METHODOLOGY FOR ESTIMATING MUNICIPAL SOLID WASTE RECYCLING BENEFITS

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PURPOSE

This "Methodology for Estimating Municipal Solid Waste (MSW) Recycling Benefits" is intended to provide a clear and complete explanation of the process used by EPA to develop estimates of the benefits associated with municipal solid waste (MSW) recycling. This methodology helps to serve as a crosswalk and explains how EPA's MSW characterization data (as reported in "Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2006" (Characterization Report))[1], are input into the Waste Reduction Model (WARM)[2] in order to derive benefit estimates. Also, this methodology provides further specifics regarding the Characterization Report and WARM, and helps to further document the linkages that exist between waste management, and its potential contributions to climate change and energy conservation.

THE LINK BETWEEN WASTE MANAGEMENT, CLIMATE CHANGE, AND ENERGY

The disposal of solid waste produces greenhouse gas emissions in a number of ways. First, the anaerobic decomposition of waste in landfills produces methane, a greenhouse gas 21 times more potent than carbon dioxide. Second, the incineration of waste also produces carbon dioxide as a by-product. Additionally, in transportating waste for disposal, greenhouse gases are emitted due to the combustion of fossil fuels. Finally, fossil fuels are also required for extracting and processing the raw materials necessary to replace those materials that are being disposed with new products.

Waste prevention and recycling—jointly referred to as waste reduction—help us better manage the solid waste we generate. But preventing waste and recycling also are potent strategies for reducing greenhouse gas emissions and conserving energy. Together, waste prevention and recycling:

- Reduces methane emissions from landfills. Waste prevention and recycling (including composting) divert organic wastes from landfills, thereby reducing the methane released when these materials decompose.
- Reduces emissions from incinerators. Recycling and waste prevention allow some materials to be diverted from incinerators and thus reduce greenhouse gas emissions from the combustion of waste.
- Reduces emissions from energy consumption. Recycling saves energy – because manufacturing goods from recycled materials typically requires less energy than producing goods from virgin materials. Waste prevention is even more effective at saving energy – because when people reuse things or when products are made with less material and/or greater durability, less energy is usually needed to extract, transport, and process raw materials and to manufacture replacement products. What's more, when energy demand decreases, fewer fossil fuels are burned and less carbon dioxide is emitted to the atmosphere.
- Increases storage of carbon in trees. Trees help absorb carbon dioxide from the atmosphere and store it in wood, in a process called carbon sequestration. Waste prevention and recycling of paper products allow more trees to remain unharvested, where they can continue to remove carbon dioxide from the atmosphere.

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[1] The Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2006 can be found on-line at http://www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm

[2] The WARM Model can be found on-line at http://epa.gov/climatechange/wycd/waste/SWMGHGreport.html.

DESCRIPTION OF DATA AND MODEL USED

The following two key information sources were used by EPA; first, as a basis for identifying the quantities of MSW being recycled, and secondly, for assessing the benefits that could be ascribed to these recycling achievements.

The MSW Characterization Report

The Environmental Protection Agency has collected and reported data on the generation and disposal of waste in the United States for more than 30 years. We use the information to measure the success of municipal solid waste (MSW) reduction and recycling programs across the country.

The Waste Reduction Model

WARM is an Environmental Protection Agency (EPA) model that covers 34 types of materials and five waste management options: source reduction, recycling, combustion, composting, and landfilling. WARM accounts for upstream energy and carbon emissions, transportation distances to disposal and recycling facilities, carbon sequestration, and utility offsets that result from landfill gas collection and combustion. WARM assesses four main stages of product life-cycles, all of which provide opportunities for GHG and energy emissions and/or offsets. These stages are: raw material acquisition, manufacturing, recycling, and waste management.

In 2006, the U.S. recycled 32.5 percent (or 81.8 million tons) of its waste, up from 31.9 percent in 2005. This resulted in 49.7 million metric tons of carbon equivalent (MTCE) saved, or the emissions equivalent of taking 39.4 million cars off the road for one year. In addition, 1.3 quadrillion BTUs of energy were saved, which is enough energy to power 13 percent of U.S. residences for one year.

METHODOLOGY FOR DERIVING BENEFITS

The benefits of MSW recycling were calculated using WARM. As noted above, generating these benefit estimates requires inputting data on MSW recycling into WARM. However for some materials, the Characterization Report and WARM do not have identical categories. More specifically, WARM contains fewer material categories than are listed in the Characterization Report. While some categories are highly similar and correct placement of the data into WARM is readily apparent, for modeling purposes it was necessary to establish standard assumptions to facilitate this process for certain specific materials. The following section explains the methodology and assumptions used by EPA to determine the GHG and energy benefits of the U.S. national 32.5 percent recycling rate based on 2006 data. Inputting data into WARM and running the model involves two major steps as summarized here.

Step one involves using the Characterization Report to identify the materials to be used as inputs to WARM. The Characterization Report Data Tables[3] list the MSW materials that can be input into WARM. Table 1 below provides a general crosswalk of the material categories in the MSW Characterization Report, as compared to the categories that are available within the WARM model. A more detailed discussion of this process for specific materials has been organized

[3] The 2006 MSW Characterization Data Tables are located at http://www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm

below in the following section, grouped according to their respective material category and associated table numbers from the MSW Characterization Report.

Step two involves using WARM to distinguish between a baseline and alternate scenario. This requires decisions such as determining the amount landfilled or combusted in the baseline scenario and recycled or source reduced in the alternate scenario. The methodology EPA used to determine national recycling benefits is discussed in the WARM walk-through section below.

Table 1. Crosswalk between Material Categories in the MSW Characterization Report and WARM

MSW Characterization Report		WARM
Table[4]	**Material Category**	**Material Category**
Table 2	Textiles	Carpet
Table 2	Wood	Dimensional Lumber
Table 2	Food Scraps	Food Scraps
Table 2	Yard Trimmings	Yard Trimmings
Table 4	Total Newspapers	Newspaper
Table 4	Books	Textbooks
Table 4	Magazines	Magazines/third-class mail
Table 4	Office-type papers	Office paper
Table 4	Telephone Directories	Phonebooks
Table 4	Standard Mail	Magazines/third-class mail
Table 4	Other Commercial Printing	Mixed Paper, office
Table 4	Corrugated Boxes	Corrugated Cardboard
Table 4	Folding Cartons	Mixed Paper, residential
Table 4	Bags and Sacks	Mixed Paper, residential
Table 5	Total Glass	Glass
Table 6	Ferrous Metals	Steel Cans
Table 6	Lead	Mixed Metals
Table 6	Total Steel Packaging	Steel Cans
Table 6	Total Aluminum Packaging	Aluminum Cans
Table 7	PET	PET
Table 7	HDPE	HDPE
Table 7	LDPE/LLDPE	LDPE
Table 7	PP	Mixed Plastics
Table 7	PS	Mixed Plastics
Table 7	Other resins	Mixed Plastics
Table 8	Rubber in Tires	Tires

[4] The tables can be found on-line in the MSW Characterization Report Data Tables at http://www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm

Materials Crosswalk

Organics

Table 2 of the Characterization Report Data Tables provides details regarding the recovery of food scraps and yard trimmings. Both categories are represented in the tables and WARM under the same name.

Table 2. Organics Crosswalk

WARM Material	Characterization Report Material	Generated (000 tons)	Recovered (000 tons)
Food Scraps	Food Scraps	31,250	680
Yard Trimmings	Yard Trimmings	32,400	20,100

Paper and Paperboard Products

Table 4 of the Characterization Report Data Tables provides details regarding the paper and paperboard categories. The category "total newspaper" is listed as a combination of "newsprint" and "groundwood inserts". To calculate the benefits of these materials, they are all classified as "newspaper". WARM's category "textbooks" is used to measure the benefits of the material the Characterization Report refers to as "books". "Telephone directories" in the Characterization Report and "phonebooks" in WARM are assumed to be the same items. Similarly, "corrugated boxes" in the Characterization Report and "corrugated cardboard" in WARM are assumed to refer to exactly the same material. The category "mixed paper, office" is used as a proxy in WARM for the "other commercial printing" category. "Standard mail" and "magazines" from Table 4 of the Characterization Report are grouped together for measurement in WARM's "magazines/third-class mail" category, while "folding cartons" and "bags and sacks" are added together in WARM's "mixed paper, residential" category.

Table 3. Paper and Paperboard Crosswalk

WARM Material	Characterization Report Material	Generated (000 tons)	Recovered (000 tons)
Corrugated Cardboard	Corrugated Boxes	31,430	22,630
Magazines/Third-class mail	Magazines and Standard Mail	8,460	3,320
Newspaper	Total Newspaper	12,360	10,870
Office Paper	Office-type Papers	6,320	4,150
Phonebooks	Telephone Directories	680	130
Textbooks	Books	1,130	290
Mixed paper (residential)	Folding Cartons and Bags and Sacks	6,910	1,230
Mixed paper (offices)	Other Commercial Printing	6,630	1,400

Glass Products

Table 5 of the Characterization Report Data Tables provides details regarding the glass category. The category "total glass" is listed as a combination of glass in durable goods and glass containers and packaging. This total amount from Table 5 is used in WARM's "glass" category to calculate benefits.

Table 4. Glass Crosswalk

WARM Material	Characterization Report Material	Generated (000 tons)	Recovered (000 tons)
Glass	Total Glass	13,200	2,880

Metal Products

Table 6 of the Characterization Report Data Tables provides details regarding the metals category. "Ferrous metals" are classified in the WARM category "steel cans" based on Exhibit 8-1 of "Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks." Lead does not have a matching category in WARM, and is thus classified as "mixed metals." "Total steel packaging" is categorized as "steel cans" and "total aluminum packaging" is classified as "aluminum cans" in the WARM.

Table 5. Metal Crosswalk

WARM Material	Characterization Report Material	Generated (000 tons)	Recovered (000 tons)
Aluminum Cans	Total Aluminum Packaging	1,940	690
Steel cans	Total Steel Packaging and Ferrous Metals	14,220	5,080
Mixed Metals	Lead	1,190	1,180

Plastics in Products

Table 7 in the Characterization Report Data Tables provides detail regarding the plastics category. The "PET," "HDPE," and "LDPE/LLDPE" categories all have matching categories in WARM, and thus are classified appropriately. The "Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks" states in Exhibit 8-1 that the emissions and energy use related to plastics such as "PP" (polypropylene), "PS" (polystyrene) and "other resins" should be measured using "mixed plastics" in WARM.

Table 6. Plastics Crosswalk

WARM Material	Characterization Report Material	Generated (000 tons)	Recovered (000 tons)
PET	PET	6,040	580
HDPE	HDPE	6,560	280
LDPE	LDPE/LLDPE	3,060	620
Mixed Plastics	Other Resins, PP, PS	12,160	560

Other Products

Table 2 in the Characterization Report Data Tables provides detail regarding the categories of both wood and textiles. The Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks", states in Exhibit 8-1 that "wood" should be measured as "dimensional lumber' in WARM, and that "textiles" should be classified as "carpet." "Rubber in tires", which can be found in Table 8 of the Data Tables, is classified as "tires" in WARM.

Table 7. Other Materials Crosswalk

WARM Material	Characterization Report Material	Generated (000 tons)	Recovered (000 tons)
Carpet	Textiles	11,840	1,810
Dimensional Lumber	Wood	13,930	1,310
Tires	Rubber in Tires	2,490	870

WARM Walk-Through

WARM differentiates between two different scenarios: baseline and alternate. Normally, the baseline scenario refers to the current or 'business as normal' situation and the alternate scenario depicts the change in waste management that is to be modeled to quantify benefits. WARM also allows the user to change certain criteria, such as distances to different management facilities or information on landfill gas recovery. EPA uses the national averages to develop its national benefits estimates. Please note if these criteria are changed, the numbers may not correspond to EPA's numbers.

Baseline Scenario

For the purposes of this exercise, EPA assumed that 87.5 percent of the recovered material was landfilled and 12.5 percent was combusted with energy recovery for the baseline scenario[5]. EPA only modeled the amount of material recycled (not generated), as stated by the Characterization Report, since the benefits numbers generated relate specifically to the benefits of recycling the material. Table 8 presents the actual numbers EPA plugged into WARM for the baseline.

Table 8. Snapshot of Baseline Scenario

Material	Baseline Generation	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	690,000			604,000	86,000	NA
Steel Cans	5,080,000			4,445,000	635,000	NA
Copper Wire						NA
Glass	2,880,000			2,520,000	360,000	NA
HDPE	580,000			507,500	72,500	NA
LDPE	280,000			245,000	35,000	NA
PET	620,000			542,500	77,500	NA
Corrugated Cardboard	22,630,000			19,801,000	2,829,000	NA
Magazines/Third-class Mail	3,320,000			2,905,000	415,000	NA
Newspaper	10,870,000			9,511,000	1,359,000	NA
Office Paper	4,150,000			3,631,000	519,000	NA
Phonebooks	130,000			114,000	16,000	NA
Textbooks	290,000			254,000	36,000	NA
Dimensional Lumber	1,310,000			1,146,000	164,000	NA
Medium-density Fiberboard						NA
Food Scraps	680,000	NA	NA	595,000	85,000	
Yard Trimmings	20,100,000	NA	NA	17,587,500	2,512,500	
Grass		NA	NA			
Leaves		NA	NA			
Branches		NA	NA			
Mixed Paper (general)		NA				NA
Mixed Paper (primarily residential)	1,230,000	NA		1,076,000	154,000	NA
Mixed Paper (primarily from offices)	1,400,000	NA		1,225,000	175,000	NA
Mixed Metals	1,180,000	NA		1,032,500	147,500	NA
Mixed Plastics	560,000	NA		490,000	70,000	NA
Mixed Recyclables		NA				NA
Mixed Organics		NA	NA			
Mixed MSW		NA	NA			NA
Carpet	1,810,000			1,584,000	226,000	NA
Personal Computers						NA
Clay Bricks Alternate Scenario			NA			NA
Concrete		NA				NA
Fly Ash		NA				NA
Tires	870,000			761,000	109,000	NA

[5] 2006 MSW Characterization Report Data Tables, Table 29.

The alternate scenario assumes that all materials from the baseline are recycled. Table 9 provides a snapshot of this alternative assessment, as modeled by WARM.

Table 9. Snapshot of Alternative Scenario

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	690,000	690,000			NA
Steel Cans	5,080,000	5,080,000			NA
Copper Wire					NA
Glass	2,880,000	2,880,000			NA
HDPE	580,000	580,000			NA
LDPE	280,000	280,000			NA
PET	620,000	620,000			NA
Corrugated Cardboard	22,630,000	22,630,000			NA
Magazines/Third-class Mail	3,320,000	3,320,000			NA
Newspaper	10,870,000	10,870,000			NA
Office Paper	4,150,000	4,150,000			NA
Phonebooks	130,000	130,000			NA
Textbooks	290,000	290,000			NA
Dimensional Lumber	1,310,000	1,310,000			NA
Medium-density Fiberboard					NA
Food Scraps	680,000	NA			680,000
Yard Trimmings	20,100,000	NA			20,100,000
Grass		NA			
Leaves		NA			
Branches		NA			
Mixed Paper (general)					NA
Mixed Paper (primarily residential)	1,230,000	1,230,000			NA
Mixed Paper (primarily from offices)	1,400,000	1,400,000			NA
Mixed Metals	1,180,000	1,180,000			NA
Mixed Plastics	560,000	560,000			NA
Mixed Recyclables					NA
Mixed Organics		NA			
Mixed MSW		NA			NA
Carpet	1,810,000	1,810,000			NA
Personal Computers					NA
Clay Bricks		NA		NA	NA
Concrete				NA	NA
Fly Ash				NA	NA
Tires	870,000	870,000			NA

WARM Benefit Results

WARM generates benefits numbers once the baseline and alternate scenarios are complete. These benefits estimates are generated in either metric tons of carbon equivalent (MTCE), metric tons of carbon dioxide equivalent (MTCO2E), or British thermal units (BTU). In addition, WARM calculates other conversions, such as the number of cars of the road or the number of households' annual energy consumption. Further conversions of these units can be estimated using the Greenhouse Gas Equivalencies Calculators at http://www.usctcgateway.gov/tool/.

Using WARM as described above, EPA has estimated the total GHG Emission Reductions and Energy Savings associated with the national MSW recycling rate of 32.5% (or 82 million tons) achieved by the U.S. in 2006, as provided below in Table 10.

Table 10. WARM Benefit Results

Benefits	Conversions
49.7 million MTCE	39.4 million cars off the road
182.2 million MTCO2E	39.4 million cars off the road
1,288 trillion BTU	6.8 million households annual energy consumption
	222.1 million barrels of oil
	10.3 billion gallons of gas