

## APPENDIX C: ROADMAP FROM THE SECOND EDITION

Since the release of the second edition of the report, numerous adjustments and improvements have been made to the underlying data and methodology supporting the life-cycle emission factors. This new edition of the report has incorporated these updates, and the improvements are also reflected in the latest versions of the Waste Reduction Model (WARM), Recycled Content (ReCon) Tool and Durable Goods Calculator (DGC).<sup>1</sup> This appendix provides a brief explanation of the changes made to the underlying data and provides details on the latest emission factors being used in this edition of the report. Additional details on these changes can be found in the body of this report.

The primary changes and improvements to the life-cycle analysis since the 2002 report include the following:

- Developed emission factors for eight new material types: copper wire, clay bricks, concrete, fly ash, tires, carpet, personal computers, and mixed metals. As information on these additional material types became available, the list of material types has been expanded to provide greater capture of the municipal solid waste stream.
- Updated the national average fuel mix for utility-generated electricity based on information from the DOE, EIA, *Annual Energy Review: 2004* on electric utility consumption of fossil fuels.
- Incorporated new energy data into calculations of utility offsets;
- Updated the characterization of the municipal waste stream based on the 2003 *Municipal Solid Waste in the United States: Facts and Figures* report. This characterization study is used to develop emission factors for several of the “mixed” material types (e.g., mixed metals, mixed MSW).
- Revised the “current mix” values for virgin and recycled content of materials based on data obtained from Franklin Associates Ltd.
- Incorporated open loop recycling of corrugated cardboard and mixed paper into the life-cycle methodology. This provides a more accurate picture of the recycling of these materials such that recycled corrugated cardboard does not always go into the production of new corrugated cardboard.
- Added retail transportation (factory to point-of-sale) to the methodology utilizing commodity transportation data from the U.S. Census Bureau.
- Updated data on the behavior of organic materials in the landfill environment based on recent studies by Dr. Barlaz of NC State University.
- Updated information on landfill gas recovery rates to reflect latest values from the U.S. Inventory of Greenhouse Gas Emissions and Sinks;
- Updated the forest carbon sequestration factors based on revised estimates from the U.S. Department of Agriculture—Forest Service.

It should be noted that the fundamental aspects of the methodology reported in the 2002 report remain unchanged and this appendix is designed to communicate changes in the GHG emission factors that have occurred since the publication of the 2002 report.

The following pages present tables showing the net emission factors presented in the 2002 report, in order for readers to see how they have changed. Because numerous factors have been updated,

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<sup>1</sup> Available online at <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWaste.html>, under the “tools” heading.

including the average fuel mix and forest carbon sequestration values, all emission factors for source reduction, recycling, combustion, and landfilling presented in the tables below have changes; however, in some cases the change may not be apparent, due to rounding. The emission factors for composting have not changed.

Exhibit C-1 presents the net emission factors for source reduction from the 2002 report, as well as the components used to generate the net emission factors.

Exhibit C-2 presents the net emission factors for recycling from the 2002 report, as well as the components used to generate the net emission factors. In addition to the general changes outlined at the beginning of the Appendix, the benefits of recycling aluminum have been revised. The process energy values were updated to incorporate revised fuel mix data for the production of aluminum sheet and transportation energy values were also updated based on energy data obtained from a personal computer life-cycle analysis performed by Franklin Associates Ltd. The process non-energy values were revised to incorporate additional anode production data provided by Franklin Associates Ltd. along with the latest data on perfluorocarbon emission characteristics for aluminum smelting.

Exhibit C-3 presents the net emission factors for composting yard trimmings from the 2002 report, as well as the components used to generate the net emission factors. Although compost emission factors were developed for grass, leaves and branches, and new columns were added to the summary table to accommodate potential CO<sub>2</sub> and CH<sub>4</sub> emissions from composting, these changes had no impact on the net emission factors.

Exhibit C-4 presents the net emission factors for combustion from the 2002 report, as well as the components used to generate the net emission factors.

Exhibit C-5 presents the net emission factors for landfilling from the 2002 report, as well as the components used to generate the net emission factors. The total carbon sequestration factors for coated paper, newsprint, leaves and grass and the landfill CH<sub>4</sub> yields for corrugated cardboard, office paper, food discards, and branches were updated based on methodology changes suggested by Dr. Mort Barlaz of NCSU.

**Exhibit C-1**

**GHG Emissions for Source Reduction  
(MTCE/Ton of Material Source Reduced)**

Material	Avoided GHG Emissions from Raw Materials Acquisition and Manufacturing		Post-consumer	Changes in Forest Carbon Storage		Net Emissions For Current Mix of Inputs	Net Emissions For 100% Virgin Inputs
	For Current Mix of Inputs	For 100% Virgin Inputs		For Current Mix of Inputs	For 100% Virgin Inputs		
Aluminum Cans	-2.49	-4.67	0.00	0.00	0.00	-2.49	-4.67
Steel Cans	-0.79	-1.01	0.00	0.00	0.00	-0.79	-1.01
Glass	-0.14	-0.16	0.00	0.00	0.00	-0.14	-0.16
HDPE	-0.49	-0.53	0.00	0.00	0.00	-0.49	-0.53
LDPE	-0.61	-0.64	0.00	0.00	0.00	-0.61	-0.64
PET	-0.49	-0.58	0.00	0.00	0.00	-0.49	-0.58
Corrugated Cardboard	-0.24	-0.22	0.00	-0.28	-0.73	-0.51	-0.96
Magazines/Third-class Mail	-0.46	-0.46	0.00	-0.58	-0.73	-1.04	-1.19
Newspaper	-0.46	-0.59	0.00	-0.35	-0.73	-0.81	-1.32
Office Paper	-0.31	-0.28	0.00	-0.50	-0.73	-0.80	-1.01
Phonebooks	-0.64	-0.67	0.00	-0.65	-0.73	-1.28	-1.40
Textbooks	-0.59	-0.59	0.00	-0.64	-0.73	-1.23	-1.32
Dimensional Lumber	-0.05	-0.05	0.00	-0.50	-0.50	-0.55	-0.55
Medium-density Fiberboard	-0.10	-0.10	0.00	-0.50	-0.50	-0.60	-0.60
Mixed Paper							
Broad Definition	NA	NA	NA	NA	NA	NA	NA
Residential Definition	NA	NA	NA	NA	NA	NA	NA
Office Paper Definition	NA	NA	NA	NA	NA	NA	NA
Mixed MSW	NA	NA	NA	NA	NA	NA	NA

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

**Exhibit C-2**  
**GHG Emissions for Recycling**  
**(MTCE/Ton of Material Recovered)**

(a)	(b)	(c)	(d)	(e)	(f)
Material	Recycled Input Credit*: Process Energy	Recycled Input Credit*: Transportation Energy	Recycled Input Credit*: Process Non- Energy	Forest Carbon Sequestration	(f = b + c + d + e) GHG Reductions From Using Recycled Inputs Instead of Virgin Inputs
Aluminum Cans	-2.92	-0.14	-1.05	0.00	-4.11
Steel Cans	-0.48	-0.01	0.00	0.00	-0.49
Glass	-0.03	0.00	-0.04	0.00	-0.08
HDPE	-0.34	0.00	-0.04	0.00	-0.38
LDPE	-0.43	0.00	-0.04	0.00	-0.47
PET	-0.40	0.00	-0.02	0.00	-0.42
Corrugated Cardboard	0.04	-0.01	0.00	-0.73	-0.71
Magazines/Third-class Mail	0.00	0.00	0.00	-0.73	-0.74
Newspaper	-0.21	-0.01	0.00	-0.73	-0.95
Office Paper	0.06	0.00	0.00	-0.73	-0.68
Phonebooks	-0.18	0.00	0.00	-0.73	-0.91
Textbooks	-0.01	0.00	0.00	-0.73	-0.75
Dimensional Lumber	0.02	0.00	0.00	-0.69	-0.67
Medium-density Fiberboard	0.01	0.00	0.00	-0.69	-0.67
Mixed Paper					
Broad Definition	0.08	-0.02	0.00	-0.73	-0.67
Residential Definition	0.08	-0.02	0.00	-0.73	-0.67
Office Paper Definition	-0.08	-0.02	0.00	-0.73	-0.83

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

\*Material that is recycled after use is then substituted for virgin inputs in the production of new products. This credit represents the difference in emissions that results from using recycled inputs rather than virgin inputs. The credit accounts for loss rates in collection, processing, and remanufacturing. Recycling credit is based on a weighted average of closed- and open-loop recycling for mixed paper. All other estimates are for closed-loop recycling.

**Exhibit C-3**

**Net GHG Emissions from Composting  
(In MTCE Per Short Ton of Yard Trimmings Composted)**

<b>Emission/ Storage Factor (for 2010)</b>					
Soil Carbon Restoration			Increased Humus Formation	Transportation Emissions	Net Carbon Flux
Unweighted	Proportion of C that is not passive	Weighted estimate			
-0.04	48%	-0.02	-0.05	0.01	-0.05

**Exhibit C-4**

**Gross Emissions of GHGs from MSW Combustion (MTCE/Ton)**

(a)	(b)	(c)	(d)	(e)
<b>Material Combusted</b>	<b>Combustion CO<sub>2</sub> Emissions From Non-Biomass Per Ton Combusted</b>	<b>Combustion N<sub>2</sub>O Emissions Per Ton Combusted</b>	<b>Transportation CO<sub>2</sub> Emissions Per Ton Combusted</b>	<b>(e = b + c + d) Gross GHG Emissions Per Ton Combusted</b>
Aluminum Cans	0.00	0.00	0.01	0.01
Steel Cans	0.00	0.00	0.01	0.01
Glass	0.00	0.00	0.01	0.01
HDPE	0.76	0.00	0.01	0.77
LDPE	0.76	0.00	0.01	0.77
PET	0.56	0.00	0.01	0.56
Corrugated Cardboard	0.00	0.01	0.01	0.02
Magazines/Third-class Mail	0.00	0.01	0.01	0.02
Newspaper	0.00	0.01	0.01	0.02
Office Paper	0.00	0.01	0.01	0.02
Phonebooks	0.00	0.01	0.01	0.02
Textbooks	0.00	0.01	0.01	0.02
Dimensional Lumber	0.00	0.01	0.01	0.02
Medium-density Fiberboard	0.00	0.01	0.01	0.02
Food Discards	0.00	0.01	0.01	0.02
Yard Trimmings	0.00	0.01	0.01	0.02
Mixed MSW	0.10	0.01	0.01	0.12
Carpet	0.47	0.00	0.01	0.48
Personal Computers	0.75	0.00	0.01	0.76

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

Note that Exhibits 6-1, 6-2, and 6-5 show coated paper but not mixed paper;

mixed paper is shown in the summary exhibit (Exhibit 6-6).

The summary values for mixed paper are based on the proportions of the four paper types (newspaper, office paper, corrugated cardboard, and coated paper) that comprise the different "mixed paper" definitions. The values for phone books and textbooks are proxies, based on newspaper and office paper, respectively.

**Exhibit C-5**  
**Net GHG Emissions from Landfilling**

(a)  Material	(b) Net GHG Emissions from CH <sub>4</sub> Generation (MTCE/Wet Ton)				(c)  Net Carbon Storage (MTCE/Wet Ton)	(d)  GHG Emissions From Transportation (MTCE/Wet Ton)	(e) (e = b + c + d) Net GHG Emissions from Landfilling (MTCE/Wet Ton)			
	Landfills Without LFG Recovery	Landfills With LFG Recovery and Flaring	Landfills With LFG Recovery and Electric Generation	Year 2000 National Average			Landfills Without LFG Recovery	Landfills With LFG Recovery and Flaring	Landfills With LFG Recovery and Electric Generation	Year 2000 National Average
Aluminum Cans	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Steel Cans	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Glass	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
HDPE	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
LDPE	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
PET	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Corrugated Cardboard	0.48	0.12	0.06	0.29	-0.22	0.01	0.27	-0.09	-0.15	0.08
Magazines/Third-class Mail	0.26	0.07	0.03	0.16	-0.29	0.01	-0.02	-0.21	-0.25	-0.12
Newspaper	0.23	0.06	0.03	0.14	-0.36	0.01	-0.12	-0.29	-0.32	-0.21
Office Paper	1.09	0.27	0.14	0.66	-0.04	0.01	1.05	0.24	0.10	0.62
Phonebooks	0.23	0.06	0.03	0.14	-0.36	0.01	-0.12	-0.29	-0.32	-0.21
Textbooks	1.09	0.27	0.14	0.66	-0.04	0.01	1.05	0.24	0.10	0.62
Dimensional Lumber	0.15	0.04	0.02	0.09	-0.21	0.01	-0.04	-0.16	-0.18	-0.10
Medium-density Fiberboard	0.15	0.04	0.02	0.09	-0.21	0.01	-0.04	-0.16	-0.18	-0.10
Food Discards	0.30	0.08	0.04	0.18	-0.02	0.01	0.29	0.06	0.03	0.17
Yard Trimmings	0.17	0.04	0.02	0.10	-0.21	0.01	-0.03	-0.15	-0.18	-0.09
Grass	0.19	0.05	0.02	0.12	-0.12	0.01	0.09	-0.06	-0.08	0.01
Leaves	0.15	0.04	0.02	0.09	-0.39	0.01	-0.23	-0.34	-0.36	-0.29
Branches	0.15	0.04	0.02	0.09	-0.21	0.01	-0.04	-0.16	-0.18	-0.10
Mixed Paper										
Broad Definition	0.53	0.13	0.07	0.32	-0.23	0.01	0.31	-0.08	-0.15	0.10
Residential Definition	0.49	0.12	0.06	0.29	-0.24	0.01	0.26	-0.10	-0.16	0.07
Office Paper Definition	0.58	0.15	0.07	0.35	-0.21	0.01	0.38	-0.05	-0.12	0.15
Mixed MSW	0.26	0.06	0.03	0.16	-0.10	0.01	0.17	-0.02	-0.06	0.07

Note that totals may not add due to rounding, and more digits may be displayed than are significant.