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# Reducing Greenhouse Gas Emissions through Recycling and Composting

A Report by the Materials Management Workgroup of the West Coast Climate and Materials Management Forum

May 2011

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## Acknowledgements

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## Table of Contents



## List of Figures and Tables

# Introduction

> **"Materials management is an approach to serving human needs by using and reusing resources most productively and sustainably throughout their life cycles, minimizing the amount of materials involved and all the associated environmental impacts."**
>
> *– Definition adapted from "Sustainable Materials Management: The Road Ahead" (U.S. EPA 2009)*

The West Coast Climate and Materials Management Forum, an EPA-led partnership of western local, state, and tribal governments, established a Materials Management & Product Stewardship Workgroup to identify key materials management strategies that could be used by local governments to reduce greenhouse gas (GHG) emissions in the near term.

The workgroup began by focusing on the life-cycle impacts of materials currently being disposed in landfills and the GHG emissions reductions that are possible by diverting discarded materials from landfills through recycling and composting. Although additional materials management approaches, including reuse, remanufacturing, source reduction, material reduction/substitution, environmentally preferable purchasing, upstream design and manufacturing changes, also promise significant emissions reductions, the scope of this paper is limited to evaluating only recycling and composting. Future Workgroup projects will focus more on the emissions reduction potential of these other approaches.

## Purpose of the Report

This report is intended to help governments and other organizations make informed and strategic decisions about how to direct their limited resources toward end-of-life management of materials that provides the most significant impact on life-cycle greenhouse gas emissions. The report also provides rationale, from a climate action, economic and pollution prevention perspective, for local jurisdictions to adopt and implement recycling and composting initiatives in their communities.

We hope this report continues to build a unified intellectual foundation from which to consider climate change in a materials management context. We also hope it opens opportunities for strategic regional cooperation to improve materials management approaches to reduce emissions attributable to goods and food throughout their life cycle.

## Report Summary

The analysis uses the U.S. EPA's Waste Reduction Model (WARM) Calculator to estimate the GHG emissions attributable to materials in the waste streams of California, Oregon, and Washington, and to identify the materials with the greatest emissions reduction potential if recycled or composted rather than landfilled.

This report draws on the WARM results to highlight ten materials, broken into four priority material types with the greatest emissions reduction potential (presented alphabetically):

- Carpet
- Core Recyclables
  - Corrugated containers
  - Office paper
  - Aluminum cans
  - Newspaper
  - Magazines
  - PET and HDPE (or mixed plastics)
  - Steel cans
- Dimensional Lumber
- Food Scraps

**Section 1** of this report outlines the objective and rationale for our analysis.

**Section 2** describes the research design and methodology used, including a brief introduction to the WARM Calculator and how it can be used.

**Section 3** presents the findings of our analysis for each state and across the three states.

**Section 4** discusses the implications of our analysis and describes how the results relate to local and state policy goals for emissions reductions.

**Section 5** highlights additional benefits of recycling and composting these priority materials, including job creation, economic development, and reduced land and marine pollution.

**Section 6** briefly describes opportunities for reducing emissions through recycling/composting of our four priority material types.

**Section 7** provides summary reflections and concludes with comments about how the Materials Management workgroup will explore ways to further reduce life-cycle emissions of materials through research on additional sustainable materials management practices.

## Section 1. Objectives and Rationale for Our Project

Traditional, sector-based accounting of GHG emissions obscures the importance of materials management in addressing global climate change. Figure 1 depicts a typical accounting of GHG emissions, attributing the majority of impacts to the industrial, transportation, and electric power sectors.[1] In this accounting, methane emissions generated by landfills (included under the Commercial sector) account for 1.8% of total U.S. GHG emissions. While the sector-based approach is useful for highlighting opportunities for end-of-pipe emissions reduction strategies, this accounting fails to illustrate the emissions associated with the life cycles of materials and land management practices.

In a September 2009 report, *Opportunities to Reduce Greenhouse Gas Emissions through Materials and Land Management Practices*, the U.S. EPA employed a systems-based accounting method to categorize U.S. GHG emissions. Figure 2 depicts the EPA's approach.[2] The systems-based accounting reveals that 42% of emissions result from materials management, *i.e.* the extraction of natural resources, and production, transport and disposal of food and goods.[3]

**Figure 1**

**Sector-based accounting of U.S. GHG Emissions**

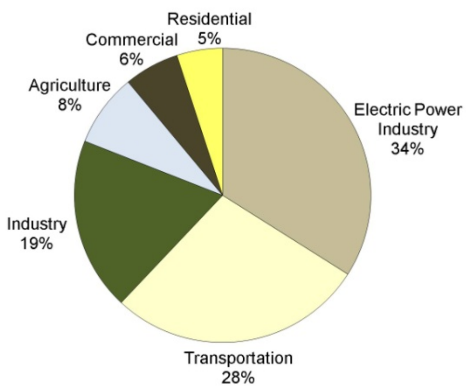
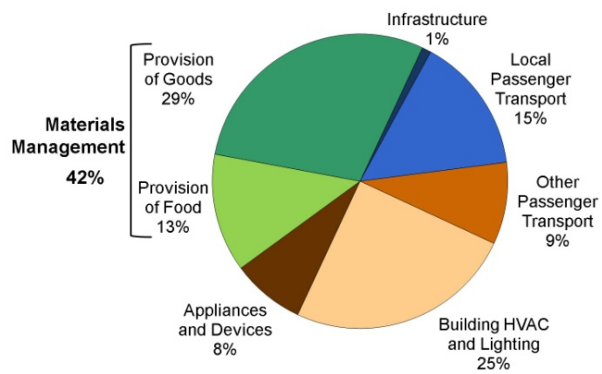



**Figure 2**

**Systems-based accounting of US GHG Emissions**




Expanding the scope of the EPA's report, the Product Policy Institute took EPA's National Emissions Inventory (NEI), subtracted out the emissions associated with exports and added in emissions associated with imports to the US. This provides a more accurate view of the emissions associated with goods used in the US. Under this global view of emissions associated with the US economy, overall GHG emissions are 12% higher than domestic emissions, and 44% of the total are associated with the production, transport, and end-of-life management of non-food materials alone.[4]

[1] *U.S. Inventory of GHG Emissions and Sinks: 1990-2006* (US EPA, 2008).

[2] *Opportunities to Reduce GHG Emissions through Materials and Land Management Practices* (US EPA, 2009).

[3] This percentage only accounts for emissions associated with domestic production. The figure would be much larger if it also measured emissions from the international production of goods that are consumed in the U.S.

[4] Joshua Stolaroff, *Products, Packaging, and US Greenhouse Gas Emissions* (Product Policy Institute, 2009).

Current trends in production, consumption, and waste management have led to enormous emissions of heat-trapping greenhouse gases. The sources of such emissions are numerous, ranging from carbon dioxide released during the extraction and production of new materials to methane from the decomposition of organic waste in landfills.

Although the direct GHG emissions reductions achieved by landfill diversion are limited, the potential upstream impacts are much higher, if the end-of-life strategies used are able to reduce future emissions generated through the provision of goods and food. For example, diversion of aluminum from landfills for recycling offers minimal reductions in landfill emissions, but the use of recycled aluminum reduces emissions by reusing the material. The energy input of producing a ton of aluminum, which is directly linked to emissions output, is 96% lower when recycled aluminum is used. This is due to the elimination of the mining and smelting process required for virgin aluminum.[5] Thus, end-of-life materials management strategies such as recycling can lead to significantly lower emissions from early stages in the material life cycle, including material extraction, manufacturing, and distribution.

This report seeks to quantify those potential life-cycle emissions reductions that could be achieved by recycling or composting waste currently being landfilled in California, Oregon, and Washington. By identifying the materials with the greatest emissions reduction potential, the analysis reveals that some of these emission reductions can be achieved in the short term through existing recycling infrastructure, while others will require new infrastructure and programs to divert these priority materials from disposal.

## Section 2. Research Design and Methodology

Our analysis uses recent, state-level waste characterization data from California, Oregon, and Washington.[6,7,8] It is important to note that the this analysis uses data on the amount of materials currently being disposed of and does not analyze the emissions reductions of materials already being diverted from disposal. While it is possible to estimate the emissions reductions from existing recycling and composting programs, the goal of this report is to identify the additional emissions reduction potential possible through recycling and composting materials still being discarded as waste, so only data on materials currently disposed are included. To identify the top ten materials by emissions reduction potential based on quantity of material available for recovery, we used the Waste Reduction Model (WARM) created by the U.S. Environmental Protection Agency (EPA).

The EPA created WARM to help solid waste planners and organizations estimate greenhouse gas (GHG) emission reductions from several different waste management practices. WARM is available as a Web-based calculator format and as a Microsoft Excel© spreadsheet. Both versions of WARM are available on the EPA's Web site.[9]

WARM calculates GHG emissions based on a comparison of a baseline and alternative waste

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[5] *Tellus Institute Packaging Study* (Tellus Institute, 1992).

[6] *California 2008 Statewide Waste Characterization Study* (Cascadia Consulting Group for CIWMB, 2009).

[7] *2009/2010 Waste Composition Study: Preliminary* (Oregon Department of Environmental Quality, 2010).

[8] *2009 Washington Statewide Waste Characterization Study* (Cascadia Consulting Group for WA Department of Ecology, 2010).

[9] http://www.epa.gov/WARM

management practice, including source reduction, recycling, combustion, composting, and landfilling. The model calculates emissions in metric tons of carbon equivalent (MTCE) or metric tons of carbon dioxide equivalent (MTCO2E) across a wide range of material types commonly found in municipal solid waste (MSW). WARM users can construct various scenarios by simply entering data on the amount of waste handled by material type and by management practice. WARM then automatically applies material-specific emission factors for each management practice to calculate the GHG emissions and energy use of each scenario.

Several key inputs, such as landfill gas recovery practices and transportation distances to MSW facilities, can be modified by the user. For this analysis, estimated tons of materials disposed, drawn from each state's waste characterization study, were entered into the WARM Calculator. The WARM Calculator quantified the GHG emissions reductions comparing two waste management scenarios: 1) all of the materials are deposited in landfills; and 2) all of the materials are instead recycled or composted. Although a small amount of waste disposed of in California, Oregon and Washington is incinerated, the large majority is disposed of in landfills, making this a reasonable, simplifying assumption.

The emissions reduction potential of recycling or composting the materials disposed of in each state was then ranked from highest to lowest and results from all three states were then compared.

The resulting list of priority materials includes the top ten materials from each state's list. For all other WARM inputs, the default settings were used. This includes whether Landfill Gas (LFG) control systems are in place, what percentage of methane is captured, whether collected methane is flared or recovered for energy, and the assumed moisture conditions and associated bulk decay rate of disposed waste, (all of which affect the rate of methane emissions from landfills), as well as the assumed transport distances for landfilling, recycling, and composting, which affect the emissions associated with these various end-of-life management options.[10,11]

Several difficulties persist for the accurate comparison of state waste measurements. First, waste policies differ across states and localities, leading to differences in the types of materials collected. Second, how waste characterization studies define material categories and gather data varies across states. For instance, California and Washington specify plastic by polymer type (i.e. PET, HDPE, etc.), while Oregon specifies it by container type (i.e. bottle, tub) and by whether it is accepted in curbside recycling programs. Both Oregon and Washington specify 15 different types of paper, broken into "packaging" and "non-packaging" subcategories, while California lumps these together and includes fewer categories altogether. Even the 15 paper types differ somewhat between Oregon and Washington, frustrating comparisons. Third, the categories and definitions included in the WARM Calculator do not always correspond with state waste characterization studies. WARM users face the challenge of reconciling their materials category definitions with those the model employs. Our reconciling of categories for this analysis is presented in Appendix A.

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[10] The WARM Calculator allows users to customize a number of settings that affect the emissions associated with end-of-life management options. These include whether Landfill Gas (LFG) control systems are in place, what percentage of methane is captured, whether collected methane is flared or recovered for energy, the assumed moisture conditions and associated bulk decay rate of disposed waste, and the assumed transport distances for the various end-of-life management scenarios. The default scenario (which is what we used) calculates emissions based on the estimated proportions of landfills with LFG control in 2008.

[11] Transportation distances only affect the model if the transportation required for the alternative scenario is significantly different from the baseline scenario (e.g. recycling means sending materials to a nearby MRF, while landfill disposal requires trucking waste to a landfill hundreds of miles away). However, it is worth noting that most emissions impacts of materials are upstream, and the transportation emissions related to any end-of-life management approach are minimal in comparison.

These discrepancies make it challenging to estimate the emissions reduction opportunities across state and local governments. Nevertheless, we believe that comparing WARM results for California, Oregon, and Washington illustrates the opportunity for a common set of strategies for GHG emissions reduction through recycling and composting in various government arenas. The WARM results, which showed remarkable similarity across the states in terms of materials, appear to support this belief.

# Section 3. Using WARM to Identify Priority Materials

The following section presents the WARM results for each of the three states featured in this report. Despite incongruities between state measures and WARM features, as well as differences between the states themselves, commonalities of top materials with emissions reduction potential among the states are unambiguous. Table 1 identifies the top ten materials with the highest emissions reduction potential for each state. Each state's WARM output is displayed graphically in Figure 3, which show the emissions reduction benefits of recycling the listed materials (or composting, in the case of food scraps), calculated against a baseline emissions scenario in which they are landfilled.

The WARM results suggest that the greatest potential for emissions reduction across all three states can be achieved through better end-of-life management of ten materials, broken into four priority material types:

- Carpet
- Core Recyclables
  - Corrugated containers
  - Office paper
  - Aluminum cans
  - Newspaper
  - Magazines
  - PET and HDPE (or mixed plastics)
  - Steel cans
- Dimensional Lumber
- Food Scraps

Carpet[12], dimensional lumber, and food scraps appear in the top ten for all three states. Six of the seven materials comprising core recyclables also appear on all three lists. Of note among the core recyclables is corrugated containers, or cardboard, which alone constitutes half of the total potential of all core recyclables in California and Oregon and roughly one third of emissions reduction potential of core recyclables in Washington.

There are two factors that determine which materials rank highest in terms of emissions reduction potential: first, the GHG emissions reduction potential of recycling or composting each material on a per ton basis according to WARM; second, the overall tonnage of each material that is disposed,

[12] The waste characterization data used in this analysis provide estimated tonnage for all carpet disposed in each state. However, our emissions factors are for carpet made with nylon fibers only, resulting in some difference in the emissions reduction potential reported here and the actual emissions reduction potential in each state, depending on what proportion of disposed carpet is made with non-nylon fiber. In its 2009 Annual Report, the Carpet America Recovery Effort estimates that 76% of carpet material recycled nationally in 2009 was nylon (49% N6, 27% N66).

relative to the tonnage of other materials disposed in the state. Most of the materials listed above rank high in GHG emissions reduction potential on a per ton basis, even though they make up a relatively small proportion of total waste disposed.

Food scraps are the exception, in that WARM does not assign them a particularly high emissions reduction potential per ton, but they nonetheless appear in the top ten because they make up a significant portion of disposed waste. The per ton emissions factors used in the WARM calculations are listed in Appendix B.

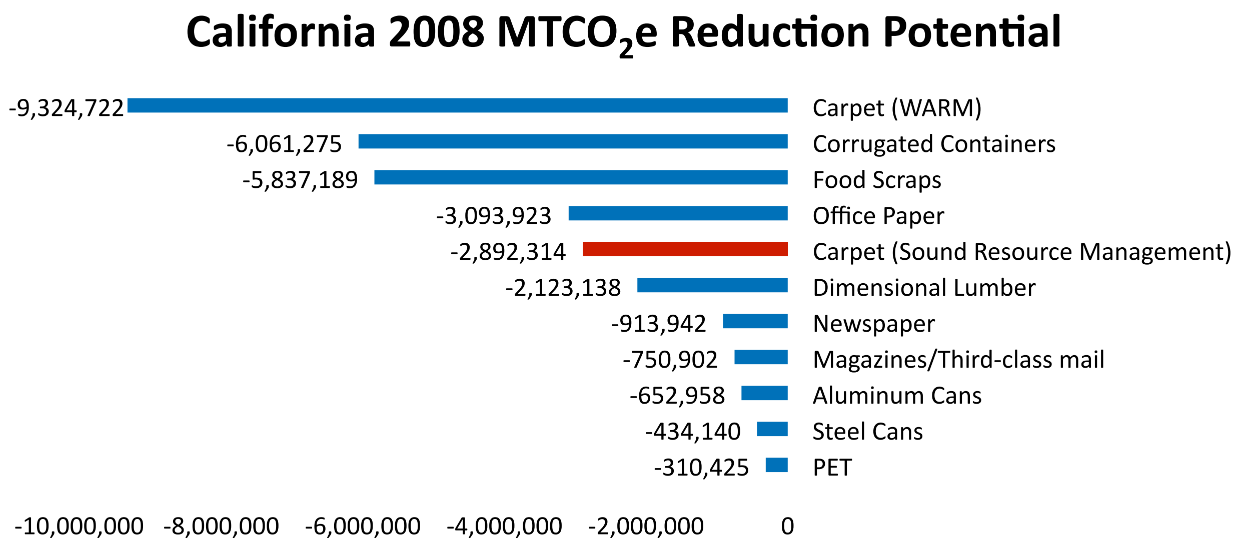
## Table 1: Materials with Highest Potential for GHG Emissions Reduction, by State

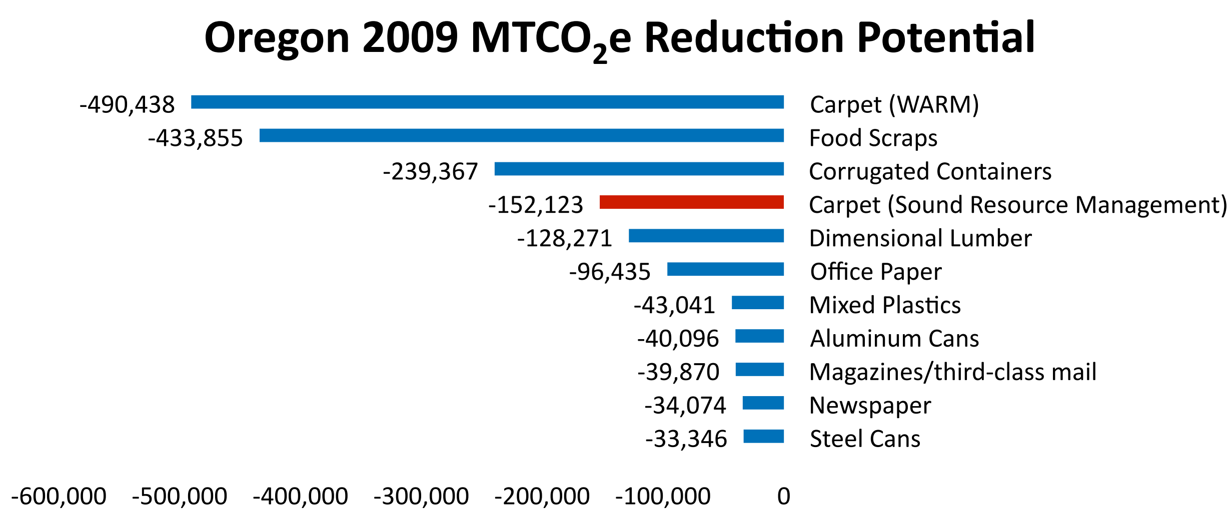
| CALIFORNIA | | | OREGON | | | WASHINGTON | | |
|---|---|---|---|---|---|---|---|---|
| **Material Type** | **Est. Tons** | **$MTCO_2e$ Reduction Potential** | **Material Type** | **Est. Tons** | **$MTCO_2e$ Reduction Potential** | **Material Type** | **Est. Tons** | **$MTCO_2e$ Reduction Potential** |
| **Carpet** (WARM)[13] | **1,285,473** | **9,324,721** | **Carpet** (WARM) | **67,610** | **490,438** | **Carpet** (WARM) | **145,282** | **1,053,864** |
| **Carpet** (Sound Resource Management)[14] | **1,285,473** | **2,892,314** | **Carpet** (Sound Resource Management) | **67,610** | **152,123** | **Carpet** (Sound Resource Management) | **145,282** | **326,885** |
| **Core Recyclables** | **3,904,101** | **12,217,563** | **Core Recyclables** | **180,860** | **526,229** | **Core Recyclables** | **495,334** | **1,616,408** |
| *Aluminum Cans* | *47,829* | *652,958* | *Aluminum Cans* | *2,937* | *40,096* | *Aluminum Cans* | *28,085* | *383,414* |
| *Corrugated Containers* | *1,905,897* | *6,061,274* | *Corrugated Containers* | *75,266* | *239,367* | *Corrugated Containers* | *189,205* | *601,724* |
| *Magazines* | *283,069* | *750,902* | *Magazines* | *15,030* | *39,870* | *Magazines* | *46,149* | *122,420* |
| *Newspaper* | *499,960* | *913,943* | *Newspaper* | *18,640* | *34,074* | *Newspaper* | *82,682* | *151,145* |
| *Office Paper* | *731,298* | *3,093,923* | *Mixed Plastics* | *28,035* | *43,041* | *Office Paper* | *49,667* | *210,128* |
| *PET* | *199,643* | *310,425* | *Office Paper* | *22,794* | *96,435* | *PET* | *48,079* | *74,758* |
| *Steel Cans* | *236,405* | *434,140* | *Steel Cans* | *18,158* | *33,346* | *HDPE* | *51,467* | *72,819* |
| **Dimensional Lumber** | **1,184,375** | **2,123,138** | **Dimensional Lumber** | **71,555** | **128,271** | **Dimensional Lumber** | **51,929** | **93,089** |
| **Food Scraps** | **6,158,120** | **5,837,189** | **Food Scraps** | **457,709** | **433,855** | **Food Scraps** | **920,676** | **872,695** |

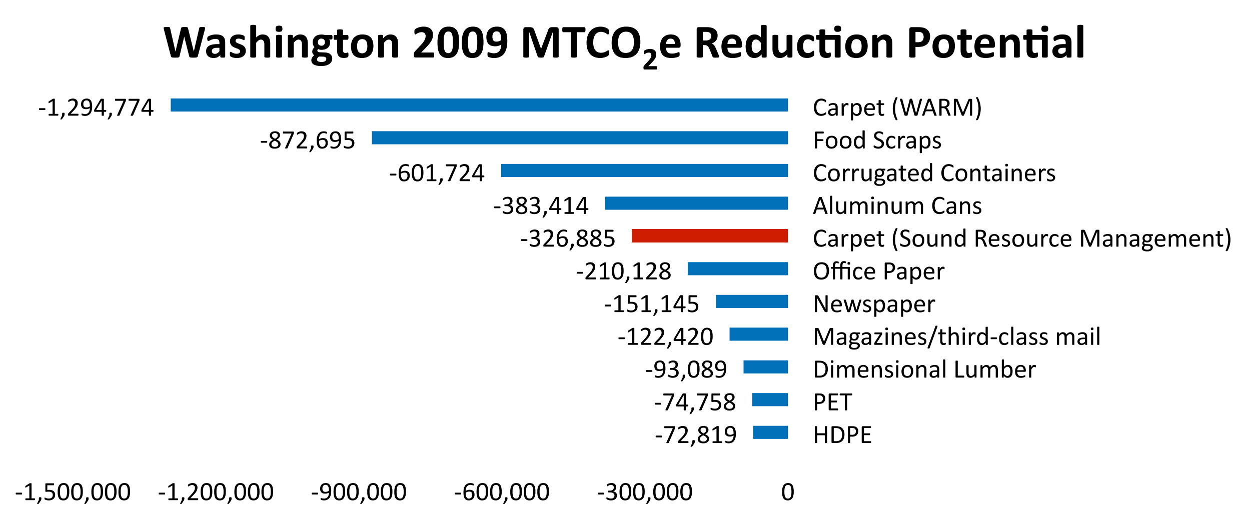
[13] The first estimate of emissions reduction potential for carpet is based on the WARM Calculator factor for open loop recycling of carpet (into carpet pad, molded plastic parts, and carpet tile backing). Because of concerns raised by several members of the Forum about the assumptions on which the emissions factor is based, we also include an estimate of emissions reduction potential for closed loop recycling from Sound Resource Management. For a detailed explanation of the concerns with the WARM factor, see Appendix C.

[14] The second estimate of emissions reduction potential for carpet is based on the emissions factor for recycling carpet into carpet (closed loop recycling) developed by Dr. Jeffrey Morris of Sound Resource Management in a report for Seattle Public Utilities titled, "Environmental Impacts from Carpet Discards Management Methods: Preliminary Results." April 26, 2010.

**Figure 3: Net Annual Emissions Reduction Potential of Recycling and Composting**



# Section 4. Implications for Emissions Reductions and Carbon Offsets

All three West Coast states have set goals for reducing greenhouse gas emissions. Our analysis shows that recycling and composting can produce significant emissions reductions, and are thus compelling tools to include in climate plans. It is worth recognizing that some of the life-cycle emissions for waste disposed in California, Oregon, and Washington that are calculated using WARM are not generated exclusively (or even predominantly) in these states. Emissions from resource extraction, manufacturing and transportation associated with materials used and discarded here sometimes occur outside of the region and would not be captured by most current state GHG inventory methods. To account for boundary issues, alternate methods for conducting inventories are being developed in several jurisdictions, including the State of Oregon and King County (WA), which are developing consumption-based inventories that account for emissions generated outside their boundaries as a result of consumption within their boundaries. The Inventory Workgroup of the West Coast Climate and Materials Management Forum has developed a toolkit for other jurisdictions interested in including consumption-based methods into emissions inventories.[15]

Even in jurisdictions that have not yet adopted consumption-based inventory methods, some GHG emissions associated with materials management, such as from long-distance trucks delivering goods and hauling solid waste out of state, are undoubtedly generated within these states and are included in existing state GHG emissions inventories. In these cases, reductions in these emissions due to recycling and composting would be captured by the states' inventories and contribute toward emissions reduction goals. In addition, methane emissions reductions due to diversion of food scraps would likely be captured, as these emissions are often counted in conventional inventories.

## Emissions Reduction

Diversion of food scraps from landfills offers the greatest quantity of in-state GHG emissions reductions. Food scraps are responsible for a large share of methane emissions generated by landfills, and while landfill emissions comprise only a small portion of life-cycle emissions attributable to goods and food, they nonetheless represent a real opportunity for emissions reduction. This is largely due to the large quantities of food that is wasted and sent to landfills.

According to our analysis, the emissions reduction potential of diverting one year's worth of food scraps from landfills through composting is equal to approximately 1.5% of California's 2050 emissions reduction goal, 0.8% of Oregon's goal, and 1.8% of Washington's goal. Note that these are not one-to-one comparisons—the 2050 emissions reduction goals are the emissions that must be reduced on an annual basis, while the emissions reductions quantified by the WARM Calculator are life-cycle emissions that occur over many years based on a single year's food waste—but are simply intended to provide a sense of scale.[16]

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[15] For more information about this, visit http://captoolkit.wikispaces.com/

[16] While the emissions reduction in 2050 from composting food waste in 2050 would be much smaller than the numbers shown in Table 4.1, emissions reductions in 2050 would also include emissions reductions resulting from food waste composting in 2049, 2048, 2047, and previous years. The sooner putrescible wastes are diverted from landfills, the sooner emissions reductions can begin accumulating.

**Table 2: Emissions Reduction Goals Relative to Potentials of Recycling and Composting**

| | California | Oregon | Washington |
|---|---|---|---|
| State 2050 annual emissions goal (%) | 80% below 1990 levels[17] | 75% below 1990 levels[18] | 50% below 1990 levels[19] |
| 1990 annual emissions ($MTCO_2e$) | 427,000,000 | 55,811,000 | 78,500,000 |
| Current annual emissions ($MTCO_2e$)<br>*Based on most recent data available* | 477,700,000[20]<br>*2008 emissions* | 68,058,000[21]<br>*2007 emissions* | 88,200,000[22]<br>*2004 emissions* |
| State 2050 annual emissions goal ($MTCO_2e$) | 85,000,000 | 13,952,750 | 39,250,000 |
| 2050 annual emissions reduction equivalency<br>*Difference between current emissions and 2050 annual emissions goal* | (392,700,000) | (54,105,250) | (48,950,000) |
| **Lifetime emissions reduction potentials of materials wasted in one year** ($MTCO_2e$) | | | |
| **Carpet**, **core recyclables**, and **dimensional lumber** (combined) | (17,233,016-23,665,424)<br>*4-6% of 2050 annual emissions reduction* | (806,623-1,144,938)<br>*1-2% of 2050 annual emissions reduction* | (2,036,382-3,004,271)<br>*4-6% of 2050 annual emissions reduction* |
| **Food scraps** | (5,837,189)<br>*1.5% of 2050 annual emissions reduction* | (433,855)<br>*0.8% of 2050 annual emissions reduction* | (872,695)<br>*1.8% of 2050 annual emissions reduction* |

The California Environmental Protection Agency Air Resources Board has recently issued a draft compost emissions reduction factor (CERF) as part of its rulemaking process for its AB 32 Mandatory Commercial Recycling regulations.[23] Whereas the WARM emissions factor for compost only considers the carbon storage effects, the CERF includes emissions reductions due to decreased water use, decreased soil erosion, and reduced fertilizer and herbicide use, as well as increased carbon storage

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[17] Office of the Governor of California, Executive Order S-3-05 (June 1, 2005).

[18] Oregon H.B. 3543, 2007. http://www.leg.state.or.us/07reg/measpdf/hb3500.dir/hb3543.en.pdf

[19] Revised Code of Washington (RCW) 70.235.020. http://apps.leg.wa.gov/rcw/default.aspx?cite=70.235.020

[20] "Trends in California Greenhouse Gas Emissions for 2000 to 2008." (California Air Resources Board, May 2010). http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_trends_00-08_2010-05-12.pdf

[21] "Oregon Greenhouse Gas Inventory, 1990-2007." (Oregon Department of Energy, 2010). http://www.oregon.gov/ENERGY/GBLWRM/Oregon_Gross_GhG_Inventory_1990-2007.htm

[22] Stacey Waterman-Hoey and Greg Nothstein, "Greenhouse Gases in Washington State: Sources and Trends." (WA Department of Community, Trade & Economic Development, December 2006).

[23] "Proposed Method for Estimating Greenhouse Gas Emission Reductions from Compost from Commercial Organic Waste." Planning and Technical Support Division, Air Resources Board. (California Environmental Protection Agency, August 31, 2010).

in soil. As a result, the CERF places the emissions reduction potential of compost at 0.42 $MTCO_2e$/ton of food scraps, more than twice as high as the WARM factor of 0.20 $MTCO_2e$/ton. If this report's calculations were done using the CERF, the total emissions reduction potential of composting food scraps would be even higher.

The WARM Calculator only evaluates the relative methane emissions reductions of open windrow composting, but GHG emissions reductions can also be achieved by managing food scraps through alternative composting methods (such as static aerated piles or enclosed systems) and by anaerobic digestion. When anaerobically digested, food scraps can also be used as an alternative energy source. The methane generated during decomposition can be captured and converted to a natural gas equivalent fuel, or used to power a turbine to generate electricity.

## Carbon Credits/Offsets

In addition to directly reducing emissions, composting and anaerobic digestion of food scraps may also provide the opportunity to generating emissions offset credits. The Climate Action Reserve, North America's largest carbon offset registry, issued an Organic Waste Digestion Protocol in 2009 and recently established an Organic Waste Composting Protocol. These protocols set standards for the quantification and verification of GHG emissions reductions from composting and anaerobic digestion projects.[24] Projects adhering to the protocol and listed by the Reserve are eligible to sell carbon offset credits, known as CRTs, generated from the projects and revenue from CRT sales can help support private investment in composting and anaerobic digestion.[25]

# Section 5. Additional Benefits of Recycling & Composting Priority Materials

The WARM results of this analysis reveal that materials management can help states achieve emissions reductions. In addition, recycling and composting can contribute to other state and local policy goals, such as job creation, economic development, and reducing land and marine pollution.

## Job Creation and Economic Development

According to, "Recycling and Economic Development," a literature review conducted by Cascadia Consulting Group for King County Solid Waste Division's LinkUp program, increasing recycling can have positive benefits for job creation and economic development.[26]

During a period in which many traditional manufacturing industries have been losing jobs in the U.S., several studies show that recycling has created manufacturing jobs, as well as jobs in recycling

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[24] For more information, visit www.climateactionreserve.org/how/protocols/adopted/organic-waste-digestion/current/ or www.climateactionreserve.org/how/protocols/adopted/organic-waste-composting/current/

[25] The first composting offset project, "Z-Best Food Waste Composting," was listed by the Climate Action Reserve on February 2. For more information, visit www.cawrecycles.org/files/zanker.pdf

[26] Cascadia Consulting Group, "Recycling and Economic Development: A Review of Existing Literature on Job Creation, Capital Investment, and Tax Revenues." (King County Solid Waste Division LinkUp, April 2009).

processing.[27] Additional research on the U.S. labor market suggests that recycling results in ten times the jobs of waste disposal.[28] And jobs in the recycling industry pay more, on average, than that national average wage.[29]

In 2001, CalRecycle (formerly the California Integrated Waste Management Board) released a study showing that diverting a ton of recyclable or compostable material has approximately twice the economic impact of sending it to a landfill. According to the report, diverting one additional ton of waste would pay $101 more in salaries and wages, produce $275 more in goods and services, and generate $135 more in sales than disposing of it in a landfill.[30]

Using these figures, if just half of core recyclables and food scraps reported here that are currently in the waste streams of California, Oregon, and Washington were recycled, that would result it almost $1.6 billion in additional salaries and wages, $818 million in additional goods and services produced, and $309 million in additional sales across the three states. These gains would translate into additional revenue for state and local governments as well, through income, property, and sales taxes.

**Table 3: Additional Revenue Potential from Recycling and Composting**

| | TOTAL | CALIFORNIA | OREGON | WASHINGTON |
|---|---|---|---|---|
| **Core Recyclables Est. Tons** | **4,580,295** | 3,904,101 | 180,860 | 495,334 |
| **Food Scraps Est. Tons** | **7,536,505** | 6,158,120 | 457,709 | 920,676 |
| **Additional Salaries and Wages** | **$611,898,400** | $508,142,161 | $32,247,735 | $71,508,505 |
| **Additional Goods and Services** | **$1,666,060,000** | $1,383,555,388 | $87,803,238 | $194,701,375 |
| **Additional Sales** | **$817,884,000** | $679,199,918 | $43,103,408 | $95,580,675 |

Market values of several recyclable materials, such as cardboard and aluminum, have increased substantially in the ten years since the CalRecycle analysis was conducted, meaning that the figures above are lowered than might be expected today.[31] Estimates of the job and economic benefits are not available for carpet or dimensional lumber recycling, but they would also likely add hundreds of millions more to these figures.

## Reduced Land and Marine Pollution

According to the 2004 Washington State Litter Study, 1,125 tons of plastic or metal beverage containers, cardboard, newspaper, magazines, food waste, carpet and wood were deposited on Washington roadways. Together these materials accounted for 17.8% of the total material littered.[32]

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27 DSM Environmental Services and MidAtlantic Solid Waste Consultants (MSW). "Recycling Economic Information Study Update." Prepared for the Northeast Recycling Council (NERC, 2009).

28 Seldman, Neil, Ph.D. "Recycling Sector Has 30-Year Record of Impressive Growth." (Institute for Local Self-Reliance, 2002).

29 R.W. Beck, "U.S. Recycling Economic Information Study." Prepared for the National Recycling Coalition (NRC, 2001).

30 Goldman, George and Aya Ogishi, "The Economic Impact of Waste Disposal and Diversion in California." (California Integrated Waste Management Board, April 4, 2001). http://are.berkeley.edu/extension/EconImpWaste.pdf

31 Market prices for recyclable materials are published monthly by *Resource Recovery.*

32 Washington 2004 State Litter Study, "Litter Generation and Composition Report." Publication 05-07-029 (WA Solid Waste and Financial Assistance Program, March 2005).

Marine pollution, demonstrated most visibly by the "Great Pacific Garbage Patch" in the northern Pacific gyre, is now a major environmental concern. Research has found that the mass of plastics in the gyre now exceeds the total mass of living creatures (plankton) by 6 to 1. Worldwide, plastics comprise 60 to 80 percent of marine debris on average, with some areas as high as 90 to 95 percent. Urban runoff—material entering the water via storm drains or being swept or blown into the water—is the primary source of marine debris and litter is the major source of trash in urban runoff.[33] Litter makes its way to the ocean through the storm drainage systems and waterways, by wind action and by direct disposal into the water.

Any efforts that increase recycling and composting and reduce disposal and littering will help reduce the amount of materials that end up in our waterways and oceans and reduce threats posed to the animals that call the ocean their home.

# Section 6. Opportunities for Reducing Emissions through Recycling and Composting of Priority Materials

## I. Carpet

Although carpet comprises only 3% of the waste stream in terms of tonnage in California, Oregon, and Washington, it is a material with one of the highest emissions reduction potentials through recycling in all three states.[34] Carpet is made from natural gas and petroleum products and requires a great deal of energy to produce. Most carpet in the U.S. is manufactured in Southern states, where energy is derived largely from coal. The tremendous fossil fuel intensity of carpet inputs and production makes the emissions of carpet manufacturing extremely high.

For many years, recycling carpet was technically challenging, expensive, and impractical. However, new techniques and advances in recycling infrastructure are making recycling carpet more viable. Several carpet manufacturers have developed processes for turning used carpet into new carpet, with much lower life-cycle emissions than manufacturing with virgin content. Carpet can also be recycled into other products, such as carpet pad or molded plastic parts (often for automobiles), also leading to significant emissions reductions. However, carpet recycling requires source separation for clean, high-value feedstock, which requires participation from private construction and demolition (C&D) firms.

The U.S. carpet industry has had voluntary recycling programs in place for over a decade but recycling rates remain relatively low. In 2002, members of the carpet industry, representatives of government agencies at the federal, state and local levels, and non-governmental organizations signed a Memorandum of Understanding for Carpet Stewardship (MOU) to improve carpet diversion and recycling through voluntary product stewardship. Product stewardship is a product-centered approach to environmental protection that calls on those in the product life cycle—manufacturers, retailers, users, and disposers—to share responsibility for reducing the environmental impacts of products.

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[33] Gordon, M. "Eliminating land-based discharges of marine debris in California: a plan of action from the plastic debris project." State Water Resources Control Board (California Coastal Commission, 2006).

[34] Although there is some debate about the exact emissions reduction potential (see Appendix C), regardless of the emissions factor used, carpet recycling clearly offers tremendous emissions reduction potential.

The agreement set an official goal of 40% landfill diversion, including a 20-25% recycling rate for post-consumer carpet, by 2012, and established the Carpet American Recovery Effort (CARE) to achieve these targets. An annual report published by CARE in 2009, however, revealed a growing gap between the yearly goals for diversion and recycling and the actual levels reported. In 2009, for example, the recycling rate missed CARE's 13% goal by 8.8%, with only a 4.2% rate being achieved. Overall diversion (including combusting carpet for energy production) totaled only 5.3%, 15.7 points lower than the 21% goal.[35]

To achieve higher diversion rates, several states have begun exploring mandatory product stewardship policies and in October 2010, the California legislature passed the first carpet product stewardship bill in the country. AB 2398 requires every producer of carpet sold in the state of California, individually or through a designated stewardship organization, to submit a stewardship plan, including a funding mechanism that provides sufficient funding to carry out the plan, and to demonstrate continuous meaningful improvement in the rates of recycling and diversion and other specified goals in order to be in compliance.[36]

In the Northwest, a similar bill, SB 5110[37], was considered in the 2011 Washington legislative session. In addition, state and local government groups have formed the Northwest Carpet Recycling Workgroup in 2009, which is actively working to increase demand for carpet recycling and products made with recovered carpet fiber, and to encourage carpet processing facilities to become established in the northwest for economic development and easier carpet recycling.[38] The effort, along with the significant contributions of private industry, has been successful and new carpet recycling facilities have opened in the area.

In 2009 CARE initiated another round of negotiations to develop a new ten-year MOU agreement among stakeholders toward setting and meeting new carpet landfill diversion goals.

## II. Core Recyclables

Since the first municipal recycling programs began in the 1970's, curbside collection of recyclables has spread throughout the West Coast and across the United States. A recent survey estimates that 74% of the U.S. population currently has access to curbside recycling collection.[39] Although the types of materials included in curbside recycling varies from place to place, most programs cover a core set of recyclable materials including aluminum and steel food and beverage containers, newspapers, magazines, high-grade paper, corrugated cardboard containers, and #1 and #2 plastic bottles. Many curbside recycling programs also accept glass containers and a wider array of paper and plastic types.

Cities with the most successful curbside recycling programs have used variable rate pricing structures to incentivize recycling participation.[40] This approach, often called "Pay As You Throw," or PAYT, sets

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[35] "A Decade of New Opportunities: Developing Market-Based Solutions for the Recycling and Reuse of Post-Consumer Carpet." (CARE, 2009).

[36] "Fact Sheet – AB 2398 (Perez, 2010) Carpet Producer Responsibility." (California Product Stewardship Council, 2010).

[37] For the text of SB 5110, visit http://apps.leg.wa.gov/billinfo/summary.aspx?bill=5110&year=2011

[38] For more information about the Northwest Carpet Recycling Workgroup, visit http://your.kingcounty.gov/solidwaste/linkup/carpet/project.asp

[39] "2008 ABA Community Survey." Produced for the American Beverage Association, (R.W. Beck, September 2009).

[40] Canterbury, Janice and Sue Eisenfeld, "The Rise and…Rise of Pay-As-You-Throw." (MSW Management, 2006).

garbage collection charges on a per unit or weight basis, rather than charging a flat fee for unlimited garbage collection. In addition, most PAYT programs provide recycling collection at free or reduced rates, making it economically attractive for waste generators to divert recyclable materials from landfill disposal. Communities with PAYT programs in place have reported significant increases in recycling and reductions in waste. Overall, PAYT programs have been shown to reduce disposal by about 17%, with 5-6% being directly diverted to recycling.[41]

West Coast cities have been leaders in instituting PAYT programs, and as a result these programs are widespread throughout the region. In fact, a recent survey of PAYT programs for the EPA estimates that virtually all communities in Washington and Oregon have PAYT programs in place, while half of California communities have them.[42]

Curbside residential recycling programs in West Coast states continue innovating to increase participation and reduce contamination through public information and outreach, including focused social marketing. And Los Angeles recently began piloting a rewards-based approach in partnership with Recyclebank.[43] Recyclebank has been successful in increasing diversion of recyclables in Philadelphia, Cincinnati, and other large cities.

Although California, Oregon, and Washington have high diversion rates of recyclable materials compared to the national average, increasing recycling of core recyclables in these states can still deliver important benefits, such as emissions reduction, cost savings, and jobs. As this analysis shows, recyclable materials still appear in the disposed waste stream of West Coast states. In California, Oregon, and Washington, core recyclables make up 7-10% of disposed waste by weight, and are responsible for 33-55% of all emissions found in this analysis to be attributable to the top ten materials in each state. This suggests that there remains significant room for improvement in recycling programs and policies targeting diversion of core recyclables.

Although already recycled at high rates, corrugated containers continue to appear in the waste streams of all three states in large quantities. Corrugated containers embody the third greatest emissions reduction potential of all materials currently landfilled, and represent a valuable recyclable commodity. An analysis of the waste characterization studies in California and Washington, which break their state waste data into substreams by source, reveals that corrugated containers come predominantly from commercial generators.[44]

In California, although commercial sources are responsible for only 50% of total waste, the commercial substream generates 75% of all corrugated containers. In Washington, the commercial sector generates 44% of total waste but 55% of all corrugated containers.

While residential recycling programs are mandatory in many places, commercial recycling remains largely voluntary, making it difficult for local and state governments to increase the diversion of

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[41] Skumatz, Lisa, "Variable-Rate or 'Pay-As-You-Throw' Waste Management: Answers to Frequently Asked Questions." Policy Study #295 (Reason Public Policy Institute, 2002).

[42] Skumatz, Lisa and David Freeman, "Pay as you Throw (PAYT) in the US: 2006 Update and Analyses." Prepared for US EPA and SERA, (Skumatz Economic Research Associates, December 2006).

[43] Carpenter, Susan, "LA Will Reward Recycling Through New Recyclebank Program." LA Times, February 24, 2010. http://latimesblogs.latimes.com/greenspace/2010/02/recycling-rewards-los-angeles.html

[44] See Appendix D for a breakdown of tonnage in California and Washington by commercial and residential substreams.

recyclable materials from the commercial waste stream. Recognizing the potential of increased recycling to reduce greenhouse gas emissions, California has begun taking steps to mandate commercial recycling statewide. The Mandatory Commercial Recycling Measure, being developed by CalRecycle as part of its implementation of the California Global Warming Solutions Act of 2006 (AB 32), would require businesses generating 4 or more cubic yards of trash and/or recyclables for weekly collection to receive recycling services. This measure is intended to achieve GHG reductions of 5 million MTCO2e.

## III. Dimensional Lumber

Dimensional lumber is among the most easily diverted wood types, and is nonetheless disposed of in sufficiently large volume to rank among the top ten materials with emissions reduction potential in each of the three West Coast states. Wood comprises a surprisingly large portion of organic materials disposed of in landfills. The broad category of wood in waste characterization studies includes many different types of materials, such as “clean” (unpainted/untreated) lumber, painted/treated lumber, hogfuel, pallets, crates, and wood furniture. Some of these wood types, such as clean lumber, could be more easily diverted from disposal through recycling than others. Because of this, the WARM Calculator—and thus this analysis—focuses only on clean dimensional lumber.

Dimensional lumber is a construction and demolition (C&D) waste with relatively good recycling options. According to CalRecycle (formerly California Integrated Waste Management Board), this type of wood waste is highly desirable and is sought by processors.[45] Lumber scraps generated during construction make an excellent feedstock for engineered wood, and can also be recycled into products such as laminates, parquet, pallets, countertops, shelving, furniture, mulch, wood pellets, and fiberboard.[46] Some dimensional scraps can be reused in non-load bearing construction.

Much processed lumber currently ends up as biomass fuel, and is not recycled back into wood products. This prevents the emission of methane from wood waste aerobically decomposing in landfills, and can replace the need for fossil fuels, but does not offer the benefit in reducing the impact of manufacturing of new wood products that recycling does.

As with carpet, recycling dimensional lumber requires source separation for clean, high-value feedstock, and thus requires participation from private C&D firms. This can be challenging for these firms, especially during demolition, when clean, reusable lumber and unrecyclable debris are often intermingled.

Local and state governments can improve lumber recycling practices by establishing C&D recycling requirements, providing education and information about the recycling process and available markets, and by supporting innovation in C&D processes that improve recycling opportunities.

For example, California’s new CalGreen statewide building code requires at least 50 percent construction materials diversion from each residential or commercial project.[47] Governments can also support market development of production of and demand for recycled wood products using locally recovered and processed dimensional lumber. Going beyond lumber recycling, governments can

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[45] “Chapter 9: Wood & Organic Waste,” from *Best Practices in Waste Reduction*. (California Integrated Waste Management Board, 2009). www.calrecycle.ca.gov/Video/2009/BestPracCh9.pdf

[46] Sherman-Huntoon, Rhonda, “Wood Waste Study Provides Clues to Recycling Success.” *BioCycle* vol. 42, n.7, p.68 (July 2001).

[47] For more information, visit www.calrecycle.ca.gov/LGCentral/Library/canddmodel/instruction/faq.htm#diversion

promote deconstruction, an alternative method for building removal that preserves materials and encourages the reuse of wood products.[48]

## IV. Food Scraps

As mentioned previously, food scraps are a major source of methane emissions from landfills. Because food decomposes relatively quickly, food scraps often begin releasing methane before landfill methane collection systems can be installed. States can reap meaningful and direct emission reductions from alternative management of food scraps. Food scraps are the single largest volume of material, by weight, disposed in landfills in California, Oregon, and Washington.

More than 90 towns and cities in the U.S. offer single-family residential food waste collection for composting and West Coast cities lead the pack.[49] Many of these communities also have commercial composting programs in place as well. Commercial sources can be used to initiate composting programs, as they offer large volumes of source-separated food, a model followed by San Francisco and other communities in California. Food scrap composting not only delivers emissions reductions, it offers potential cost savings as well. Seattle Public Utilities estimates that its program costs about 20% less per load than landfilling. In 2009, this translated into a savings of approximately $250,000.[50]

Compost produced by food scraps offers several additional benefits during its use, including reducing or eliminating the need for chemical fertilizers, improving soil porosity and water retention, facilitating reforestation and habitat restoration, and bioremediation, and promoting higher yields of agricultural crops. As mentioned above, the WARM emissions factor leaves out a number of benefits from composting, including emissions reductions from decreased water use, decreased soil erosion, and reduced fertilizer and herbicide use. If these components were included, as they are in the California Air Resources Board's methodology, the emissions reduction potential of food scraps would be even greater[51]. ARB's analysis estimates 0.42 $MTCO_2e$ reduction for every ton composted, without considering landfill methane avoidance. For further discussion of WARM and composting, see Appendix E.

As discussed earlier, GHG emissions reductions can also be achieved by diverting food scraps to anaerobic digestion. The emissions reduction potential of anaerobic digestion is not presented here because it is not included in the WARM Calculator. On the West Coast, the East Bay Municipal Utility District is currently investigating the possibility of of anaerobically co-digesting food waste at its main wastewater treatment plant.[52]And, in Washington, Cedar Grove Composting is seeking a permit to use anaerobic digestion to convert food and yard scraps into biogas to produce electricity and natural gas.[53]

Environment Canada commissioned an evaluation of the life-cycle GHG benefits of composting and anaerobic digestion, and found that if one considers the carbon storage benefits of compost,

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[48] For more information, visit www.epa.gov/osw/conserve/rrr/imr/cdm/reuse.htm

[49] Yespen, Rhodes, "U.S. Residential Food Waste Collection and Composting." *Biocycle* vol. 50, n.12, p.35 (December 2009).

[50] Bloom, Jonathan, "American Wasteland." p. 295 (Da Capo Press, 2010).

[51] "Proposed Method for Estimating Greenhouse Gas Emission Reductions from Compost from Commercial Organic Waste." Planning and Technical Support Division, Air Resources Board. (California Environmental Protection Agency, August 31, 2010).

[52] U.S. EPA, "Turning Food Waste into Energy at the East Bay Municipal Utility District (EBMUD)." http://www.epa.gov/region9/waste/features/foodtoenergy/

[53] "Cedar Grove Composting Announces Partnership with BIOFerm." *BIOFerm blog (July 7, 2010).* http://www.biofermenergy.com/us/blog/?p=225

composting is preferable to anaerobic digestion, although both reduce emissions relative to landfilling (given average Canadian conditions).[54] Food anaerobic digestion operations can combine digestion with composting, taking advantage of the carbon storage role of compost and avoiding landfill disposal of digestion residuals. A proposed San Jose facility would combine dry fermentation anaerobic digestion with in-vessel composting.[55]

However, compost facilities can be problematic if not operated optimally. This can lead to emissions of VOCs, as well as odor and vector issues, undermining community support. Best practices have been developed by the U.S. Composting Council under a grant from the EPA that suggest how to minimize odor and other potential issues through proper aeration, feedstock management, carbon/nitrogen balance and covering rows with finished compost.[56] However, in some regions, anaerobic digestion of food waste may be a better option.[57]

Also, although not measured in the WARM Calculator, there are opportunities to "recycle" food by diverting what is discarded by grocery stores and commercial food service operations to food banks and soup kitchens. So-called "food rescue" programs exist in many communities for coordinating the collection and distribution of discarded pre-consumer food waste.[58] These programs deliver the benefits of waste prevention while providing a valuable resource to people in need.

Of course, as with all of the top ten materials, reducing the amount of food wasted overall delivers powerful emissions reductions as well. In a successful example from abroad, the UK's "Love Food, Hate Waste" campaign, spearheaded by the British government, has engaged citizens with information and educational outreach on how to waste less food. Since its launch in 2009, the campaign estimates that it has reduced 2.8 million $MTCO_2e$.[59]

Estimates for the U.S. suggest that between 26% and 40% of all available food is wasted.[60] Preventing that waste is a huge opportunity for emissions reductions and cost savings for individuals and governments alike.

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[54] ICF Consulting, "Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update, Final Report." Prepared for Environment Canada and Natural Resources Canada (October 2005).

[55] For more information, visit http://zerowasteenergy.com/content/san-jose-anaerobic-digestioncomposting-plant

[56] Christiansen, Eva, "Best Management Practices for Incorporation Food Residuals into Existing Yard Waste Composting Operations." (U.S. Composting Council, 2009).

[57] CalRecycle's final Program Environmental Impact Report for anaerobic digestion facilities will be published in May 2011. This Program EIR assesses the environmental effects that may result from the development of anaerobic digestion facilities in California. The results of the Program EIR will inform future policy considerations related to anaerobic digestion facilities and provide background information on technologies, potential impacts, and mitigation measures. For more information, visit http://www.calrecycle.ca.gov/swfacilities/Compostables/AnaerobicDig/default.htm

[58] Examples of these programs include Food Lifeline's Grocery Rescue program in Western Washington and Metro's Fork It Over program in the Portland metropolitan area.

[59] Personal communication with Andrew Parry, Household Food Waste Programme Manager, WRAP UK. January 20, 2011.

[60] Kantor, Lisa Scott et al. "Estimating and Addressing America's Food Losses," *Food Review*, January-April 1997, pp.2-12 (USDA Economic Research Service, 1997).

# Section 7. Summary Reflections and Next Steps

The WARM results presented in this report provide policymakers and materials management professionals in California, Oregon, and Washington a good idea of which materials carry the greatest potential for emissions reduction if diverted from landfill disposal through recycling or composting. At a time when limited resources are available for meeting multiple urgent policy goals, programs that focus on diverting these priority material types from landfill disposal through recycling or composting can deliver emissions reductions and contribute to climate action goals, while producing other more widely accepted benefits such as resource conservation, cost savings, job creation and economic development.

Although recycling is an established practice in many West Coast communities, this report shows that further progress can be made, both to divert greater quantities of materials currently being recycled and to establish new programs for additional materials. For some materials, such as carpet and dimensional lumber, effective materials management strategies and mechanisms are relatively new or still being developed and more research and experimentation is needed to understand how communities can recycle these materials most effectively. Likewise, food scrap management offers new and rapidly evolving opportunities. Further research and evaluation of on-the-ground results will be important for helping communities determine how best to divert food scraps from landfills and reap the GHG emissions reductions benefits. Even best practices for core recyclables are undergoing change, such as a transition to single-stream collection and processing systems and expansion of mandatory recycling to the commercial sector.

Meeting these opportunities will require expansion of processing, reuse, and manufacturing infrastructure. The West Coast is deficient in food composting and anaerobic digestion facilities, although several composting and digestion facilities employing various technologies are either planned or under construction. Many traditional recycled materials are exported rather than utilized domestically at the same time that domestic recyclers are in need of more materials. While increasing diversion and recycling of more materials will generate more jobs domestically in the collection, transport, sorting and marketing areas, the material will need to be recycled domestically to have the greatest impact on job creation and economic activity. Reuse opportunities can also be expanded, especially for deconstructed building materials.

These changes create challenges as well as opportunities, and necessitate continued innovation and improvements. The Materials Management Workgroup of the West Coast Climate and Materials Management Forum is committed to continuing to provide research and information on current strategies and best practices in recycling and composting of these priority materials.

## Materials Management Beyond Recycling and Composting

The analysis featured here estimates the emissions reduction potential of recycling and composting various materials versus depositing them in a landfill, but it does not provide a comprehensive comparison of other life-cycle materials management strategies, such as green purchasing, producer responsibility, product stewardship, and decreased consumption, except to the extent that these strategies might be used to achieve the recycling results simulated in the model's recycling scenario.

The analysis also fails to capture the significant GHG emissions reduction that can be achieved through changes to materials management-related issues such as transportation modes, manufacturing practices, distribution infrastructure, energy sources, and product design.

To fully understand the emissions reduction potential of sustainable materials management, the entire spectrum of strategies available across the entire life cycle of materials must be examined. The workgroup looks forward to the opportunity to focus on these strategies in future projects.

# APPENDIX A: State Waste Tonnage Data by WARM Category

| WARM v.11 | California | | Oregon | | Washington | |
|---|---|---|---|---|---|---|
| Material Categories | 2008 CA Waste Characterization Study, Table 50 | Est. Tons | 2009 OR Waste Composition Study | Est. Tons | 2009 WA Waste Characterization Study, Table 9 | Est. Tons |
| **Aluminum Cans** | **Aluminum Cans** | **47,829** | **Aluminum Cans** | **2,937** | **Aluminum Cans** *(Combined)* | **28,085** |
| | | | | | Aluminum Beverage Cans | 23,031 |
| | | | | | Food Cans - Coated | 5,054 |
| **Steel Cans** | **Tin/Steel Cans** | **236,405** | **Steel (Tinned) Cans** | **18,158** | **Food Cans - Tinned** | **35,772** |
| **Glass** | **Glass** *(Combined)* | **459,006** | **Glass** *(Combined)* | **40,925** | **Glass** *(Combined)* | **73,517** |
| | Clear Glass Bottles and Containers | 196,093 | Depost Beverage Glass | 6,818 | Clear Glass Containers | 42,353 |
| | Green Glass Bottles and Containers | 79,491 | No-Deposit Glass Containers | 23,964 | Green Glass Containers | 8,592 |
| | Brown Glass Bottles and Containers | 108,953 | Flat Window Glass | 10,143 | Brown Glass Containers | 17,490 |
| | Other Glass Bottles and Containers | 40,570 | | | Plate Glass | 5,082 |
| | Flat Glass | 33,899 | | | | |
| **HDPE** | **HDPE Containers** | **157,779** | **not available** | **na** | **HDPE** *(Combined)* | **51,467** |
| | | | | | #2 HDPE Plastic Natural Bottles | 12,547 |
| | | | | | #2 HDPE Plastic Colored Bottles | 17,017 |
| | | | | | #2 HDPE Plastic Jars & Tubs | 20,020 |
| | | | | | #2 HDPE Plastic Products | 1,883 |
| **LDPE** | **not available** | **na** | **not available** | **Na** | **LDPE** *(Combined)* | **445** |
| | | | | | #4 LDPE Plastic Packaging | 329 |
| | | | | | #4 LDPE Plastic Products | 116 |
| **PET** | **PETE Containers** *(Combined)* | **199,643** | **not available** | **na** | **PETE** *(Combined)* | **48,079** |
| | PETE Water Bottles | 51,706 | | | #1 PETE Plastic Bottles | 33,344 |
| | PETE Sealed Containers | 18,477 | | | #1 PETE Plastic Non-Bottles | 14,563 |
| | Other PETE Containers | 129,460 | | | #1 PETE Plastic Products | 172 |
| **Mixed Plastics** | **not applicable** | **N/A** | **Plastic (recyclable) acceptable at curb** | **28,035** | **not applicable** | **N/A** |
| **Corrugated Containers** | **Uncoated Corrugated Containers** | **1,905,897** | **Cardboard** *(Combined)* | **75,266** | **Corrugated Containers** *(Combined)* | **189,205** |
| | | | Cardboard Packaging Paper | 72,652 | Cardboad/Kraft Paper Packaging | 185,311 |
| | | | Waxed Corrugated Cardboard | 2,614 | Cardboard/Kraft Paper Products | 3,894 |
| **Magazines/ Third-class Mail** | **Magazines and Catalogs** | **283,069** | **Magazines** | **15,030** | **Magazines** | **46,149** |
| **Newspaper** | **Newspaper** | **499,960** | **Newspaper** | **18,640** | **Newspaper** *(Combined)* | **82,682** |
| | | | | | Newspaper | 70,594 |
| | | | | | Newspaper Packaging | 12,088 |
| **Office Paper** | **Office Paper** *(Combined)* | **731,298** | **High Grade Paper** | **22,794** | **High-Grade Paper Products** | **49,667** |
| | White Ledger Paper | 259,151 | | | | |
| | Other Office Paper | 472,147 | | | | |
| **Phonebooks** | **Phone Books and Directories** | **24,149** | **not available** | **na** | **Other Groundwood Paper Products** | **13,874** |
| **Dimensional Lumber** | **Clean Dimensional Lumber** | **1,184,375** | **Unpainted Lumber** | **71,555** | **Dimensional Lumber** | **51,929** |

| WARM v.11 | California | | Oregon | | Washington | |
|---|---|---|---|---|---|---|
| Material Categories | 2008 CA Statewide Waste Characterization Study, Table 50 | Est. Tons | 2009 OR Statewide Waste Composition Study | Est. Tons | 2009 WA Statewide Waste Characterization Study, Table 9 | Est. Tons |
| **Food Scraps** | **Food** | **6,158,120** | **Food** *(Combined)* | **457,709** | **Food** *(Combined)* | **920,676** |
| | | | Food not otherwise specified | 254,896 | Food - Vegetative | 654,458 |
| | | | Non-packaged bakery goods | 13,312 | Food - Non-Vegetative | 258,823 |
| | | | Packaged bakery goods | 12,638 | Fruit Waste | 7,395 |
| | | | Non-packaged other vegetative food | 97,084 | | |
| | | | Packaged other vegetative food | 30,609 | | |
| | | | Non-packaged non-vegetative food | 31,979 | | |
| | | | Packaged non-vegetative food | 17,191 | | |
| **Yard Trimmings** | **Prunings and Trimmings** | **1,058,854** | **All Prunings and Stumps** | **25,473** | **Prunings** | **26,941** |
| **Grass** | **not applicable** | **N/A** | **Grass Clippings** | **40,737** | **n/a** | |
| **Leaves** | **Leaves and Grass** | **1,512,832** | **Leaves/Weeds** | **55,169** | **Leaves & Grass** | **203,909** |
| **Branches** | **Branches and Stumps** | **245,830** | **not available** | **na** | **n/a** | |
| **Carpet** | **Carpet** | **1,285,473** | **Carpet/Rugs** | **67,610** | **Carpet** | **145,282** |
| **Personal Computers** | **Computer-related Electronics** *(Combined)* | **32,931** | **Computers & Monitors** | **4,776** | **Computers** *(Combined)* | **3,090** |
| | Computer-related Electronics - Large | 26,357 | | | Computer Monitors - CRT | 1,476 |
| | Computer-related Electronics-Small | 6,574 | | | Computer Monitors - LCD | 322 |
| | | | | | Computers | 1,292 |
| **Concrete** | **Concrete** | **483,367** | **Rock, Concrete** | **31,168** | **Concrete** | **10,917** |
| **Fly Ash** | **Ash** | **40,736** | **not available** | **na** | **Ash** | **7,889** |
| **Tires** | **Tires** *(Combined)* | **60,180** | **Tires** | **4,773** | **Tires & Rubber** | **15,216** |
| | Vehicle and Truck Tires | 23,627 | | | | |
| | Other Tires | 36,553 | | | | |
| **Asphalt Concrete** | **Asphalt Paving** | **129,834** | **Not** | | **Asphalt Paving** | **9,676** |
| **Asphalt Shingles** | **Asphalt Roofing** *(Combined)* | **1,121,945** | **Asphalt Roofing & Tarpaper** | **101,246** | **Asphalt Roofing** | **62,215** |
| | Asphalt Composition Shingles | 637,912 | | | | |
| | Roofing Tar Paper/Felt | 100,648 | | | | |
| | Roofing Mastic | 18,559 | | | | |
| | Built-up Roofing | 108,162 | | | | |
| | Other Asphalt Roofing Material | 256,664 | | | | |
| **Drywall** | **Gypsum Board** *(Combined)* | **642,511** | **Gypsum Wallboard** | **73,593** | **Drywall** | **131,475** |
| | Clean Gypsum Board | 449,097 | | | | |
| | Painted/Demolition Gypsum Board | 193,414 | | | | |
| **TOTAL** | | **18,502,023** | | **1,155,594** | | **2,208,157** |

# Appendix B: WARM Per Ton Emissions Estimates for Alternative Management Scenarios

| Material | GHG Emissions per Ton Source Reduced (MTCO2E) | GHG Emissions per Ton Recycled (MTCO2E) | GHG Emissions per Ton Landfilled (MTCO2E) | GHG Emissions per Ton Combusted (MTCO2E) | GHG Emissions per Ton Composted (MTCO2E) |
|---|---|---|---|---|---|
| Aluminum Cans | (8.26) | (13.61) | 0.04 | 0.05 | NA |
| Steel Cans | (3.19) | (1.80) | 0.04 | (1.55) | NA |
| Copper Wire | (7.38) | (4.97) | 0.04 | 0.04 | NA |
| Glass | (0.53) | (0.28) | 0.04 | 0.04 | NA |
| HDPE | (1.77) | (1.38) | 0.04 | 1.73 | NA |
| LDPE | (2.25) | (1.67) | 0.04 | 1.73 | NA |
| PET | (2.07) | (1.52) | 0.04 | 1.50 | NA |
| Corrugated Containers | (5.60) | (3.10) | 0.08 | (0.35) | NA |
| Magazines/ Third-class mail | (8.65) | (3.07) | (0.42) | (0.24) | NA |
| Newspaper | (4.89) | (2.80) | (0.97) | (0.40) | NA |
| Office Paper | (8.00) | (2.85) | 1.38 | (0.33) | NA |
| Phonebooks | (6.29) | (2.65) | (0.97) | (0.40) | NA |
| Textbooks | (9.13) | (3.11) | 1.38 | (0.33) | NA |
| Dimensional Lumber | (2.02) | (2.46) | (0.66) | (0.42) | NA |
| Medium-density Fiberboard | (2.23) | (2.47) | (0.66) | (0.42) | NA |
| Food Scraps | 0.00 | NA | 0.75 | (0.07) | (0.20) |
| Yard Trimmings | 0.00 | NA | (0.11) | (0.10) | (0.20) |
| Grass | 0.00 | NA | 0.28 | (0.10) | (0.20) |
| Leaves | 0.00 | NA | (0.54) | (0.10) | (0.20) |
| Branches | 0.00 | NA | (0.66) | (0.10) | (0.20) |
| Mixed Paper | NA | (3.51) | 0.05 | (0.35) | NA |
| Mixed Metals | NA | (5.40) | 0.04 | (1.06) | NA |
| Mixed Plastics | NA | (1.50) | 0.04 | 1.63 | NA |
| Mixed Recyclables | NA | (2.87) | (0.05) | (0.29) | NA |
| Mixed Organics | NA | NA | 0.31 | (0.09) | (0.20) |
| Mixed MSW | NA | NA | 1.15 | 0.05 | NA |
| Carpet | (4.02) | (7.22)/(2.21)* | 0.04 | 0.96 | NA |
| Personal Computers | (55.78) | (2.26) | 0.04 | (0.13) | NA |
| Clay Bricks | (0.29) | NA | 0.04 | NA | NA |
| Concrete | NA | (0.01) | 0.04 | NA | NA |
| Fly Ash | NA | (0.87) | 0.04 | NA | NA |
| Tires | (4.34) | (0.39) | 0.04 | 0.51 | NA |
| Asphalt Concrete | (0.11) | (0.08) | 0.04 | NA | NA |
| Asphalt Shingles | (0.20) | (0.09) | 0.04 | (0.34) | NA |
| Drywall | (0.22) | 0.03 | 0.13 | NA | NA |
| Vinyl Flooring | (0.63) | NA | 0.04 | (0.15) | NA |
| Wood Flooring | (4.08) | NA | 0.07 | (0.55) | NA |

NOTE: Categories that appear in parentheses are net emissions reductions, while others are net emissions increases.

** See Appendix C for an explanation of the two emissions factors used for carpet recycling*

# APPENDIX C: Concerns with WARM Emissions Factor for Carpet Recycling

The first emissions factor for carpet recycling (7.22 MTCO2e net emissions reduction) comes from the WARM Calculator and assumes an open loop recycling process. A number of industry and government stakeholders have expressed concerns with the assumptions used in the development in the emissions factor. Specifically, there are three major concerns:

1) The WARM factor was developed using data about the material composition of residential carpet, which is significantly different from commercial carpet. Because residential carpet makes up a minority of carpet in the waste stream (only 22% of carpet landfilled in California is from the residential sector, and only 10% in Washington is), the use of residential carpet data may be misleading.
2) The WARM factor calculation assumes that carpet recycling is an "open loop" process, and that carpet is recycled in the following proportions: 67% is recycled into carpet pad, 25% is recycled into molded plastic parts, and 8% is recycled into carpet tile backing. These assumptions do not match the latest reports from the carpet industry about how carpet is recycled. According to the Carpet American Recovery Effort (CARE) 2009 Annual Report, carpet is recycled as follows: 45% is turned back into carpet, 33% is recycled into plastic pellets (used in plastic product manufacturing), 12% is recycled into carpet pad, 5% is recycled directly into molded plastic parts, 4% is recycled into other products, and 1% is used as engineered fuel.
3) The WARM factor calculation assumes that the current mix of inputs for carpet manufacturing is 100% virgin materials. With 45% of all recycled carpet being recycled back into carpet, this is clearly not entirely accurate. However, as of 2009, only 4.2% of all post-consumer carpet is recycled, so it is likely that most carpet manufacturing includes little if any recycled content.

The U.S. EPA is aware of the limitations and potential flaws in the WARM emissions factor for carpet recycling and is working with experts in the industry and academic community to revise these factors for future versions.

In the meantime, we have chosen to calculate the emissions reduction potential for carpet in two ways. First, we continue using the WARM emissions factor for consistency and because the assumptions and calculations are transparent and freely available for review and critique at http://www.epa.gov/climatechange/wycd/waste/downloads/carpet-chapter10-28-10.pdf.

Second, we use an emissions factor for closed loop carpet recycling (2.21MTCO2e net emissions reduction for carpet recycled back into carpet) developed by Dr. Jeffrey Morris of Sound Resource Management in a report to Seattle Public Utilities titled, "Environmental Impacts from Carpet Discards Management Methods: Preliminary Results."

Because neither the assumptions used for WARM nor Dr. Morris's analysis accurately reflect the nature of the carpet recycling market today, both emissions factors present skewed estimates of the emissions reduction potential of recycling carpet currently in the waste stream in WA, OR, and CA. Unfortunately, they represent the best estimates currently available for public use. We hope that by providing both in our analysis, we reflect the range of estimated emissions reduction potential for carpet recycling.

# APPENDIX D: Proportions of Waste from Commercial and Residential Substreams in California and Washington

### CALIFORNIA 2008[61]

| Material Categories | All Sectors (tons) | Commercial (tons) | % | Residential (tons) | % | Multi-Family (tons) | % | Single-Family (tons) | % |
|---|---|---|---|---|---|---|---|---|---|
| **TOTAL TONS** | **39,722,818** | **19,672,547** | **50%** | **11,935,174** | **30%** | **3,351,428** | **8%** | **8,583,746** | **22%** |
| **Carpet** | **1,285,473** | **697,461** | **54%** | **278,641** | **22%** | **159,536** | **12%** | **119,105** | **9%** |
| **Core Recyclables** | **4,061,880** | **2,481,237** | **61%** | **1,338,042** | **33%** | **487,042** | **12%** | **851,000** | **21%** |
| Aluminum Cans | 47,829 | 20,169 | 42% | 26,171 | 55% | 4,561 | 10% | 21,610 | 45% |
| Steel Cans | 236,405 | 113,789 | 48% | 115,921 | 49% | 30,862 | 13% | 85,059 | 36% |
| HDPE | 157,779 | 74,261 | 47% | 78,845 | 50% | 31,186 | 20% | 47,659 | 30% |
| LDPE | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| PET | 199,643 | 89,176 | 45% | 105,169 | 53% | 34,922 | 17% | 70,247 | 35% |
| Corrugated Containers | 1,905,897 | 1,423,530 | 75% | 323,059 | 17% | 147,048 | 8% | 176,011 | 9% |
| Magazines | 283,069 | 117,828 | 42% | 153,432 | 54% | 40,627 | 14% | 112,805 | 40% |
| Newspaper | 499,960 | 190,237 | 38% | 288,197 | 58% | 99,735 | 20% | 188,462 | 38% |
| Office Paper | 731,298 | 452,247 | 62% | 247,248 | 34% | 98,101 | 13% | 149,147 | 20% |
| **Dimensional Lumber** | **1184375** | **730278** | **62%** | **74,475** | **6%** | **22663** | **2%** | **51812** | **4%** |
| **Food Scraps** | **6,158,120** | **3,032,805** | **49%** | **3,034,040** | **49%** | **756,846** | **12%** | **2,277,194** | **37%** |

### WASHINGTON 2009[62]

| Material Categories | All Sectors (tons) | Commercial (tons) | % | Residential (tons) | % |
|---|---|---|---|---|---|
| **TOTAL TONS** | **4,978,496** | **2,174,075** | **44%** | **1,826,521** | **37%** |
| **Carpet** | **145,282** | **87,897** | **61%** | **14,222** | **10%** |
| **Core Recyclables** | **531,551** | **248,158** | **47%** | **212,768** | **40%** |
| Aluminum Cans | 28,085 | 10,064 | 36% | 15,927 | 57% |
| Steel Cans | 35,772 | 16,266 | 45% | 17,999 | 50% |
| HDPE | 51,467 | 25,016 | 49% | 22,745 | 44% |
| LDPE | 445 | 95 | 21% | 186 | 42% |
| PET | 48,079 | 16,714 | 35% | 29,071 | 60% |
| Corrugated Containers | 189,205 | 103,609 | 55% | 46,208 | 24% |
| Magazines | 46,149 | 16,108 | 35% | 23,302 | 50% |
| Newspaper | 82,682 | 31,615 | 38% | 38,643 | 47% |
| Office Paper | 49,667 | 28,671 | 58% | 18,687 | 38% |
| **Dimensional Lumber** | **51,929** | **16,942** | **33%** | **1,551** | **3%** |
| **Food Scraps** | **920,676** | **484,521** | **53%** | **414,006** | **45%** |

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[61] *California 2008 Statewide Waste Characterization Study* (Cascadia Consulting Group for CA Integrated Waste Management Board, 2009).

[62] *2009 Washington Statewide Waste Characterization Study* (Cascadia Consulting Group for WA Department of Ecology, 2010).

# APPENDIX E: Benefits and Limitations of WARM Model

**From "Materials Management Approaches for State and Local Climate Protection"**

*http://captoolkit.wikispaces.com/WARM*

EPA's Waste Reduction Model (WARM) is a tool for assessing the GHG emissions of a baseline and an alternative waste management method for handling any of 32 materials and 8 mixed materials categories. It was created to help solid waste planners and organizations track and voluntarily repo rt GHG emissions reductions from several different waste management practices. WARM is publicly available both as a Web-based calculator and as a Microsoft Excel spreadsheet.

WARM calculates and totals GHG emissions of baseline and alternative waste management practices (i.e. landfilling, incineration, source reduction, recycling, and composting). The model calculates emissions in metric tons of carbon equivalent (MTCE), metric tons of carbon dioxide equivalent (MTCO2E), and energy units (million BTU) across 40 material types commonly found in municipal solid waste (MSW). The emission factors represent the GHG emissions associated with managing 1 short ton of MSW in a specified manner. GHG savings must be calculated by comparing the emissions associated with the alternative scenario with the emissions associated with the baseline scenario. Without the comparison, part of the emissions savings or cost will be excluded.

The model takes a life cycle view and incorporates in the emissions factors for each material the emissions from raw materials acquisition, processing, manufacturing, transportation, and end-of-life management. However, the use phase of materials is not considered in the model's calculations. For most materials, recycling is modeled as a closed-loop. For example, a plastic PET bottle is recycled into a plastic PET bottle. For those materials where there is not a dominant use of a recycled material or a lack of data, an open-looped process may be modeled. Open-loops are common for many of the paper-based material categories. Details for what is and isn't included can be found in the FAQ.

(http://www.epa.gov/climatechange/wycd/waste/calculators/WARM_faq.html )

WARM is widely used by national, state, and local governments. Because it is commonly used, it lends some universality and comparability to the analyses that are done with it. It is a "common denominator" for solid waste GHG emissions in the US. Other available tools sometimes have drawbacks that WARM does not; they may be proprietary and accessed only through contract, may carry costs for use, and may not be as widely used.

Although it remains one of the best options available for state and local governments to estimate the emissions reduction potential of recycling, composting, and source reduction (relative to incineration and landfilling), WARM is not without limitations. Here are some that have implications for this report:

## WARM and Materials Categories

WARM users face the challenge of reconciling their own materials category definitions with those the model employs. WARM's categories for mixed paper and corrugated cardboard remain ambiguous since there are a many materials with different emissions impacts that would fall into these categories in varying ratios.

## WARM and Products

WARM focuses on materials, not products, which leaves out some significant pieces of the solid waste stream. It doesn't, for example, include such categories as sheetrock, textiles (which can have multiple materials in products) or household items – furniture, toys, sporting goods, electronics other than PCs. Material list is found on the WARM homepage: http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_home.html

## WARM and Alternative Materials Management

Some materials management efforts are better evaluated using other methods and tools. WARM is not easily adapted to comprehensive comparisons of materials management strategies such as product stewardship, EPP or reuse programs. For example, the lack of "upstream" (or production-related) emissions for food limits WARM's utility for evaluating food waste prevention projects. Also, WARM currently has no capacity to calculate reuse separate from source reduction. The source reduction management option assumes materials not manufactured. Using the source reduction calculations as a proxy for reuse activities only works if one assumes that the reuse actually substitutes for the mining and manufacture of virgin materials that would have otherwise been necessary. This is a shaky assumption, since some reuse activities don't actually displace production of new materials.

## WARM and Methane Global Warming Potential (GWP)

GWP is a concept designed to compare the ability of a greenhouse gas to trap heat in the atmosphere relative to another gas. The definition of a GWP for a particular greenhouse gas is the ratio of heat trapped by one unit mass of the greenhouse gas to that of one unit mass of $CO_2$ over a specified time period. WARM uses 21 as the GWP for methane, which is the 100 year GWP listed in the IPCC's second assessment from 1996. According to the EPA, November 2009, this will not be changed anytime soon as the GWP is set by the United Nations Framework Convention on Climate Change (UNFCCC) which EPA must use for national GHG inventories (and which is based on the IPCC second assessment). It is important to note that the more recent IPCC Assessment 4 (2007) uses a 100 year GWP for methane of 25. However, many state and local inventory and waste professionals believe that using a 20 year horizon GWP of 72 for methane highlights the potential for important short-term emissions reduction benefits, since methane decays quickly (it has a 12 year lifetime) and thus has its maximum warming impact well before 100 years is reached.

## WARM and Composting

As of August 2010, a new version of WARM includes a more comprehensive analysis of composting yard and food waste than it has in the past. First, the calculation of landfill emissions from organics is based on a first-order decay rate to better measure when emissions are generated. Previous versions of the model only calculated the lifetime methane yield. In addition, landfill gas capture systems is modeled with a time element, assuming systems are phased in at landfills. With these two new elements, the model is able to estimate the amount of methane being generated at a particular time and the amount of methane being captured at that time. This new calculation methodology most affects food waste and grass.

The emission factors for branches, which degrade at a very slow rate, changed very little. The new emission factor takes into account the higher soil carbon sequestration capacity for compost-improved soil as well as the GHG emissions involved in composting machinery and transportation. However, the updated model still does not include an emission factor for other compostable materials, like non-recyclable paper. WARM also does not include GHG emissions or emissions reductions associated with other co-benefits associated with the use of compost, such as water conservation and changes in fertilizer use. Finally, WARM does not differentiate between the potential for varying emissions from compost sites themselves as a function of technology (e.g., anaerobic vs. aerobic composting, or centralized vs. home composting).

### WARM and Emissions Timing

WARM does not currently break emissions and emissions reductions into the years in which they actually occur. Rather, WARM rolls all future emissions and emissions reductions into a single number. While appropriate for comparing program options against each other, this limits WARM's usefulness in inventories, since most other emissions are reported in the years in which they actually occur. Organic materials (e.g. cardboard, paper, lumber) have avoided emissions associated with source reduction and recycling that are time-sensitive.

Forest carbon sequestration: When paper is recycled, fewer trees are cut down. This carbon sequestration reduces the net emissions associated with paper source reduction and recycling. The reductions occur over decades, since every year following the actual recycling or source reduction event, over their lifetime, these trees absorb carbon as they continue to grow.

Avoided landfill emissions: When paper is recycled, less of it goes into the landfill. Landfill methane emissions are reduced, and these avoided emissions reduce the net emissions associated with paper source reduction and recycling. These reductions occur over decades, since decay in the landfill occurs over decades. The same is true for diversion of other putrescible wastes, such as food waste composting.

### WARM and International Processes

WARM treats international production – both of virgin and recycled materials – as if production in other countries have the same emissions factors (emissions per ton) as domestic production. Given the international flow of products and recycled feedstocks, and the potential for significant regional differences in emissions based on regional fuel mixes and technology patterns, this is a potential limitation. This is particularly acute in the forest carbon sequestration element of WARM (for paper recycling and source reduction), which is based entirely on modeling of forest management practices in the domestic US. Forest management practices, and the associated carbon benefits/impacts of reducing use of wood, likely vary widely between the US and some other areas of the world, including areas that would supply virgin fiber to foreign mills were it not for their use of wastepaper exported from the US.