Supplemental Technical Report

DEQ
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Department of Environmental Quality

Treatment of Greenhouse Gas Reductions from Recycling and Composting in Oregon's Consumption-based Greenhouse Gas Emissions Inventory

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Summary

Waste recycling (and composting of some wastes) reduces greenhouse gas emissions when viewed from a life-cycle perspective. Since 2004, the Oregon Department of Environmental Quality has estimated the life-cycle GHG reductions associated with recycling and composting in Oregon. A separate project (CBEI, or consumption-based emissions inventory) estimates greenhouse gas emissions associated with consumption in 2005. This report attempts to reconcile these two efforts by examining how they compare in their treatment of the life-cycle emissions and emissions reductions associated with recycling and composting. Of the estimated GHG reductions of roughly 3.3 million metric tons of carbon dioxide equivalent (CO2e) resulting from recycling and composting in 2005, DEQ estimates that roughly two-thirds (or 2.2 million metric tons of CO2e) are not included in the consumption-based inventory.

Background and Scope

Since 1992, Oregon DEQ has annually estimated the quantity of materials generated in Oregon that are recycled and composted as part of the calculation of Oregon's material recovery rate. Beginning with calendar year 2004, DEQ has applied emissions factors – drawn largely but not exclusively from EPA's Waste Reduction Model (WARM) tool – to estimate the net reduction in global greenhouse gas emissions associated with these recycling and composting actions. For calendar year 2005, DEQ estimated that waste recovery in Oregon resulted in a reduction of approximately 3.3 million metric tons of carbon dioxide equivalent (MMTCO2e), equivalent to the tailpipe emissions of about 700,000 Oregon light passenger vehicles. Clearly, waste recovery offers significant greenhouse gas reduction benefits.

DEQ recently published a consumption-based GHG emissions inventory for Oregon. That inventory, called "CBEI" (for Consumption Based Emissions Inventory), is the first of its kind for a U.S. state, estimating the global emissions associated with consumption in Oregon. (CBEI currently only estimates consumption-based emissions for calendar year 2005; DEQ may extend the analysis to future years.) Included are life-cycle emissions of materials that are "consumed" in Oregon (purchased by households and governments and as part of investment expenditures), as well as emissions associated with materials used by businesses that satisfy, directly or indirectly, other in-state consumption (for example, office paper used by out-of-state firms that produce motor fuels consumed in Oregon). DEQ includes some emissions and emissions reductions associated with recycling and composting in the estimate of consumption-based emissions.

How do these two emissions accounting exercises compare against each other? Specifically, how much of the estimated 3.3 MMTCO2e in emissions reductions associated with recycling and composting is included in CBEI? By extension, how much is excluded? This technical report explores those questions. It is organized into three sections:

1. An overview of EPA's WARM tool and the various life cycle emissions sources, sinks and offsets that contribute to DEQ's recycling/composting estimate (3.3 MMTCO2e).
2. An overview of how CBEI treats emissions associated with recycling and composting, and how this relates to EPA's approach.
3. A rough estimate of the magnitude of recycling/composting emissions reductions not included in CBEI, and an explanation of how this rough estimate was derived.

Overview of EPA's WARM Approach and DEQ Annual Estimates of GHG Emissions Reductions Associated with Recycling and Composting

EPA's Waste Reduction Model tool is widely used in the U.S. to estimate greenhouse gas emissions and emissions reductions associated with recycling and composting. Full documentation for the tool is provided at www.epa.gov/WARM. In summary, WARM uses a life-cycle approach for about 40 different materials. As a tool, WARM is designed to compare two scenarios against each other – for example, composting food waste vs. landfilling food waste. To estimate recycling and composting benefits in Oregon requires building an "Oregon average" disposal scenario, one which reflects the unique blend of incineration and landfill facilities that would otherwise handle these wastes (were they not recycled or composted). To do this, DEQ built a model based largely on emissions factors derived from the WARM tool documentation, supplemented with Oregon-specific disposal characteristics.

For estimating the GHG impacts of recycling and composting in Oregon, DEQ uses the following categories of emissions and emissions reductions:

1. **Recycling: "Upstream" emissions and emissions reductions, less recycling-related transportation emissions.** Recycling and the use of recycled materials to make new product requires energy for transportation (collection and transport of recyclable wastes) and also energy to produce new products from recycled wastes. However, as recycled feedstocks displace virgin feedstocks, there are also reductions in emissions associated with reduced use of fossil fuels in manufacturing, reduced use of fossil fuels in extracting and transporting virgin feedstocks, and reduced non-energy emissions from industrial processes (such as carbon dioxide emissions from converting limestone to lime, which is used in the production of steel and aluminum). This category represents net emissions reductions associated with recycling (emissions associated with recycling and making product from recycled feedstock, minus avoided emissions associated with virgin production) unless specified in another category below.
2. **Recycling: Indirect carbon storage in forests**. Decreasing demand for timber (as a result of paper recycling) is projected to indirectly increase carbon storage in forests.
3. **Composting: Carbon storage in agricultural soils.** Soils depleted of carbon have the potential to store carbon if treated with finished compost. This offers the potential of removing carbon from the atmosphere.

4. **Composting: Transportation and equipment emissions.** Fossil fuels are burned, and emissions result, as waste is transported to compost facilities, and equipment (e.g., windrow turners) is used to operate the facilities.
5. **Recycling and Composting: Avoided transport to incinerator.** Roughly 6 percent of Oregon's municipal solid waste is disposed of in one of two mixed-waste incinerators. Recycling and composting reduces emissions associated with transporting waste to these facilities.
6. **Recycling and Composting: Avoided emissions from incineration of wastes**. These include nitrous oxide as well as CO_2 from the combustion of fossil carbon-derived materials such as plastics and synthetic textiles.
7. **Recycling and Composting: Avoided energy recovery credits (incineration)**. One of Oregon's two incinerators recovers energy from the combustion process and uses this to generate electricity. In the WARM tool, a "credit" (emissions reduction) is assigned to this action, under the logic that if the waste were not combusted (and energy recovered), electricity would have to be generated using some other process, with associated emissions. To the extent that recycling and composting decrease this credit, it is included here as an increase in emissions.
8. **Recycling and Composting: Avoided transport to landfill and landfill equipment.** Recycling and composting reduces emissions associated with transporting waste to landfills. It also reduces the use of fossil-fuel combusting landfill equipment.
9. **Recycling and Composting: Avoided methane emissions from landfills**. In the oxygen-poor landfill environment, a portion of carbon in waste converts to methane. Many large landfills capture a portion of this methane and convert the carbon back to CO_2 through combustion. The remaining methane, if not oxidized at the landfill surface, escapes to the atmosphere, where it is a potent greenhouse gas. Recycling and composting (of degradable materials) reduce these emissions.
10. **Recycling and Composting: Avoided carbon storage in landfills**. Slow-to-degrade materials, such as wood, may increase carbon sequestration if disposed of in landfills. To the extent that recycling and composting keep materials out of landfills, the potential for carbon storage is reduced, so this is counted as a contributor to emissions.
11. **Recycling and Composting: Avoided energy recovery credits (landfills)**. Some landfills recover energy from captured methane, thus displacing (offsetting) combustion of fossil fuels elsewhere. As with incineration, to the extent that recycling and composting decrease this credit, it is included here as an increase in emissions.

Table 1 lists each of these emissions categories. The second column illustrates how each contributed to the estimated net emissions reduction of 3.3 MMTCO2e. The largest categories of emissions reductions are indirect forest carbon storage resulting from paper recycling (-2.1 MMTCO2e), and net reductions in "upstream" emissions as recycled wastes displace virgin feedstocks in production (-1.5 MMTCO2e). Composting processes and soil carbon storage contribute relatively little to the total. So do avoided emissions or offsets associated with waste combustion. Landfill-related emissions are significant, with avoided fugitive methane emissions (-0.7 MMTCO2e) offset by avoided landfill carbon storage of non-putrescible biogenic carbon (+1.0 MMTCO2e).

Table 1.
Comparison of WARM and CBEI Treatment of Recycling and Composting in Oregon, 2005

WARM emission/sink/offset category	Emissions, 2005 Oregon material recovery	Reflected in CBEI aggregate results?	Significant omission from CBEI?
1. Recycling: Avoided "upstream" emissions (as recycled materials displace virgin materials) minus recycling transportation emissions	-1,480,000 MTCO2e	Partially – lower emissions associated with average use of recycled material by global industry is reflected in supply chain emissions for consumption in Oregon	Possibly – large emissions reductions only partially included in CBEI
2. Recycling: Indirect forest carbon storage	-2,130,000 MTCO2e	No – forest carbon flux is out of scope	Yes – very large emissions reductions not included in CBEI
3. Composting: Soil carbon restoration and increased humus foundation	-80,000 MTCO2e	No – soil carbon flux is out of scope	Possibly – small emissions reductions not included in CBEI
4. Composting: Transportation, equipment emissions	10,000 MTCO2e	Partially*	No – very small emissions, partially included in CBEI
5. Recycling and composting: Avoided emissions from transport of waste to incinerator	-10,000 MTCO2e	Partially* (CBEI doesn't include emissions for transportation that doesn't occur)	No – net emissions are small, and partially included in CBEI
6. Recycling and composting: Avoided combustion emissions from incineration	-30,000 MTCO2e	Partially* (CBEI doesn't include emissions from combustion that doesn't occur)	
7. Recycling and composting: Avoided energy recovery credit from incineration	70,000 MTCO2e	Partially (CBEI doesn't include energy recovery credit for combustion that doesn't occur; Oregon electricity emissions factor already reflects emissions from Covanta rather than alternative source, but these are distributed across the regional grid)	
8. Recycling and composting: Avoided transport of waste to landfill, landfill equipment	-60,000 MTCO2e	Partially* (CBEI doesn't include emissions for transportation that doesn't occur)	Perhaps – but largely cancelled out by avoided landfill energy recovery credit (below)
9. Recycling and composting: Avoided future fugitive landfill methane emissions	-690,000 MTCO2e	No – CBEI reports landfill emissions on the basis of actual (2005) emissions, not future emissions associated with waste disposal in 2005. However, the actual 2005 emissions are lower than they would be in the absence of recycling and composting, due to historic (pre-2005) recovery activities.*	Potentially – depends on how future emissions reductions from year-2005 recovery compare to year 2005 emissions reductions from pre-2005 recovery
10. Recycling and composting: Avoided carbon storage credit	990,000 MTCO2e	No – carbon flux is out of scope	Yes – large emissions reductions not included in CBEI

WARM emission/sink/offset category	Emissions, 2005 Oregon material recovery	Reflected in CBEI aggregate results?	Significant omission from CBEI?
11. Recycling and composting: Avoided energy recovery credit from landfill gas-to-energy	60,000 MTCO2e	Partially (CBEI doesn't include energy recovery credit for combustion that doesn't occur; Oregon electricity emissions factor already reflects emissions from landfill waste-to-energy rather than alternative sources, but these are distributed across the regional grid)	Perhaps – but largely cancelled out by avoided landfill transport and equipment operations (above)
Total, Recycling and Composting	-3,350,000 MTCO2e**		

*Changes to in-state emissions associated with these activities are reflected in CBEI aggregate results if feedstocks originate from households or government; if feedstocks originate from businesses, then changes to in-state emissions are reflected in CBEI aggregate results to the extent that in-state waste generators are providing goods and services that satisfy (directly or indirectly) final demand in Oregon.
**Doesn't exactly match sum of individual rows due in part to rounding.

CBEI's Treatment of Emissions Associated with Recycling and Composting, and Comparison to WARM

CBEI uses a very different set of boundaries for emissions than EPA's WARM tool. CBEI begins with "consumption," defined in economic terms to equal "final demand" or the purchase of goods and services by Oregon households and governments, as well as investment capital by Oregon businesses. "Consumption" is denominated in dollars. The CBEI model then uses economic input/output approaches to estimate all of the production activity required to satisfy Oregon consumption. Production activity includes activity by final producers, as well as the entire supply chain (first-tier suppliers, second-tier suppliers, etc.). Production activity is divided into three regions (Oregon, rest of U.S. and rest of world), and then multiplied by emissions intensities (emissions per dollar) for each commodity and region. Emissions associated with the purchase of disposal services (by households and government; investment capital does not include purchase of disposal services) is treated in the same manner. Emissions and emissions flux associated with land-use change is not included in CBEI.

How does this treatment compare to treatment of emissions, sinks and offsets in Oregon's separate estimates of the benefits of recycling and composting? The third column in Table 1 compares the two approaches. To summarize:

- Carbon flux associated with paper recycling (indirect carbon storage in forests), composting (storage of carbon in soils treated with finished compost), and landfills (carbon storage in landfills) is not included in CBEI.
- Direct emissions from waste disposal facilities (incinerators and landfills), facility equipment and facility transportation are partially accounted for in CBEI, but only for waste from households and government, and a portion of Oregon businesses.
    - Oregon businesses contribute to these emissions in proportion to how much of their economic activity (production) satisfies "final demand" by Oregon consumers, either directly (as a final producer) or indirectly (as part of a supply chain). Disposal emissions associated with waste from Oregon businesses do not appear in CBEI as "end-of-life" emissions but rather are "upstream" of the consumer; for example, when an Oregon restaurant purchases disposal *services*, CBEI treats the associated disposal emissions in a manner consistent with all other purchases by that restaurant.

  - CBEI uses estimates of landfill emissions for calendar year 2005, which reflects methane generation resulting from waste disposed of in 2005 and years prior (mostly, years prior). In contrast, the recycling/composting benefit calculation takes a "methane commitment" approach, and estimates the lifetime (future) emissions avoidance from waste that otherwise would have been disposed of in 2005 (had it not been recycled or composted). Because a significant portion of waste from Oregon is disposed of in dry landfills, and because the methane generation curve (distribution of emissions over time) at such landfills is expected to be very long and flat (emissions occur in small annual increments for hundreds of years following disposal), future potential emissions reductions from avoided waste disposal in 2005 are probably higher than current (2005) emissions reductions resulting from prior avoided waste disposal. So the avoided landfill emissions benefit of recycling and composting in 2005 may be higher than what is reflected in the CBEI model.
- Avoided energy production credits (at landfills and incinerators) are partially reflected in CBEI, but in a manner that is even more diffuse than the direct emissions from those facilities. CBEI does not provide for a direct "credit" in the same manner that WARM does. Rather, any reduction in emissions as landfills and incinerators produce power that would otherwise be produced by fossil fuel combustion is already reflected in the estimate of emissions associated with regional electricity generation. These emissions "reductions" are reflected both in emissions as Oregon consumers purchase electricity directly (e.g., for home use), and also as regional manufacturers and service providers purchase electricity in the course of satisfying final demand by Oregon consumers (e.g., a restaurant purchases electricity). Alternatively, for the few landfills that sell fuels for thermal (non-electric) applications, associated emissions reductions are reflected in the traditional GHG inventory for Oregon, which in turn serves as the basis in CBEI for estimating emissions intensities for various producing sectors of Oregon economy.
- Emissions reductions as industry uses recycled feedstocks (sourced from Oregon) in the manufacture of new products are reflected in the emissions factors (intensities) for those industries. This is true regardless of whether the recycled feedstocks came from Oregon consumers (households, government) or non-consumers (businesses), or elsewhere. The emissions from producing industries (steel, paper, etc.) reflect average levels of recycled content (vs. virgin feedstocks). To the extent that Oregon may recycle materials at rates that deviate from average, that differential is not reflected in CBEI.

Rough Estimate of Recycling and Composting Benefits (Emissions Reductions) Not Included in CBEI

The final column of Table 1 highlights those types of emissions where exclusion from CBEI may be significant. These are limited to:

- Carbon flux associated with paper recycling (indirect carbon storage in forests), composting (storage of carbon in soils treated with finished compost), and landfills (carbon storage in landfills); net emissions reduction of 1,220,000 MTCO2e not included in CBEI.
- "Upstream" benefits of industry using recycled feedstocks in production, but only to the extent that Oregon recycles materials at rates higher than national or global averages; some fraction of 1,480,000 MTCO2e in reductions not included in CBEI.
- Avoided landfill methane emissions; some fraction of 690,000 MTCO2e in reductions not included in CBEI.

How much of these emissions are actually excluded from CBEI? Approximately 2.2 million MTCO2e, derived as follows:

- Carbon flux associated with paper recycling (indirect carbon storage in forests), composting (storage of carbon in soils treated with finished compost), and landfills (carbon storage in landfills): net emissions reduction of **1,220,000 MTCO2e** not included in CBEI.
- "Upstream" benefits of industry using recycled feedstocks in production: Recovery rates for most materials (in Oregon) can be estimated by comparing recovery quantities against estimated disposal quantities, as derived from Oregon's 2005 waste composition study. These material-specific recovery rates are then compared against national averages provided by EPA (see http://www.epa.gov/osw/nonhaz/municipal/pubs/mswchar05.pdf). For most, although not all, materials, Oregon recycles at rates higher than the national average. If Oregon recycled at national average rates, upstream benefits of recycling would be only 830,000 MTCO2e in reductions. The difference (1,480,000 minus 830,000, or **660,000 MTCO2e** after rounding) are the "added" upstream benefits from recycling in Oregon that represent reductions associated with recycling at rates higher than the national average.

- Avoided landfill methane emissions: recycling and composting in 2005 reduce future landfill GHG emissions by approximately 690,000 MTCO2e. In contrast, landfill emissions in 2005, used in CBEI, are lower than they would have been in the absence of historic (prior year) recycling and composting, due to historic recycling and composting. DEQ roughly estimates that historic (pre-2005) recycling and composting activities in Oregon reduced landfill methane emissions in 2005 by approximately 370,000 MTCO2e. This result was derived by: 1) generating estimates of annual recovery tonnage for methane-producing wastes (food, cardboard, etc.) for the years 1975 to 2005 (using actual data for 1992 to 2005, and extrapolating/estimating backwards to 1975); 2) combining this with lifetime GHG generation potentials (per-ton) and generation (timing) curves for both wet and dry landfills to project avoided methane generation in 2005 for wet and dry landfills (as if all recovery kept waste out of wet or dry landfills, separately); 3) converting from generation to emissions by accounting for average 2005 gas collection and oxidation rates for wet and dry landfills (separately); 4) calculating a weighted average based on wet vs. dry landfills' relative contribution to overall methane emissions in 2005. It is important to understand that these two values represent very different sets of emissions reductions: 690,000 MTCO2e is the avoided future (all years) landfill emissions reductions resulting from recycling and composting in 2005, while 370,000 MTCO2e is an estimate of the reduction in emissions in 2005 resulting from recycling and composting in prior years. None of the former emissions reductions are included in CBEI. Not all of the latter emissions are included, as a portion of Oregon landfill emissions are assigned to non-Oregon consumers (as a consequence of Oregon businesses sending waste to landfills in the course of satisfying out-of-state demand). Nevertheless, the difference between these two approximations, or **320,000 MTCO2e,** provides a rough estimate of the landfill-avoidance benefit of recycling and composting activities in 2005 that isn't otherwise accounted for in CBEI.

Thus, recycling and composting in Oregon in 2005 reduce greenhouse gas emissions by approximately 3.3 million MTCO2e, taking a broad life-cycle perspective. Of this, about 2.2 million MTCO2e of emissions reductions are not included in CBEI. Compared to a total consumption-based inventory of 78.1 million MTCO2e, these additional reductions are relatively small, but not insignificant.