MEMORANDUM

To: Henry Ferland, EPA

From: Jeremy Scharfenberg, Lauren Pederson, and Anne Choate, ICF

Date: September 7, 2004

Re: WARM Model Transportation Research - *Draft*. Methane Contract 009, Task 06

This memorandum outlines recent research and refinement efforts associated with WARM's underlying streamlined life-cycle analysis methodology. The general focus of these efforts was on the transportation component of the material life-cycle. This research focused on three specific objectives:

1) Improving estimates of emissions from transporting finished material products from the manufacturing point to the retail point;

2) Improving estimates of emissions from waste transport, including refinements to the "user specified" waste transport mileage methodology currently employed in WARM; and

3) Examining the sensitivity of existing material-specific emission factors to transportation emissions for virgin and recycled materials (based on raw material acquisition and manufacturing).

<u>Retail Transport of Material</u>

The life-cycle methodology used in WARM does not account for greenhouse gas (GHG) emissions associated with the transport of materials as commodities (i.e., manufactured products or materials) from the manufacturing point to the retail/distribution point. The rationale for this was twofold: (1) a screening analysis indicated that the emissions were very minimal in comparison to the emissions associated with other parts of the life cycle and (2) the difference between transport emissions for virgin and recycled materials was expected to be negligible. In the two years since the latest version of the MSW Report was published, some of the climate and waste stakeholders have asked why EPA is not looking more closely at these emissions. In response to this request, we conducted new research to expand the life-cycle analysis to include these emissions.

The U.S. Census Bureau along with the Bureau of Transportation Statistics recently conducted a Commodity Flow Survey that determined the average distance commodities were shipped in the United States and the percentage each of the various transportation modes was used in shipping these commodities.[1] In order to simplify calculations, the "Water" transportation mode was taken as an average of the three possible types of water transport (deep draft, shallow draft, Great Lakes) reported in the Survey. Please see Table 1 for shipping distance by commodity type, and Table 2 for the average distribution of transport modes for all commodities. The commodity types listed in the flow survey were matched to the appropriate WARM material type were possible. For those material types that did not have a suitable match or surrogate commodity type, we recommend using an average of all material types.

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[1] U.S. Census Bureau, 2003. *Commodity Flow Survey*. United States Census Bureau. December, 2003. http://www.census.gov/prod/ec02/02tcf-usp.pdf

Table 1. Product, Commodity Types, and Average Miles Per Shipment

WARM Material Type	Proxy Commodity Type in Flow Survey	Average Shipping Distance (miles)
Aluminum Cans	Base Metal in primary or semifinished forms and in finished basic shapes	275
Steel Cans	Base Metal in primary or semifinished forms and in finished basic shapes	275
Glass	Nonmetallic Mineral Products	903
HDPE	Plastics and Rubber	430
LDPE	Plastics and Rubber	430
PET	Plastics and Rubber	430
Corrugated Cardboard	Paper or Paperboard articles	282

Source: U.S. Census, 2003. *Commodity Flow Survey*.

Table 2. Transportation Mode Distribution

Mode of Transportation	Percent of Total
Combination Truck	41.1
Rail	39.8
Water[1]	13.6
Other Modes	5.5

Source: U.S. Census, 2003. *Commodity Flow Survey*.
[1] Ave. of deep draft, shallow draft, and Great Lakes water shipping modes.

The percentage for each mode of transportation used to ship commodities was applied to the average miles-per-commodity shipment data to determine the theoretical mileage traveled within each mode by commodity. The estimated transportation energy for each material type was estimated by applying the transportation fuel efficiency and fuel-specific heating value to the average miles that commodities were shipped within each mode. Emission factors were then created by applying carbon coefficients for each fuel type (i.e., diesel, residual oil, and gasoline) to the transportation energy required for each mode. For example, the factors associated with combination truck (tractor-trailer) shipping mode are a diesel fuel consumption rate of 0.0118 gal/ton-mile, standard Intergovernmental Panel on Climate Change (IPCC) energy and CO_2 emission factors for combustion of distillate (diesel) fuel oil, a scaling factor of 1.185 to reflect pre-combustion energy.[2] Please see Table 3 below for the energy and emission factors associated with transportation from the manufacturing point to the retail point for each material type. The "other" category listed above is attributed to the combustion of gasoline. While these factors may be small relative to the larger raw materials acquisition and manufacturing emissions for each material, their inclusion fills an important gap in our existing life-cycle methodology. Because this adjustment will be made to both the 100 percent virgin and 100 percent recycled material types, the change in transportation emissions will drop out when virgin and recycled materials are compared. Because source reduction emission factors reflect the benefit of not transporting the material in the first place, this adjustment will be more noticeable.

[2] U.S. EPA, 1998. *Greenhouse Gas Emissions From the Management of Selected Materials*. United States Environmental Protection Agency, Municipal and Industrial Solid Waste Division. December 18, 1998.

Table 3. Retail Transportation Energy and Emission Factors by Material Type

Material Type	Transportation Energy (Million Btu Per Ton of Product)	Transportation Emission Factor (MTCE per Ton of Product)
Aluminum Cans	0.309	0.006
Steel Cans	0.309	0.006
Glass	1.016	0.021
HDPE	0.484	0.010
LDPE	0.484	0.010
PET	0.484	0.010
Corrugated Cardboard	0.317	0.006
Magazines/Third-class Mail	0.262	0.005
Newspaper	0.262	0.005
Office Paper	0.262	0.005
Phonebooks	1.016	0.021
Textbooks	1.016	0.021
Dimensional Lumber	0.122	0.002
Medium-density Fiberboard	0.317	0.006
Boxboard	0.317	0.006

<u>Transportation of Waste to the Point of Disposal</u>

We conducted research into the waste transport emission factor currently utilized in WARM for user-specified waste transport distances. The default transport emission factor (for the first 20 miles) includes GHG emissions associated with the operation of local waste collection and landfill vehicles. This default value is then adjusted based on user specifications for transport mileages greater than the default value of 20 miles. The existing factor of 0.00023 MTCE/ton-mile was based on older research conducted for waste transport. The new factor is 0.00004 MTCE/ton-mile. This new factor is based on diesel combination truck hauling of waste materials. The underlying assumptions for the new waste transport factor are a combination truck diesel fuel consumption rate of 0.0118 gal/ton-mile, standard IPCC energy and CO_2 emission factors for combustion of distillate (diesel) fuel oil, and a scaling factor of 1.185 to reflect pre-combustion energy (this is similar to the approach used in the previous section).[3] Because this change in the methodology is relatively simple (i.e., a single factor), it has already been updated in the online version of WARM and the downloadable Excel version.

Additional research was conducted to determine information on typical shipping distances and the modes of transport used to ship waste to a disposal/processing sites. Research indicates that the primary mode of transport for waste is through the use of combination diesel trucks. However, as landfill space becomes more limited, there is likely to be a shift towards the use of rail transport for shipping waste over longer distances.[4] Rail transport is much more efficient than combination truck (0.012 gal/ton-mile for combination truck and 0.003 gal/ton-mile for rail) in terms of diesel fuel consumption.[5] This would result in a lower GHG emission rate factor for waste transport on a per-ton-mile basis. Long distance waste transport using multiple modes is an area that should be considered for further research, and may present an opportunity to further customize WARM results.

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[3] U.S. EPA, 1998. op. cit.
[4] WM, 2004. *Waste by Rail*. Waste Management, Inc. 2004. http://www.wm.com
[5] U.S. EPA, 1998. op. cit.

Transportation Sensitivity Analysis

As part of our recent efforts to improve the accuracy of the transportation component of our streamlined life-cycle analysis, we decided to perform a sensitivity analysis on the current transportation energy/emissions data contained within WARM. For this analysis, the transportation related emission factors for the "100 percent virgin" and "100 percent recycled" components of each material type were reduced by 50 percent and increased by 100 percent (a two-fold increase) and 200 percent (a three-fold increase). The emission factors for source reduction were chosen because the current mix scenarios generally include some virgin and recycled material. The results of the sensitivity analysis are presented in Table 4 below. As can be seen, the dramatic changes in the transportation component had very little impact on the overall emission factor for source reduction. This analysis indicates that the emission factors used in the WARM model are driven largely by emissions associated with process energy consumption during raw materials acquisition and manufacturing. The steel cans material type is noted as being the most susceptible to changes in the transportation emissions component.

Table 4. Transportation Sensitivity Analysis

Transportation Energy Scaling Factor	**Average Change in Overall EF (percent)**	**Greatest Change in Overall EF (percent)**
-50 percent	-1.1	-5.1 *[steel]*
+100 percent	+2.1	+10.3 *["]*
+200 percent	+4.2	+20.5 *["]*
+300 percent	+6.3	+30.8 *["]*

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Please contact Jeremy Scharfenberg at 202-862-1113 with comments or questions about the contents of this memo.