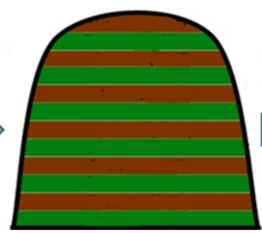
Composting in WARM

Composting is a waste management practice for what the Waste Reduction Model (WARM) calls "organics" (materials of plant or animal origin such as food and leaves). Composting uses microbes to help organics decompose aerobically (i.e., in the presence of air) into a stable, soil-like material. The resulting compost is typically added to soil in order to improve its quality and provide nutrients to plants. The composting pathway in WARM is modeled on large-scale industrial composting, in which large heaps of compost are mechanically turned to ensure even distribution of air, heat, and moisture.

WARM does not model small-scale and backyard composting due to uncertainty caused by the wide range of practices used in those settings. WARM models composting for the following materials: polylactide (PLA), food scraps, yard trimmings, grass, leaves, branches, and mixed organics. The composting **emission factor** (EF) quantifies the greenhouse gas impact (in metric tons of carbon dioxide equivalents ($MtCO_2e$)) per ton of organic materials processed into compost. In WARM, the net greenhouse gas impact from composting all types of organics is negative, implying that composting is a carbon sink—that composting stores more carbon in the soil than it emits to the air.



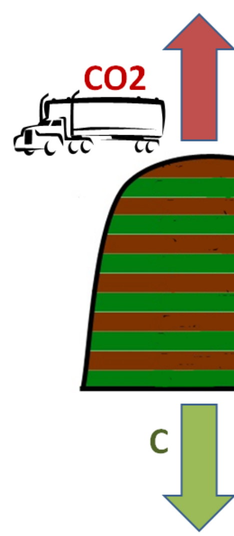
How Is Composting Modeled?

As it is currently modeled, the EF for composting can be divided into three parts: Collection and Transportation, Mechanical Turning of Compost, and Soil Carbon Storage.

1. **Collection and Transportation** (0.02 $MTCO_2e$/ton) results in emissions from the combustion of fossil fuels. In WARM, the default distance for transportation to a central compost facility is 20 miles.[1] This distance can be adjusted by the user to match the individual circumstances being modeled.

2. **Mechanical Turning of Compost** (0.02 $MTCO_2e$/ton) also results in emissions from the combustion of fossil fuels to turn the compost heaps. Compost is turned over regularly for a number of weeks or months (depending on the weather) until the organic inputs have fully broken down.

3. **Soil Carbon Storage** (-0.24 $MTCO_2e$/ton = -0.07 $MTCO_2e$/ton + -0.17 $MTCO_2e$/ton) occurs after the compost is added to the soil. In WARM, the calculation (explained further below) accounts for the organic carbon contained in compost that is then stored in the soil it is applied to.



During composting, most organic compounds decay and release approximately 80 percent of their original carbon as either methane (CH_4) or carbon dioxide (CO_2). The remaining carbon slowly begins to stabilize in the form of "non-reactive humic compounds", which are carbon-

[1] Franklin Associates, Ltd. (1994). *The Role of Recycling in Integrated Solid Waste Management for the Year 2000.*

based soil compounds that are resistant to decomposition. At this point, compost is typically applied to depleted soils, and soil carbon storage can occur.

WARM includes two pieces in its composting soil carbon storage EF. The net soil carbon storage factor combines **direct carbon storage in depleted soils** and carbon **storage through increased formation of stable, non-reactive humus compounds.**

a. **Direct soil carbon storage** occurs when C-rich compost is applied to C-depleted soil. Instead of being released into the atmosphere, this carbon is instead retained by the system. This component of net carbon storage is equivalent to -0.07 $MTCO_2e$/ton.

b. **Increased formation of stable, non-reactive humus compounds** occurs as compost matures and the remaining carbon slowly turns into humic substances (stable carbon compounds). These compounds are resistant to decomposition by microbes and stay in the soil for several decades. This component of net carbon storage is equivalent to -0.17 MTCO2e/ton.

WARM models the extent of direct soil carbon storage using the CENTURY model, a model of plant-soil interactions that simulates long-term behavior of carbon, nitrogen, phosphorus, and sulfur. It tracks the movement of carbon through soils and estimates changes in carbon levels from the addition of compost. The scenario used for WARM assumes that compost is applied to former prairie land now used for corn cultivation.

Combining the EFs for these steps provides the final EF for composting in WARM:

(Collection & Transportation) + (Mechanical Turning) + (Direct Soil Carbon Storage) + (Carbon Stored in Humus Compounds) = ***Net Composting Emissions***

In numerical terms, this is equivalent to:

0.02 $MTCO_2e$ + 0.02 $MTCO_2e$ + -0.07 $MTCO_2e$ + -0.17 $MTCO_2e$ **= -0.20 $MTCO_2e$**

Caveats

The EF developed for the compost pathway in WARM incorporates a number of assumptions. These assumptions are divided into two categories by their impact on the final composting EF, sorted into positive **emissions** and carbon-negative **credits**.

Emissions:

a. Process Emissions: Currently, the EF assumes that composting does not emit any CH_4 or N_2O, because EPA assumes that compost piles are well-managed at centralized compost facilities where these emissions are typically negligible. However, some scientific literature suggests that CH_4 and N_2O emissions are measurable even in well-managed compost piles and may vary widely based on the types of organic inputs. These emissions would increase the greenhouse gas emissions from composting.

Credits:

b. Fertilizer Credit: The nutrient concentration found in compost makes it an excellent soil amendment for some agricultural purposes. If compost is used in place of synthetic fertilizer, it may result in “source reduction” of fertilizer and offset the greenhouse gas emissions of fertilizer manufacturing. However, preliminary research suggests that compost is not usually used to directly replace synthetic fertilizer, but is instead incorporated as part of a plan of soil health improvement, often as part of organic agriculture. Therefore, fertilizer being used to directly offset synthetic fertilizers is likely (1) negligible in amount, (2) not common practice, and (3) highly uncertain.

c. Soil Carbon Storage: WARM uses the CENTURY model to assess the impact of compost use on soil carbon storage in a specific scenario: use as a soil amendment on former prairie land for corn agriculture. This assumption may not be in agreement with current common uses of compost.

The net effect of these changes on the final composting EF is unclear and may require further research. Differences in how compost is marketed and used (in as far as they differ from how WARM models these) may change how compost affects soil carbon storage. Also, the types of organic materials that go into making the compost could differ significantly from what WARM models, and so could have a large impact on the resulting emissions and credits. These caveats have been included to provide users with an understanding of the current limitations and uncertainties of composting in WARM.