GHG emissions intensity again, down to 0.067 tons of CO₂e/m² of glass input.

In addition, "HannStar has proceeded ISO 14064-1 inventory and external verification since 2005 and reduces GHG voluntarily."

Sources:

HannStar 2012 Corporate Social Responsibility Report. (http://www.hannstar.com/HannStarUserFile/files/Quality/Hannstar_2012CSR_en.pdf)

HannStar 2013 Corporate Social Responsibility Report (http://www.hannstar.com/HannStarUserFile/files/Quality/HannStar_2013CSR_en.pdf)

Overview	Process optimization	<p>HannStar is optimizing the use of F-GHGs in the process chambers. Additional details not available.</p> <p>Sources: HannStar TTLA presentation at APEC meeting, August 2012, Taiwan.</p>
	Use of alternatives	<p>HannStar is using lower-GWP gases, where possible. Additional details not available.</p> <p>Sources: HannStar TTLA presentation at APEC meeting, August 2012, Taiwan.</p>
	Capture and recycling	Information not available.
F-GHG Reduction Efforts	Abatement	
	+ Full or partial installation of abatement systems across all new generation fabs	<p>HannStar has installed abatement systems in all newer generation fabs. HannStar promised to install abatement equipment in all fabs established after 2003 to reduce more than 90 percent of F-GHG emissions.</p> <p>Additional details not available.</p> <p>Sources: HannStar 2012 Corporate Social Responsibility Report. (http://www.hannstar.com/HannStarUserFile/files/Quality/Hannstar_2012CSR_en.pdf)</p> <p>Taiwan Environmental Protection Administration. "The Initiative and Efforts from Electronic Corporations in Taiwan - Semiconductor and TFT-LCD." http://unfccc.epa.gov.tw/unfccc/english/_uploads/downloads/05_The_Initiative_and_Efforts_form_Electronic_Industry_in_Taiwan.pdf</p> <p>TTLA presentation at APEC meeting, August 2012, Taiwan.</p>

F-GHG Reduction Efforts

+ Ensured that abatement systems are installed, operated, and maintained according to manufacturer specifications

Upon installation at the facility and before HannStar begins operating the abatement system, the abatement equipment manufacturer verifies that the system can meet the default DRE.

Sources:
HannStar
TTLA

+ Indicate whether default factors or actual measurements were used to estimate the DRE

Reported destruction or removal efficiency (DRE)

Default factors used.

HannStar uses the 2006 IPCC Tier 2b Guidelines for National Greenhouse Gas Inventories for electronics industry emissions, which apply a 90 percent default DRE value for SF₆, CF₄, HFCs and PFCs abatement technologies and a 95 percent default DRE value for NF₃ abatement technologies.

Source:
HannStar

+ Practices for monitoring abatement systems

Information not available.

Total annual F-GHG emissions in CO₂e, emitted across all flat panel display manufacturing fabs (2013)

In 2013, HannStar's F-GHG emissions from SF₆ and NF₃ used in LCD manufacturing totaled 103,600 metric tons of CO₂e, a decrease from F-GHG emissions in 2012. F-GHG emissions account for 33.7 percent of HannStar's total GHG inventory and for 95 percent of HannStar's Scope 1 emissions.

For reference, listed below is HannStar's 2012 inventory.

2012 GHG Emission Inventory

GHG	Emissions (t-CO ₂ e)	Ration to total emissions (%)
CO ₂	196,894.76	62.1%
CH ₄	433.58	0.1%
N ₂ O	1.65	0.0%
HFC	1,191.79	0.4%
PFCs	1,863.98	0.6%
SF ₆	116,463.25	36.8%
Total	316,849.01	100.0%

Important: The emissions listed cannot be compared to the emissions from other suppliers because they may use different estimation methods and monitoring practices to calculate their emissions. These process emissions may also reflect manufacturing processes that create additional products other than large-area flat panel displays.

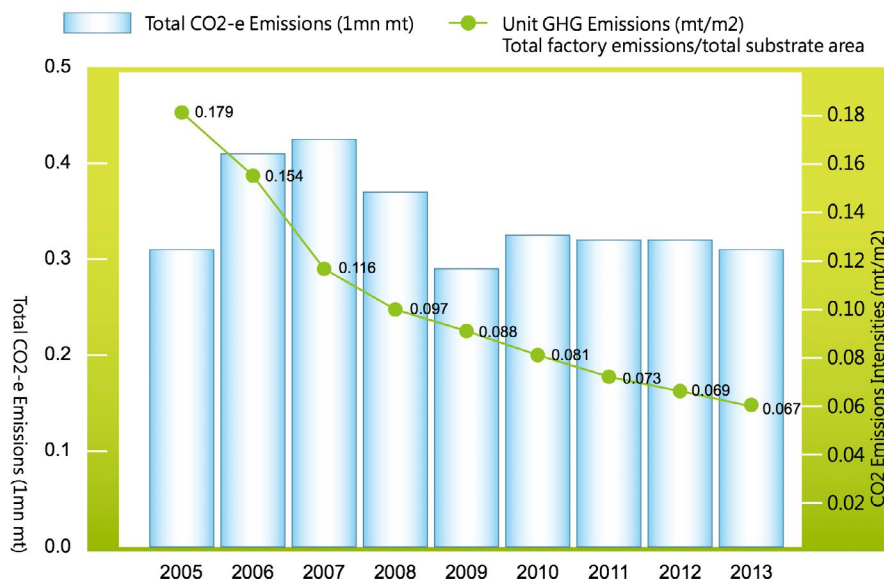
Source:
HannStar

HannStar 2013 Corporate Social Responsibility Report (page 25)
(http://www.hannstar.com/HannStarUserFile/files/Quality/HannStar_2013CSR_en.pdf)

F-GHG Emissions Measurements

Total annual F-GHG emissions reductions and/or rate of emissions reductions

With regard to F-GHG emissions, HannStar reduced approximately 1.33 million tons of CO₂e from 2007-2012. In 2013, HannStar reduced F-GHG emissions by 89,000 tons of CO₂e. (F-GHG emissions intensity in tons of CO₂e/m² of glass input for Taiwan plant only in 2013.)



Source:
 HannStar 2013 Corporate Social Responsibility Report (page 25)
 (http://www.hannstar.com/HannStarUserFile/files/Quality/HannStar_2013CSR_en.pdf)

Methodology used to estimate F-GHG emissions

HannStar estimates its F-GHG emissions based on the Tier 2b method provided by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for electronics industry emissions.

Source:
 HannStar

Third party assurance for F-GHG emissions estimates

HannStar has proceeded ISO 14064-1 inventory and external verification since 2005 and reduces GHG voluntarily.

Source:
 HannStar 2013 Corporate Social Responsibility Report
 (http://www.hannstar.com/HannStarUserFile/files/Quality/HannStar_2013CSR_en.pdf)

Innolux Corporation (INX)

Overview

Specific F-GHG emissions reduction efforts and/or goals

In 2013, Innolux (INX) reduced approximately 2.6 million tons of F-GHG emissions. INX attributes achieving its results to 1) optimizing manufacturing processes and thereby reducing the amount of F-GHGs needed and 2) replacing or installing a local burn-type scrubbers at newly built factories and those constructed prior to 2003 to achieve better abatement.

In 2010, INX's F-GHG emissions intensity in producing LCD panels was 0.0094 tons of CO₂e/m² of glass substrate. INX then set a new goal to further reduce F-GHG emissions intensity to 0.0089 tons of CO₂e/m² in 2013. In 2012, the F-GHG emissions intensity was 0.008558 tons of CO₂e/m² and in 2013, it dropped to 0.0073 tons of CO₂e/m².

Sources:
INX

INX's responses to the 2014 Carbon Disclosure Project Investor and Supply Chain Questionnaires.

2013 INX CSR Report http://www.innolux.com/Files/OWNFiles/CSR/Report_Download/2013_INX_CSR_English.pdf (see page 46)

"SF₆ Abatement Strategy in Taiwan." Presentation by Taiwan's Industrial Technology Research Institute (ITRI), 2004. (www.epa.gov/electricpower-sf6/documents/conf04_lu.pdf)

+ F-GHG emissions reduction efforts/goals target the following key processes that emit F-GHGs

Etching and cleaning processes.
INX uses a small amount of fluorinated heat transfer fluids, but has not inventoried them.

Sources:
INX
TTLA presentation at APEC meeting, August 2012, Taiwan.

+ F-GHG emissions reduction efforts/goals target the following F-GHGs emitted

SF₆, PFCs, HFCs, NF₃.

Sources:
INX's responses to the 2014 Carbon Disclosure Project Investor Questionnaire
TTLA presentation at APEC meeting, August 2012, Taiwan.

Participation in national and/or international mandatory and/or voluntary efforts to reduce F-GHG emissions from flat panel display manufacturing

INX is a member of the Taiwanese TFT-LCD Association (TTLA). TTLA participates on behalf of Taiwan's LCD suppliers in the World Display device Industry Cooperation Committee (WDICC), an international industry initiative that previously set goals to reduce F-GHG emissions (formerly the World LCD Industry Cooperation Committee).

In 2004, TTLA and Taiwan's Environmental Protection Agency signed an MOU, agreeing to reduce F-GHGs emissions intensity to 0.0335 tons of CO₂e/m² of glass substrate area by 2010, using 2002 as the base year. This target reflected TTLA's collective goal, though Innolux also met the goal individually. In 2013, Innolux, together with TTLA, began discussing with the Taiwan EPA to initiate a second MOU to pursue additional commitments to voluntary reductions. In response to requests by Walmart, Dell and Lenovo from LCD panel suppliers to reduce carbon emissions voluntarily, INX is also participating through TTLA and the WDICC in an effort to set goals for a long-term reduction in F-GHG emissions in cooperation with panel manufacturers of other countries.

The TTLA and Taiwan's Industrial Development Bureau, Ministry of Economic Affairs signed a "Voluntary GHG Reduction Agreement," for 2011-2015, which aims to achieve additional GHG reductions by 12 million metric tons of CO₂e within 5 years. In Taiwan, F-GHG emission reductions by flat panel display manufacturers are still voluntary. However, as of 2012, Taiwan's EPA listed PFCs, HFCs, and SF₆ (including non-F-GHGs CO₂, CH₄, and N₂O) as air pollutants and has indicated that it will implement emissions control measures under the Air Pollution Control Act in the future. In 2013, INX discussed with the Taiwan EPA the methodology for developing Taiwan's carbon credit calculation as part of its forthcoming cap and trade program. Innolux indicated that in 2014, it would join Taiwan's "Clean Carbon Alliance" to gain a better understanding of management trends in Taiwan to reduce carbon-related risks and create more opportunities to develop carbon asset value.

Sources:

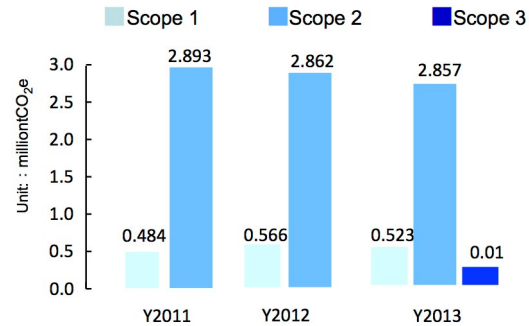
INX's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.

"SF₆ Abatement Strategy in Taiwan." Presentation by Taiwan's Industrial Technology Research Institute (ITRI), 2004. (www.epa.gov/electricpower-sf6/documents/conf04_lu.pdf)

TTLA

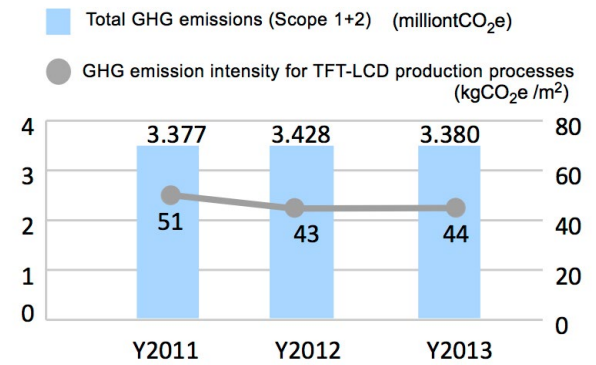
Corporate-wide GHG emissions reduction goals and reduction initiatives

In 2013, INX's overall GHG emissions decreased by approximately 1 percent despite a 7.5 percent increase in input substrate at the TFT-LCD stage.



*Note : IPCC 1995 SAR GWP values are employed for Taiwan and IPCC 2007 AR4 GWP values are adopted for China

GHG emission amounts for each Scope



GHG emission intensity per unit area

In addition, in 2013, INX released its own Product Carbon Footprint system to help streamline calculations of emissions on a per-product basis.

Sources:

INX's responses to the 2014 Carbon Disclosure Project Investor and Supply Chain Questionnaires.

2013 INX CSR Report http://www.innolux.com/Files/OWNFiles/CSR/Report_Download/2013_INX_CSR_English.pdf (see page 46)

Process optimization

INX is optimizing the use of F-GHGs in the process chambers. Additional details are not available.

Sources:

INX

TTLA presentation at APEC meeting, August 2012, Taiwan.

Use of alternatives

INX is using lower GWP gases, where possible. Additional details are not available.

Sources:

INX

TTLA presentation at APEC meeting, August 2012, Taiwan.

Capture and recycling

INX is working with Industrial Technology Research Institute of Taiwan to a testing SF₆ liquefaction recovery system. If it works, INX will expand the system across applicable fabs.

Source:

INX

Abatement

- + Full or partial installation of abatement systems across all new generation fabs

INX has installed abatement systems in all newer generation fabs. In addition, fabs constructed prior to 2003 have also been successively equipped with burn type point of use (POU) abatement systems. For process emissions that use F-GHGs, INX has installed point of use abatement systems that are mostly combustion-type local scrubbers fitted to the back end of production machinery and some thermal-type local scrubbers on select equipment. F-GHGs emissions undergo special combustion treatment before being neutralized by central scrubbers to further reduce emissions.

Sources:

2013 INX CSR Report http://www.innolux.com/Files/OWNFiles/CSR/Report_Download/2013_INX_CSR_English.pdf (see page 46)

Taiwan Environmental Protection Administration.

“The Initiative and Efforts from Electronic Corporations in Taiwan- Semiconductor and TFT-LCD.”

http://unfccc.epa.gov.tw/unfccc/english/_uploads/downloads/05_The_Initiative_and_Efforts_form_Electronic_Industry_in_Taiwan.pdf

TTLA presentation at APEC meeting, August 2012, Taiwan.

F-GHG Reduction Efforts

+ Ensured that abatement systems are installed, operated, and maintained according to manufacturer specifications

Upon installation at the facility and before INX begins operating the abatement system, the abatement equipment manufacturer verifies that the system can meet the default DRE.

Sources:
 INX
 TTLA

+ Indicate whether default factors or actual measurements were used to estimate the DRE

Default factors used.

Innolux uses the 2006 IPCC Tier 2b Guidelines for National Greenhouse Gas Inventories for electronics industry emissions, which apply a 90 percent default DRE value for SF₆, CF₄, HFCs and PFCs abatement technologies and a 95 percent default DRE value for NF₃ abatement technologies.

Reported destruction or removal efficiency (DRE)

Source: INX's responses to the 2012 Carbon Disclosure Project Investor Questionnaire (responded as CMI)

+ Practices for monitoring abatement systems

INX controls all processes to follow the standard in the whole process. Additional details are not available.

Source:
 INX

Total annual F-GHG emissions in CO₂e, emitted across all flat panel display manufacturing fabs (2013)

F-GHG emissions represented approximately 11 percent of INX's 2011 total GHG emissions inventory (Scope 1 and 2 emissions). In 2012, F-GHGs represented 15 percent of INX's total GHG emissions.

As part of its **2014** responses to the Carbon Disclosure Project, which discloses its GHG emissions from **Jan 1, 2013 to Dec 31, 2013**, INX lists its total Scope 1 emissions. These Scope 1 emissions represent its organizational boundary, using an operational control approach that includes facilities within Taiwan and in other countries. Its F-GHG emissions, as reported, are as follows, in metric tons of CO₂e:

HFCs: 7,286.74 (increase compared to 5,590 in CY 2012)
 PFCs: 20,052.59 (decrease compared 23,253 in CY 2012)
 SF₆: 463,324.39 (decrease compared to 491,183 in CY 2012)

Context:

INX's F-GHG emissions increased from CY 2011 to CY 2012 mainly due to increased capacity in production. In CY 2013, INX's absolute F-GHG emissions of SF₆, PFCs, and HFCs decreased by 29,363 metric tons of CO₂e, or 5.7 percent.

Important: The emissions listed cannot be compared to the emissions from other suppliers because they may use different estimation methods and monitoring practices to calculate their emissions. These process emissions may also reflect manufacturing processes that create additional products other than large-area flat panel displays.

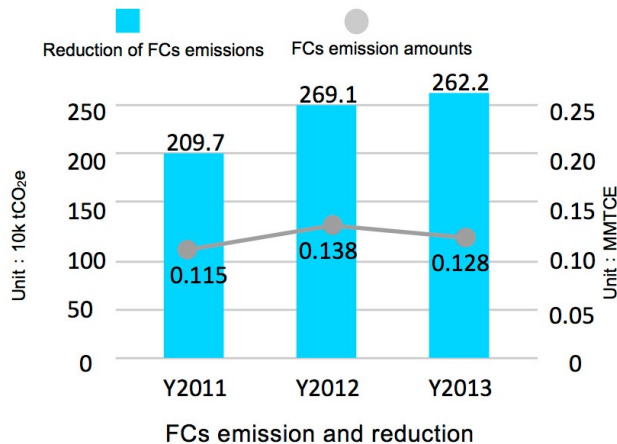
Sources:

INX's responses to the 2014 Carbon Disclosure Project Investor and Supply Chain Questionnaires

2013 INX CSR Report http://www.innolux.com/Files/OWNFiles/CSR/Report_Download/2013_INX_CSR_English.pdf (see page 46)

Total annual F-GHG emissions reductions and/or rate of emissions reductions

In 2013, INX reduced total annual F-GHG emissions by 2,622,000 tons of CO₂e, similar to the amount of F-GHG emissions reduced in 2012.



Sources:
INX

2013 INX CSR Report http://www.innolux.com/Files/OWNFiles/CSR/Report_Download/2013_INX_CSR_English.pdf (see page 46)

INX's responses to the 2014 Carbon Disclosure Project Investor and Supply Chain Questionnaires.

Methodology used to estimate F-GHG emissions

INX estimates its F-GHG emissions based on the Tier 2b method provided by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for electronics industry emissions.

Source:
INX's responses to the 2014 Carbon Disclosure Project Investor and Supply Chain Questionnaires.

Third party assurance for F-GHG emissions estimates

INX received third party verification for its 2013 GHG inventory, which was verified in accordance with the ISO-14064-3 standard.

Source:
INX

INX's responses to the 2014 Carbon Disclosure Project Investor and Supply Chain Questionnaires.

LG Display

Overview

Specific F-GHG emissions reduction efforts and/or goals

LG Display's F-GHG emissions reduction efforts are part of its broader goals to reduce corporate-wide GHG emissions. LG Display has installed F-GHG abatement systems to reduce NF_3 emissions from all of its flat panel display (LCD, OLED) manufacturing fabs, and SF_6 emissions from two of its flat panel display (LCD) manufacturing fabs.

Sources: LG Display

LG Display's 2013-2014 Sustainability Report: <http://www.lgdisplay.com/eng/sustainability/report#>

LG Display's responses to the 2011 Carbon Disclosure Project Investor Questionnaire.

"Point of Use Abatement Device to Reduce SF_6 Emissions in LCD Manufacturing Operations in the Republic of Korea (South Korea)." LG Display's SF_6 Abatement Project. Clean Development Mechanism Project: 3440. <https://cdm.unfccc.int/Projects/DB/SGS-UKL1266943063.39/view>

+ F-GHG emissions reduction efforts/goals target the following key processes that emit F-GHGs

Etching and cleaning processes.
Fluorinated heat transfer fluids are not used.

*Sources:
LG Display
Korea Display Industry Association*

+ F-GHG emissions reduction efforts/goals target the following F-GHGs emitted

SF_6 , PFCs, NF_3 .
(HFCs are not used in processes).

*Sources:
LG Display
LG Display's responses to the 2011 Carbon Disclosure Project Investor Questionnaire.*

Participation in national and/or international mandatory and/or voluntary efforts to reduce F-GHG emissions from flat panel display manufacturing

LG Display is a member of the Korea Display Industry Association (KDIA), where it participates in an environmental working group that promotes information exchange on GHG emissions reduction technologies and initiatives. KDIA represents Korea's flat panel display suppliers in the World Display device Industry Cooperation Committee (WDICC), an international industry initiative that previously set goals to reduce F-GHG emissions (formerly the World LCD Industry Cooperation Committee).

Since 2010, LG Display has been participating in a United Nations Clean Development Mechanism (CDM) Project to reduce SF₆ emissions at two of its manufacturing fabs. Between August 2010 and April 2011, LG Display was credited by the UNFCCC for 557,053 tons of CO₂e in GHG reductions. LG Display discontinued its participation in the CDM Project in April 2013.

The South Korean government set a single long-term national GHG emissions reduction goal, and it also set different reduction goals for various industries, including the display panel industry. In 2010, the government launched a GHG target management scheme, which regulates CO₂, HFCs, PFCs, and SF₆ (and non-F-GHGs N₂O and CH₄). Starting in 2015, the government will launch a 'cap and trade' system for limiting and trading domestic GHG emissions. To prepare for participation in the cap and trade program, LG Display began investing in R&D for a substitution gas for the etching process, which most commonly uses SF₆.

Sources:
LG Display

Korea Display Industry Association

LG Display's 2013-2014 Sustainability Report: <http://www.lgdisplay.com/eng/sustainability/report#>

LG Display's responses to the 2014 Carbon Disclosure Project Investor Questionnaire (page 6 and page 9 discuss preparation for cap and trade schemes).

"Point of Use Abatement Device to Reduce SF₆ Emissions in LCD Manufacturing Operations in the Republic of Korea (South Korea)." LG Display's SF₆ Abatement Project. Clean Development Mechanism Project: 3440. <https://cdm.unfccc.int/Projects/DB/SGS-UKL1266943063.39/view>

Overview	Corporate-wide GHG emissions reduction goals and reduction initiatives	<p>LG Display set a corporate-wide GHG reduction goal to reduce its GHG emissions intensity in metric tons of CO₂e per unit of production by 29 percent from 2009 to 2020 (as revised from 40 percent), including both Scope 1 and Scope 2 emissions from all domestic and four overseas operation sites.</p> <p>LG Display sets its goals in consultation with LG Corporation, which is the holding company. LG Corporation has been monitoring the results and LG Display's reduction target has been completed since 2010.</p> <p>LG Display participates in the Carbon Disclosure Project and most recently reported on its GHG management efforts in 2014 for its 2013 calendar year (CY).</p> <p><i>Sources: LG Display</i></p> <p><i>LG Display's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.</i></p>
	Process optimization	<p>LG Display has applied end-point detection and revised processes to optimize the use of F-GHGs.</p> <p><i>Source: LG Display</i></p>
F-GHG Reduction Efforts	Use of alternatives	<p>LG Display has applied NF₃ remote plasma source chamber clean (RPSC) to all CVD manufacturing lines. An ordinary chamber's NF₃ utilization rate is only 70 percent, however RPSC's NF₃ utilization rate is 97 percent. LG Display has also used F₂ in chamber cleaning on one of its manufacturing lines instead of NF₃. In addition, LG Display continues to research alternative lower-GWP etching gases than SF₆ for the dry etching process.</p> <p><i>Sources: LG Display</i></p> <p><i>LG Display's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.</i></p>
	Capture and recycling	<p>LG Display is currently developing new SF₆-concentrating and -capturing technology with funding from industry and the South Korean government.</p> <p><i>Source: LG Display</i></p>

Abatement

<p>+ Full or partial installation of abatement systems across all new generation fabs</p>	<p>LG Display has installed F-GHG abatement systems on all lines of CVD tools and on two lines of etch tools. For NF_3 in CVD tools, electrically heated point of use systems are installed. For SF_6 and PFCs in etch tools, combustion-type centralized systems are installed.</p> <p><i>Source: LG Display</i></p>
<p>+ Ensured that abatement systems are installed, operated, and maintained according to manufacturer specifications</p>	<p>Yes.</p> <p>At the construction stage, LG Display checks and monitors all items and processes in accordance with the specification. At the commissioning stage, LG Display confirms the performance of abatement in accordance with the guarantee condition of the manufacturer. At the operation stage, LG Display makes an operation contract with the manufacturer, and every year checks the operational performance.</p> <p>In the case of etch tools, LG Display is verified by a third party, which is the Designated Operational Entity of CDM projects.</p> <p><i>Source: LG Display</i></p>
<p>+ Indicate whether default factors or actual measurements were used to estimate the DRE</p> <p>Reported destruction or removal efficiency (DRE)</p>	<p>Actual and default used.</p> <p>LG Display conducts actual measurements for its centralized abatement systems for its SF_6 abatement projects under the CDM. Under the South Korean government's regulation, LG Display uses the 90 percent default DRE value from 2006 IPCC Tier 2b Guidelines for National Greenhouse Gas Inventories for electronics industry emissions for its SF_6 abatement technologies. In the case of NF_3, which is not regulated by Korean law, LG Display applies the 95 percent default DRE value for NF_3, also taken from the 2006 IPCC Tier 2b Guidelines, in WLICC (now WDICC) activities.</p> <p><i>Sources: LG Display</i></p> <p><i>"Point of Use Abatement Device to Reduce SF_6 Emissions in LCD Manufacturing Operations in the Republic of Korea (South Korea)." LG Display's SF_6 Abatement Project. Clean Development Mechanism Project: 3440.</i> https://cdm.unfccc.int/Projects/DB/SGS-UKL1266943063.39/view</p>

F-GHG Reduction Efforts

+ Practices for monitoring abatement systems

For its centralized abatement systems, LG Display employs a continuous monitoring (FTIR, Annabar system), namely for its CDM project that destroys SF₆. For its POU systems, LG Display monitors the abatement systems on an as-needed basis.

Source: LG Display

“Point of Use Abatement Device to Reduce SF₆ Emissions in LCD Manufacturing Operations in the Republic of Korea (South Korea).” LG Display’s SF₆ Abatement Project. Clean Development Mechanism Project: 3440. Monitoring Reports available at: <https://cdm.unfccc.int/Projects/DB/SGS-UKL1266943063.39/view>

F-GHG Emissions Measurements

Total annual F-GHG emissions in CO₂e, emitted across all flat panel display manufacturing fabs (2013)

The following data for 2013 was verified by a third party:
Total amount of F-GHG emissions in metric tons of CO₂e: 3,891,229 (increase compared to 3,115,747 in CY 2012)

SF₆ emissions: 3,846,096 (increase compared to 3,074,008 in CY 2012)

PFCs emissions: 13,058 (increase compared to 5,833 in CY 2012)

HFCs emissions: 0 (same as CY 2012)

NF₃ emissions: 32,075 (decrease compared to 35,906 in CY 2012)

The data for 2014 is undergoing verification by a third party.

Important: The emissions listed cannot be compared to the emissions from other suppliers because they may use different estimation methods and monitoring practices to calculate their emissions. In addition, these process emissions may encompass more than emissions associated only with flat panel display manufacturing.

Source: LG Display

Total annual F-GHG emissions reductions and/or rate of emissions reductions

Total amount of F-GHG reductions in 2013 in metric tons of CO₂e: 888,404 (decrease in reductions compared to 1,825,238 in CY 2012)
 SF₆ reductions: 278,985 (decrease in reductions compared to 1,143,028 in CY 2012)
 PFCs reductions: 0 (same as CY 2012)
 HFCs reductions: 0 (same as CY 2012)
 NF₃ reductions: 609,420 (decrease in reductions compared to 682,210 in CY 2012)

The data for 2014 is undergoing verification by a third party.

Equation for SF₆ reductions:
 = Emissions without destruction – Emissions with destruction

Equation for NF₃ reductions:
 = Emissions without remote plasma source chamber clean (RPSC), destruction – Emissions with RPSC, destruction

Important: The reductions listed cannot be compared to the reductions from other suppliers because they may use different estimation methods and monitoring practices to calculate their reductions.

Source: LG Display

Methodology used to estimate F-GHG emissions

LG Display uses national GHGs emissions estimation guidelines issued by the South Korean Ministry of Environment and estimates NF₃ emissions by using the 2006 IPCC Tier 2b guidelines.

Source: LG Display

Third party assurance for F-GHG emissions estimates

LG Display's GHG emissions, such as CO₂, N₂O, CH₄, HFCs, PFCs and SF₆, are assured by a third party in accordance with South Korean government regulations. Also, LG Display received third party assurance for its SF₆ abatement project under the CDM. However, NF₃ emissions estimated by the 2006 IPCC Tier 2b Guidelines for National Greenhouse Gas Inventories for electronics industry emissions are not assured by a third party, but cross-checked by WDICC members.

Sources: LG Display

"Point of Use Abatement Device to Reduce SF₆ Emissions in LCD Manufacturing Operations in the Republic of Korea (South Korea)." LG Display's SF₆ Abatement Project. Clean Development Mechanism Project: 3440. Validation Report, May 2, 2010.

Panasonic

Overview	<p>Specific F-GHG emissions reduction efforts and/or goals</p>	<p>Panasonic Liquid Crystal Display (PLD) considers installation of abatement systems to be the most effective and realistic technique to reduce F-GHG emissions. PLD established 100 percent installation of abatement systems for both SF₆ and NF₃ from the start-up of the Himeji factory in 2010. Currently, because its production lines are integrated in the Himeji factory, PLD has a 100-percent rate of abatement system installation. PLD would like to continue studying while assessing technology trends both inside and outside the company for further improvements in the future.</p> <p><i>Source: Panasonic Liquid Crystal Display</i></p>
	<p>+ F-GHG emissions reduction efforts/goals target the following key processes that emit F-GHGs</p>	<p>Etch and clean processes. PLD uses fluorinated heat transfer fluids for dry-etcher and exposure equipment. PLD manages leakage prevention properly with high sealability.</p> <p><i>Source: Panasonic Liquid Crystal Display</i></p>
	<p>+ F-GHG emissions reduction efforts/goals target the following F-GHGs emitted</p>	<p>SF₆, NF₃.</p> <p><i>Source: Panasonic Liquid Crystal Display</i></p>
	<p>Participation in national and/or international mandatory and/or voluntary efforts to reduce F-GHG emissions from flat panel display manufacturing</p>	<p>Panasonic is a member of the Japan Electronics & Information Technology Industries Association (JEITA), which participates on behalf of Japan's LCD suppliers in the World Display device Industry Cooperation Committee (WDICC), an international industry initiative that previously set goals to reduce F-GHG emissions (formerly the World LCD Industry Cooperation Committee). JEITA engages in WDICC activities to share information and promote activities to reduce F-GHG emissions via the installation of abatement systems and through other efforts. Japan's LCD industry set a collective goal to reduce F-GHG emissions by 70 percent from 2000 to 2012.</p> <p>The Japanese government established a Greenhouse Gas Accounting, Reporting and Disclosure system as part of their Global Warming Countermeasures Law, where companies are required to report F-GHG emissions that exceed 3,000 tons of CO₂e. In addition, the government also established a target for reducing F-GHG emissions to help achieve GHG reduction targets under the Kyoto Protocol.</p> <p><i>Source: JEITA</i></p>

Overview	Corporate-wide GHG emissions reduction goals and reduction initiatives	<p>Panasonic participates in the Carbon Disclosure Project (CDP) and most recently publicly reported on its GHG management efforts for its April 2013–March 2014 reporting fiscal year (FY).</p> <p><i>Source: Panasonic's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.</i></p>
	Process optimization	<p>PLD is working on process optimization daily. Additional details are not available.</p> <p><i>Source: Panasonic Liquid Crystal Display</i></p>
F-GHG Reduction Efforts	Use of alternatives	<p>PLD uses SF₆ as an etching gas, and NF₃ as a cleaning gas for CVD. Regarding further improvements, PLD would like to assess technology trends and respond accordingly.</p> <p><i>Source: Panasonic Liquid Crystal Display</i></p>
	Capture and recycling	<p>PLD will continue gathering information to proceed with discussion and review [of capture and recycling technologies].</p> <p><i>Source: Panasonic Liquid Crystal Display</i></p>
	Abatement	
	+ Full or partial installation of abatement systems across all new generation fabs	<p>PLD installs abatement systems to all CVD equipment and all dry-etchers.</p> <p><i>Source: Panasonic Liquid Crystal Display</i></p>
	+ Ensured that abatement systems are installed, operated, and maintained, according to manufacturer specifications	<p>PLD checks the performance at the time of installation of abatement systems, and operates them under proper management to ensure optimal results.</p> <p><i>Source: Panasonic Liquid Crystal Display</i></p>

F-GHG Reduction Efforts

+ Indicate whether default factors or actual measurements were used to estimate the DRE

Reported destruction or removal efficiency (DRE)

The Sustainability Report by the Panasonic Group and CDP is calculated with reference to the abatement rate actually measured. However, the figures used in the calculation have great allowance and therefore the actual abatement efficiency is higher.

Source: Panasonic Liquid Crystal Display

+ Practices for monitoring abatement systems

PLD checks the performance at the time of installation of abatement systems.

Source: Panasonic Liquid Crystal Display

F-GHG Emissions Measurements

Total annual F-GHG emissions in CO₂e, emitted across all flat panel display manufacturing fabs (2014)

PLD's F-GHG emissions are disclosed in the Panasonic Group's Sustainability Report 2014, and are also included in its reporting to the CDP. PLD's F-GHG emissions from its Himeji factory only, as reported from April 1, 2013– March 31, 2014, are as follows in tons of CO₂e:

SF₆ emissions: 5,100 (a decrease from FY2013, when emissions were 6,583).

According to PLD, when calculated by the IPCC Tier 2b guidelines, default factors used in the Questionnaire of JEITA Display Devices Environment Committee, F-GHG emissions are as follows in tons of CO₂e:

SF₆ emissions: 6,900 (a decrease from FY2013, when emissions were 8,477)

NF₃ emissions: 1,700 (a decrease from FY2013, when emissions were 2,145)

Important: The emissions listed cannot be compared to the emissions from other suppliers because they may use different estimation methods and monitoring practices to calculate their emissions.

Sources:

Panasonic Liquid Crystal Display

Sustainability Report 2014 by the Panasonic Group (<http://www.panasonic.com/global/corporate/sustainability/downloads.html>)

F-GHG Emissions Measurements

Total annual F-GHG emissions reductions and/or rate of emissions reductions

Himeji factory started production in mid-2010. PLD will continue monitoring the transition between the fiscal years.
Source: Panasonic Liquid Crystal Display

Methodology used to estimate F-GHG emissions

PLD estimates F-GHG emissions based on the Greenhouse Gas Accounting, Reporting and Disclosure system of the Japanese government.
Source: Panasonic Liquid Crystal Display

Third party assurance for F-GHG emissions estimates

The Sustainability Report by the Panasonic Group is audited by a third-party organization as described in the report.
*Source:
 Sustainability Report 2014 by the Panasonic Group
 (<http://www.panasonic.com/global/corporate/sustainability/downloads.html>)*

Sharp

Overview	Specific F-GHG emissions reduction efforts and/or goals	<p>Sharp has, as a part of F-GHG emissions reduction activities, installed abatement systems on all F-GHG-using process lines of all LCD manufacturing fabs, and has been maintaining the abatement systems appropriately.</p> <p><i>Source:</i> Sharp (Sharp Corporation)</p>
	+ F-GHG emissions reduction efforts/goals target the following key processes that emit F-GHGs	<p>Etching and cleaning processes. Information on fluorinated heat transfer fluids not available.</p> <p><i>Source:</i> Nishida, et al. PFC Emission Reduction Strategy for the LCD Industry. Journal of the SID 13/10. 2005</p>
	+ F-GHG emissions reduction efforts/goals target the following F-GHGs emitted	<p>SF₆, PFCs (CF₄, C₂F₆, C₄F₈), HFCs (CHF₃), and NF₃.</p> <p><i>Source: Japan Electronics and Information Technology Industries Association (JEITA).</i></p>
	Participation in national and/or international mandatory and/or voluntary efforts to reduce F-GHG emissions from flat panel display manufacturing	<p>Sharp is a member of the Japan Electronics and Information Technology Industries Association (JEITA), which participates on behalf of Japan's LCD suppliers in the World Display device Industry Cooperation Committee (WDICC), an international industry initiative that previously set goals to reduce F-GHG emissions (formerly the World LCD Industry Cooperation Committee). JEITA engages in WDICC activities to share information and promote activities to reduce F-GHG emissions via the installation of abatement systems and through other efforts. Japan's LCD industry set a collective goal to reduce F-GHG emissions by 70 percent from 2000 to 2012.</p> <p>The Japanese government established a Greenhouse Gas Accounting, Reporting and Disclosure system as part of their Global Warming Countermeasures Law, where companies are required to report F-GHG emissions that exceed 3,000 tons of CO₂e. In addition, the government also established a target for reducing F-GHG emissions to help achieve GHG reduction targets under the Kyoto Protocol.</p> <p><i>Source: JEITA</i></p>

Overview	Corporate-wide GHG emissions reduction goals and reduction initiatives	<p>Sharp set a goal to reduce absolute GHG emissions per year to below the 2007 baseline fiscal year emissions levels for ten manufacturing fabs by 2011. Its most recent base year emissions were reported as 968,000 metric tons of CO₂e. Sharp also set another goal to reduce GHG emissions intensity by 35 percent per adjusted production unit (tons of CO₂e/100 million yen) across the ten fabs by 2012. By end of fiscal year 2011, Sharp met both of its goals and reduced total emissions by 40 percent and emissions intensity by 42 percent.</p> <p>Sharp participates in the Carbon Disclosure Project and most recently publicly reported on its GHG management efforts in 2013 for its April 2013-March 2014 reporting year.</p> <p><i>Source: Sharp's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.</i></p>
F-GHG Reduction Efforts	Process optimization	<p>Sharp has been researching ways to improve process optimization and manufacturing process conditions at the time that manufacturing equipment is first installed and in daily operations.</p> <p><i>Source: Sharp (Sharp Corporation)</i></p>
	Use of alternatives	<p>Sharp has been collecting the latest information from relevant sources and researching the possibility of using lower GWP alternative gases.</p> <p><i>Source: Sharp (Sharp Corporation)</i></p>
	Capture and recycling	<p>Sharp implements the recycling of F-GHGs in some manufacturing processes.</p> <p><i>Source: Sharp (Sharp Corporation)</i></p>
	Abatement	
	+ Full or partial installation of abatement systems across all new generation fabs	<p>Sharp has installed abatement systems on all etching and cleaning process equipment.</p> <p><i>Source: Sharp (Sharp Corporation)</i></p>

F-GHG Reduction Efforts	+ Ensured that abatement systems are installed, operated, and maintained according to manufacturer specifications	<p>Sharp has been managing abatement systems appropriately during all installation, operation and maintenance processes, in cooperation with the abatement system manufacturing professionals.</p> <p><i>Source: Sharp (Sharp Corporation)</i></p>
	+ Indicate whether default factors or actual measurements were used to estimate the DRE	<p>Sharp uses the IPCC Tier 2b Guidelines Default Factors to answer the questionnaire from JEITA.</p>
	Reported destruction or removal efficiency (DRE)	
	+ Practices for monitoring abatement systems	<p>Sharp verifies the performance of abatement systems at the time of installation, and implements the maintenance and verifications for performance retention.</p> <p><i>Source: Sharp (Sharp Corporation)</i></p>
F-GHG Emissions Measurements	<p>Total annual F-GHG emissions in CO₂e, emitted across all flat panel display manufacturing fabs (2014)</p>	<p>The total amount of F-GHG emissions attributed to panel manufacturing is not publicly available.</p> <p>As part of its 2014 responses to the Sharp Corporation's Sustainability Report 2014, which discloses its corporate GHG emissions from April 1, 2013 to March 31, 2014, Sharp lists its Scope 1 emissions. These Scope 1 emissions represent its organizational boundary, using a financial control approach, which includes factories and offices within Japan and in other countries. Sharp's F-GHG emissions, as reported, are as follows, in metric tons of CO₂e.</p> <p>HFCs: 7,000 (an increase from FY 2013, when emissions were 4,000) PFCs: 32,000 (an increase from FY 2013, when emissions were 31,000) SF₆: 41,000 (an increase from FY 2013, when emissions were 33,000)</p> <p>Important: The emissions listed cannot be compared to the emissions from other suppliers because they may use different estimation methods and monitoring practices to calculate their emissions. These process emissions may also reflect manufacturing processes that create additional products other than large-area flat panel displays.</p> <p><i>Source: Sharp (Sharp Corporation)</i> Sustainability Report 2014 by the Sharp Corporation (http://www.sharp.co.jp/corporate/eco/report/ssr/index.html)</p>

F-GHG Emissions Measurements

Total annual F-GHG emissions reductions and/or rate of emissions reductions

Sharp works to reduce F-GHG emissions in accordance with the targets of Ministry of Economy, Trade and Industry, JEITA and other industrial associations.

Source: Sharp (Sharp Corporation)

Methodology used to estimate F-GHG emissions

Sharp uses the IPCC Tier 2b Guidelines Default Factors to estimate F-GHG emissions.

Source: Sharp (Sharp Corporation)

Third party assurance for F-GHG emissions estimates

Sharp Sustainability Report is audited by a third-party organization: KPMG AZSA Sustainability Co., Ltd.

*Source: Sustainability Report 2014 by the Sharp Corporation
(<http://www.sharp.co.jp/corporate/eco/report/ssr/index.html>)*