ROADMAP FROM THE 3RD EDITION OF THE REPORT

Since the release in 2006 of the 3rd edition of the *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks* Report*,* numerous adjustments and improvements have been made to the underlying data and methodology supporting the life-cycle emission factors used by the EPA in the Waste Reduction Model (WARM). This document provides a brief explanation of the changes made to the underlying data and provides details on the latest emission factors used by EPA.

All of the listed "Changes Made Between the 3rd Edition of the Report and October, 2010 (Version 11)" are also reflected in the latest version of the Recycled Content (ReCon) Tool,[1] Individual Waste Reduction Model (iWARM),[2] and SMART BET.[3] However, subsequent changes listed in "Annual Changes in WARM Version 12" and "Changes Made in 2011 for WARM Version 12" have not been implemented in other EPA tools including ReCon, iWARM, and SMART BET.

Additional details on these changes can be found in the supporting documents on the various material types and waste management options analyzed by EPA.[4]

Changes Made Between the 3rd Edition of the Report and October, 2010 (WARM Version 11)

The primary changes and improvements to the life-cycle analysis since the 3rd edition of the report include the following:

Overarching Changes

- Since the 3rd edition, EPA has decided to restructure the life-cycle emission factor documentation. As of October, 2010, the resulting documentation is now composed of individual chapters on each material type and waste management practice that EPA has analyzed.[5] This option is more suited to the model structure and allows for easier updating in the future than the previous hard copy report structure. The new documentation will be updated to reflect the regular annual updates made to WARM (see section on "Annual Updates" below), as well as other changes and improvements made to the model.

- New GHG equivalencies were added to show the change in emissions calculated by the user in terms of gallons of gasoline, cylinders of propane, railway cars of coal, as a percentage of the annual CO_2 emissions from the U.S. transportation sector, and as a percentage of the annual CO_2 emissions from the U.S. electricity sector. All the GHG equivalencies were updated to match EPA's GHG Equivalency Calculator. [6]

- EPA modified the interface to display results in metric tons of carbon dioxide equivalent ($MTCO_2E$) as the default unit for GHG emissions, but results are still available in units of metric tons of carbon equivalent (MTCE).

- The 1605(b) functionality in the Excel version of WARM was removed because 1605(b) no longer supports the reporting of savings from waste reduction.

---

[1] Available online at http://www.epa.gov/climatechange/wycd/waste/tools.html
[2] Available online at http://www.epa.gov/osw/conserve/tools/iwarm/
[3] Available online at http://www.epa.gov/osw/conserve/tools/payt/tools/smart-bet/
[4] Available online at http://www.epa.gov/climatechange/wycd/waste/SWMGHGreport.html
[5] Available online at http://www.epa.gov/climatechange/wycd/waste/SWMGHGreport.html
[6] Available online at http://www.epa.gov/cleanenergy/energy-resources/calculator.html

Changes affecting Material Types

- New emission factors were added for six construction and demolition (C&D) materials: asphalt concrete, asphalt shingles, drywall, fiberglass insulation, vinyl flooring, and wood flooring.

- Emission factors for tires were updated: the tire recycling pathway now encompasses ground and shredded rubber applications and no longer includes retreading as a recycling application. This change has decreased the overall net benefit of recycling scrap tires.

- The non-biogenic carbon content of mixed MSW was updated using annual waste disposal data from EPA's *Municipal Solid Waste in the United States, 2008 Facts and Figures* and *BioCycle's* "State of Garbage in America" 2008 report.

- The characterization of the municipal waste stream was updated based on the *Municipal Solid Waste in the United States,* 2008 *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).

- The material type "corrugated cardboard" was renamed to "corrugated containers" to eliminate redundancy of the former naming convention.

Changes affecting Waste Management Options

- The latest statistics from 2008 on national average electricity generation fuel mix, transmission and distribution losses, coal weighting for electricity generation, and generation per fuel type were added from the EIA's, *Annual Energy Review: 2008*.

- The Excel version of WARM now incorporates region-specific electricity grid factors to more accurately model emissions associated with avoided generation of electricity due to landfill gas recovery in the landfilling pathway and waste-to-energy in the combustion pathway. This change increases the flexibility of WARM and allows the user to generate more precise results for their scenario. This functionality is not available in the online version of WARM where the default national average electricity grid mix (i.e., national average) is implicit.

- The Excel version of WARM includes an updated method for estimating the landfill gas collection efficiency, allowing the user to select between three landfill gas collection efficiency scenarios based on specific landfill recovery characteristics: typical operation, worst-case collection, and aggressive gas collection. This change increases the flexibility of WARM and allows the user to generate more precise results for their scenario. This functionality is not available in the online version of WARM where the default national average landfill gas collection scenario (i.e., typical operation) is implicit.

- Statistics on the carbon content of fuels, landfill methane generation distribution (by type of landfill), and landfill gas recovery and flaring rates have been incorporated from EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008*.

- The landfill carbon storage factors were revised to reflect new data from Dr. Mort Barlaz. This change has resulted in decreased carbon storage for grass and increased carbon storage for leaves. It also affects the carbon stored associated with landfilling mixed waste that includes grass and leaves in the mix (e.g., mixed organics).

- Component-specific decay rates were added to the Excel version of WARM for all organic materials to more accurately model the rate at which each material decays within a landfill under given landfill moisture conditions: dry, average, wet, or bioreactor. This change increases

the flexibility of WARM and allows the user to generate more precise results for their scenario. This functionality is not available in the online version of WARM where the default national average landfill moisture conditions (i.e., average) scenario is implicit.

- Transportation energy required by material type is updated with data from the U.S. Census Bureau's 2007 *Commodity Flow Survey*.

- The waste-to-energy combustion pathway energy values (MMBTU) incorporate a revised methodology that considers the ratio of mass burn combustion facilities (17.8%) and the national average electric utility grid combustion efficiency (32%).

- The recycling emission factors for the mixed paper material types were modified to include updated recycled boxboard data.

Changes to the component-specific decay rates and landfill gas collection system efficiency are improvements that most significantly affect EPA's life-cycle emission factors. However, it should be noted that, these two factors aside, the fundamental aspects of the methodology provided in the 3rd edition of the report in 2006 remain unchanged. This Roadmap document is designed to communicate changes in the GHG emission factors that have occurred since the 3rd edition publication.

Annual Changes

Certain updates to underlying WARM data are made annually, and have been implemented in WARM Version 12. These include:

- Assumptions about landfill methane generation are updated based on the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* and EPA's Landfill Methane Outreach Program.

- MSW generation and recovery rates are updated based on the latest *Municipal Solid Waste in the United States, Facts and Figures* report.

- Assumptions about the percent of MSW landfilled and incinerated are updated based on *BioCycle*'s "State of Garbage in America" report.

- The composition of yard waste is updated based on the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.

- Various aspects of the U.S. average electricity mix are updated based on EIA's *Annual Energy Review* and the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.

- State electricity grid emission factors are updated based on the eGRID database.

- GHG equivalencies are updated to match EPA's GHG Equivalency Calculator.

Changes Made for WARM Version 12

Other updates made to WARM since Version 11 include:

- The Excel macro programming in WARM has been removed. The removal of macros does not affect the results or functionality of the tool. All of the energy and emissions (both $MTCO_2E$ and MTCE) results are displayed automatically (previously, the user could choose which to display).

- The emission factor for the broadloom carpet recycling pathway was updated to include two new plastic resin components. These were based on input and data from Dr. Matthew Realff of the Georgia Institute of Technology, which were informed by the 2009 Carpet America Recovery Effort (CARE) 2009 annual report.

- The energy content of broadloom carpet was updated to incorporate more recent data provided by Dr. Matthew Realff of Georgia Institute of Technology, which were informed by the 2009 Carpet America Recovery Effort (CARE) 2009 annual report.

- Revised the emission factors for three plastics: high-density polyethylene (HDPE), low-density polyethylene (LDPE), and polyethylene terephthalate (PET).

- Developed emission and energy factors for four new plastics to add to the model: Linear low-density polyethylene (LLDPE), polypropylene (PP), polystyrene (PS) and polyvinyl chloride (PVC).

- The "Mixed Recyclables" and "Mixed Plastics" emission and energy factors were updated to remove the inclusion of LDPE as a recycled plastic type. Previously, these factor incorporated LDPE, but updated data for recycling LDPE plastic were unavailable.

- The "Mixed Recyclables" and "Mixed Plastics" emission and energy factors were updated to reflect revisions to the underlying numbers in the virgin and recycled HDPE and PET emission factors.

- The emission and energy factors for aluminum cans were updated based on life-cycle data from the Aluminum Association. In addition, new emission and energy factors for aluminum ingot were developed.

- The emission and energy factors for polylactide (PLA), a biopolymer, were developed using life-cycle data provided by NatureWorks.