How EPA’s Waste Reduction Model (WARM) Quantifies the Greenhouse Gas Impacts of Organics Management
EPA’s Waste Reduction Model (WARM)

Liz Resek
Chief, Municipal Source Reduction Branch
Office of Resource Conservation & Recovery
US EPA
In 1998, EPA created the Waste Reduction Model (WARM) to help solid waste planners and organizations track and voluntarily report greenhouse gas (GHG) emissions reductions from several different waste management practices.

WARM calculates and totals GHG emissions of baseline and alternative waste management practices—source reduction, recycling, combustion, composting, anaerobic digestion and landfilling.

The model calculates emissions in metric tons of carbon equivalent (MTCE), metric tons of carbon dioxide equivalent (MTCO2E), and energy units (million BTU) across a wide range of material types commonly found in municipal solid waste (MSW).

WARM recognizes 54 materials from paper to plastic to organics.
Waste Reduction Model (WARM)

WARM is a national tool

It is based on data that represents the national average and common practices across the country.

Our waste management categories are not based on any regionally specific practice but rather what best represent the current practices and GHG savings associated with those practices across the country.

We use a life cycle approach for all of our material categories.
WARM Documentation and Website

Documentation Chapters
Any material or waste management option that is modeled in WARN can be found in our chapters.
In each chapter, you will find emission factors, assumptions, limitations, offsets and emissions from acquisition to end of life.

WARM Model History
The most recent versions of WARM can be found at www.epa.gov/WARM.
Each Version includes a paragraph on any major updates that were done from the previous version along with any annual changes that are made.
WARM Organics Update

In recent updates, WARM has expanded its organics section to include
• Food Waste (meat)
• Food Waste (non-meat)
• Mixed Food Waste

As part of these updates, we have expanded the waste management options for organics handling to include
• Source Reduction
• Anaerobic Digestion
• Composting
• Combustion
• Landfilling
Planned Updates

**Organics Module**
A subset of the WARM model that will only covers organic materials and the waste management options associated with it

Users to customize the results to their situation

Food donation will be included
Thank you

Please free to contact Tiffany Kollar with any questions

Kollar.tiffany@epa.gov
703-308-8675
Organic Materials Management in U.S. EPA’s Waste Reduction Model

Bobby Renz
Manager
ICF International

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CHANGING HOW WE THINK ABOUT OUR RESOURCES FOR A BETTER TOMORROW

www.epa.gov/ismm
Outline

- Organic materials and management practices in WARM
- Anaerobic digestion
  - Modelling approach
  - Emissions sources and offsets
  - Results
- Other organics management practices
  - Source reduction
  - Composting
  - Landfilling
- Results comparison – organics management practices
- Food donation
- Organics module
Organics in WARM

• Refers to a group of municipal solid waste (MSW) materials in WARM predominantly derived from plants
• Includes food waste, yard trimmings, and mixed combinations of the two (mixed organics)
• Excludes paper products
• Due to their properties, they have different materials management options compared to other common MSW materials
<table>
<thead>
<tr>
<th>Management Practice</th>
<th>Food Waste</th>
<th>Yard Trimmings</th>
<th>Mixed Organics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Reduction</td>
<td>Modeled specifically for all food waste types</td>
<td>Not modeled – does not apply for yard trimmings</td>
<td></td>
</tr>
<tr>
<td>Anaerobic Digestion</td>
<td>Assuming weighted average food waste properties for all food types</td>
<td>Modeled based on specific properties for grass, leaves, and branches</td>
<td>Weighted average of food waste, grass, leaves, and branches</td>
</tr>
<tr>
<td>Composting</td>
<td>Assuming weighted average food waste properties for all food types</td>
<td>Assuming weighted average green waste properties</td>
<td>Weighted average of food waste and yard trimmings</td>
</tr>
<tr>
<td>Combustion</td>
<td>Assuming weighted average food waste properties for all food types</td>
<td>Assuming weighted average green waste properties</td>
<td>Weighted average of food waste and yard trimmings</td>
</tr>
<tr>
<td>Landfilling</td>
<td>Assuming weighted average food waste properties for all food types</td>
<td>Modeled based on specific properties for grass, leaves, and branches</td>
<td>Weighted average of food waste and yard trimmings</td>
</tr>
<tr>
<td>Donation</td>
<td>In development; guidance available to estimate avoided landfilling</td>
<td>Not modeled – does not apply for yard trimmings</td>
<td></td>
</tr>
</tbody>
</table>
# Organic Materials in WARM

<table>
<thead>
<tr>
<th>Material Name</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Waste</td>
<td>Weighted average of beef, poultry, grains, bread, fruits and vegetables, and dairy products</td>
</tr>
<tr>
<td>Food Waste (non-meat)</td>
<td>Weighted average of grains, fruits and vegetables, and dairy products</td>
</tr>
<tr>
<td>Food Waste (meat only)</td>
<td>Weighted average of beef and poultry</td>
</tr>
<tr>
<td>Beef</td>
<td></td>
</tr>
<tr>
<td>Poultry</td>
<td>Assumes broiler chicken</td>
</tr>
<tr>
<td>Grains</td>
<td>Weighted average of corn, wheat, and rice</td>
</tr>
<tr>
<td>Bread</td>
<td>Assumes wheat grain</td>
</tr>
<tr>
<td>Fruits and Vegetables</td>
<td>Weighted average of potatoes, tomatoes, citrus, melons, apples and bananas</td>
</tr>
<tr>
<td>Dairy Products</td>
<td>Weighted average of dairy products</td>
</tr>
<tr>
<td>Yard Trimmings</td>
<td>Weighted average of grass, leaves, and branches</td>
</tr>
<tr>
<td>Grass</td>
<td></td>
</tr>
<tr>
<td>Leaves</td>
<td></td>
</tr>
<tr>
<td>Branches</td>
<td></td>
</tr>
<tr>
<td>Mixed Organics</td>
<td>Weighted average of food waste and yard trimmings</td>
</tr>
</tbody>
</table>

**CHANGING HOW WE THINK ABOUT OUR RESOURCES FOR A BETTER TOMORROW**
Anaerobic Digestion – Introduction

• Added this spring as part of WARM v14
• An anaerobic digestion (AD) facility generates biogas via the anaerobic degradation of organic materials in an engineered environment
• Degradable materials are digested in a reactor in the absence of oxygen to produce biogas that is 50-70% methane (with the rest mainly CO$_2$)
• Resulting solid and liquid digestates must be recovered or treated
Challenges to Modeling AD

• AD is a rapidly growing materials management practice making it difficult to model current national average practices
• Biogas can beneficially utilized in different ways
  – Burned on-site for electricity and/or heat generation
  – Upgraded to vehicle fuel
  – Upgraded to pipeline-quality natural gas
• Resulting solid and liquid digestates must be recovered or treated
• Numerous possible configurations of AD facilities
  – Standalone vs. co-digestion options
  – Wet systems vs. dry systems
Modeling Approach

- Model developed by Dr. Morton Barlaz and Dr. James Levis, North Carolina State University, adapted from SWOLF model
Modeling Approach

• Two digester configuration options modeled
  • Wet digester
    – Continuous, single-stage, mesophilic digester
    – Accepts only food waste materials in WARM
  • Dry digester
    – Single-stage, mesophilic digester
    – Accepts all organic materials in WARM (food waste, yard trimmings, mixed organics)
• Two digestate treatment options:
  – Aerobic curing before land application (default)
  – Direct land application without curing
AD Energy & Emissions Sources & Offsets

• Transport of materials
• Preprocessing and digester operations
• Biogas collection and utilization
• Curing and land application
• Fugitive CH$_4$ and N$_2$O emissions
• Carbon storage after land application
• Avoided fertilizer offsets
• Net electricity offsets (adjustable for regional electricity grid)
Results – Wet Digester

Greenhouse Gas Emissions (MTCO2e/short ton)

- Transportation Energy
- Process Non-Energy
- Soil carbon storage
- Avoided Fertilizer Application
- Avoided Utility Emissions
- Process Energy
- Net Emissions

Food Waste - Curing
Food Waste - Direct Application

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## AD Results

### Net Greenhouse Gas Emissions – MTCO$_2$e/short ton

<table>
<thead>
<tr>
<th>Material</th>
<th>Wet Digestion – Curing</th>
<th>Wet Digestion – Direct Application</th>
<th>Dry Digestion – Curing</th>
<th>Dry Digestion – Direct Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Waste</td>
<td>-0.06</td>
<td>-0.14</td>
<td>-0.05</td>
<td>-0.11</td>
</tr>
<tr>
<td>Yard Trimmings</td>
<td>NA</td>
<td>NA</td>
<td>-0.09</td>
<td>-0.35</td>
</tr>
<tr>
<td>Grass</td>
<td>NA</td>
<td>NA</td>
<td>0.00</td>
<td>-0.06</td>
</tr>
<tr>
<td>Leaves</td>
<td>NA</td>
<td>NA</td>
<td>-0.14</td>
<td>-0.53</td>
</tr>
<tr>
<td>Branches</td>
<td>NA</td>
<td>NA</td>
<td>-0.23</td>
<td>-0.73</td>
</tr>
<tr>
<td>Mixed Organics</td>
<td>NA</td>
<td>NA</td>
<td>-0.07</td>
<td>-0.22</td>
</tr>
</tbody>
</table>

### Net Energy – MMBtu/short ton

<table>
<thead>
<tr>
<th>Material</th>
<th>Wet Digestion – Curing</th>
<th>Wet Digestion – Direct Application</th>
<th>Dry Digestion – Curing</th>
<th>Dry Digestion – Direct Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Waste</td>
<td>-1.40</td>
<td>-1.44</td>
<td>-1.52</td>
<td>-1.53</td>
</tr>
<tr>
<td>Yard Trimmings</td>
<td>NA</td>
<td>NA</td>
<td>-0.21</td>
<td>-0.21</td>
</tr>
<tr>
<td>Grass</td>
<td>NA</td>
<td>NA</td>
<td>-0.20</td>
<td>-0.21</td>
</tr>
<tr>
<td>Leaves</td>
<td>NA</td>
<td>NA</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Branches</td>
<td>NA</td>
<td>NA</td>
<td>-0.41</td>
<td>-0.46</td>
</tr>
<tr>
<td>Mixed Organics</td>
<td>NA</td>
<td>NA</td>
<td>-0.88</td>
<td>-0.90</td>
</tr>
</tbody>
</table>
Food Waste Source Reduction in WARM

- Modeled in detail for all food waste materials (beef, poultry, grains, bread, fruits and vegetables, dairy products)
- Not applicable for yard trimmings
- Quantifies the energy and emissions avoided by preventing the production of different food products
- Energy and emissions offsets:
  - Energy from raw material acquisition and manufacturing processes
  - Transportation energy
  - Non-energy emissions (e.g., refrigerants, enteric fermentation from livestock)
**Composting Organics in WARM**

- Modeled for food waste, yard trimmings, mixed organics, and PLA
- Energy and emissions sources:
  - Transport to composting facility
  - Equipment use
  - Fugitive CH$_4$ and N$_2$O emissions
- Emissions offsets
  - Soil carbon storage after land application
- Uses same soil carbon storage model and assumptions as for land application of AD digestate
Landfilling Organics in WARM

- Modeled for all materials
- User options for landfill gas recovery and moisture conditions
- Energy and emissions sources:
  - Transport to landfill
  - Equipment use
  - Landfill CH$_4$ emissions
- Emissions offsets
  - Landfill carbon storage
- Net electricity offsets (adjustable for regional electricity grid)
- Uses same material properties and electricity offset assumptions as for AD
Organics Results – With Source Reduction

- Source Reduction
- Composting
- Landfilling
- AD - Wet, curing
- AD - Wet, direct application
- AD - Dry, curing
- AD - Dry, direct application

Greenhouse Gas Emissions (MTCO2e/short ton)

- Food Waste
- Yard Trimmings
- Mixed Organics

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Food Donation

• Not currently modeled as a separate management practice in WARM
• Differs from source reduction – management of existing food materials rather than avoiding food production
• EPA has prepared a guidance document: “Modeling Food Donation Benefits in EPA’s Waste Reduction Model”
• Document provides a method for estimating avoided landfilling impacts from food donation
• Accounts for losses during food donation process
• Temporary option until donation can be modeled in more detail
Next Steps – Organics Module

• Currently under development
• Separate, stand-alone tool that will only include organic materials and relevant pathways
• Redesigned interface focused on organic materials
• Food donation explicitly modeled
• Additional user inputs for AD and other management practices
Organics Module – Potential Features

• Additional user inputs for AD under consideration
  – Impacts from co-digestion (e.g., heat used at wastewater treatment facility)
  – Other biogas uses (e.g., upgrade to pipeline-quality natural gas)
  – Other digestate uses

• Food donation modeled
  – Use data from major food banks to model national average practices
  – Quantify emissions savings by donating food
  – Capture differences by donated food source (restaurants, grocery stores, farms)
  – Account for transport, storage, and losses during the process

• Composting – reassess potential for avoided synthetic fertilizer offset
Questions?

Bobby Renz
ICF International
Bobby.Renz@icfi.com

Tiffany Kollar
U.S. EPA
Kollar.Tiffany@epa.gov

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Key Parameter for AD – Methane Yield

• Most critical input value
• Literature review showed food waste methane generation can range from approximately 200 to 600 m$^3$ CH$_4$/dry metric ton; mean value of 360 m$^3$ CH$_4$/dry metric ton
• WARM uses the following methane yields:
  – Food waste: 369 m$^3$ CH$_4$/dry metric ton, adjusted from mean value in literature based on stakeholder input
  – Yard trimmings: ranges from 65 m$^3$ CH$_4$/dry metric ton for leaves to 195 m$^3$ CH$_4$/dry metric ton for grass
• Results modeled for low- and high-methane yield for food waste to test sensitivity
  – Low methane yield decreased net emissions savings by 53%
  – High methane yield increased net emissions savings by 68%
AD – Key Assumptions

- Yard trimmings are assumed to be co-digested with food waste and not digested alone in dry digester.
- Feedstocks are pre-processed (e.g., grinding, screening, mixing) and fed to the reactor.
- Biogas is combusted in an internal combustion engine to generate electricity. Small percent of methane assumed leaked and some flared during engine downtime.
- Heat from the engine is recovered to heat the reactor and the net electricity generated is exported to the electrical grid to offset fossil electricity generation.
- Digestate is dewatered and the liquids are recovered and returned to the reactor in the wet digester.
- Model includes default with aerobically curing of solids in turned windrows, followed by compost screening, transport to agricultural fields, and application to land.
- A nitrogen fertilizer offset is included. It is not currently included for composting pathway in WARM because food waste is the primary feedstock for AD, and it contains significant nitrogen.
- Process model is black-box with respect to reactor configuration (i.e., microbial kinetics not explicitly modeled).