Landfill Carbon Storage in EPA's Waste Reduction Model

The storage of carbon in landfills is one of the greenhouse gas (GHG) emission offsets and sinks modeled by EPA's Waste Reduction Model (WARM). WARM allows users to estimate the life-cycle GHG emission benefits associated with waste management practices (recycling, source reduction, landfilling, incineration with energy recovery and composting. The results illustrate the benefits of smarter waste management practices by comparing a baseline waste management scenario to an alternative scenario. Although source reduction and waste prevention are more effective ways to minimize the GHG impact of managing materials, conserving resources, and reducing pollution, landfilling does offer some GHG mitigation potential through carbon storage and offsetting electricity production.

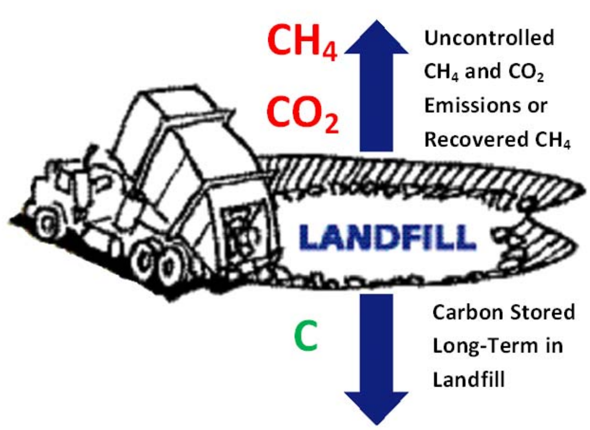
When organic materials derived from biomass sources are landfilled, a portion of the carbon in these materials does not decompose; however, under natural conditions, virtually all of the material would decompose aerobically, and the carbon would be released as biogenic carbon dioxide (CO_2). When the materials are landfilled, aerobic biodegradation is prevented. The carbon in those materials that does not fully decompose in landfills (anaerobically) is removed from the global carbon cycle, is said to be "stored", and is counted as an anthropogenic sink.

Why is Landfill Carbon Storage Included in WARM?

Carbon storage represents a significant part of the overall landfill carbon balance for some materials. EPA estimated that the stock of carbon in U.S. landfills was about 9.5 million metric tons of carbon dioxide equivalent ($MTCO_2E$) in 2008, which is equivalent to offsetting about 7.5 percent of landfill methane emissions. EPA follows the approach outlined by the Intergovernmental Panel on Climate Change (IPCC) international guidelines on GHG inventories, which accounts for the landfill carbon storage of harvested wood products. In addition, the U.S. *Inventory of U.S. Greenhouse Gas Emissions and Sinks* includes carbon storage for yard trimmings and food scraps in accordance with the IPCC recommendation that countries account for all significant emission sources and sinks. Accounting for landfill carbon storage in WARM along with landfill methane emissions provides a more comprehensive estimate of the GHG implications associated with landfilling materials.

Carbon Flows in a Landfill

In landfills, anaerobic bacteria digest organic materials that are derived from biomass sources, including food scraps, yard trimmings, paper, and wood, to produce methane (CH_4) and CO_2. Although the CO_2 emissions would naturally occur from these materials due to natural degradation, the CH_4 emissions would not, and are therefore considered anthropogenic GHGs and accounted for in WARM. The landfilled materials that are not fully decomposed by anaerobic bacteria are stored in the landfill. This remaining undecomposed carbon is considered an anthropogenic sink, since this carbon would have normally been released as biogenic CO_2 from natural decomposition



completing the photosynthesis/respiration cycle. The figure at right illustrates the carbon flows within a landfill. Carbon entering the landfill can have one of three fates: (1) exit as CH_4 (either uncontrolled emissions or recovered and burned for energy), (2) exit as uncontrolled CO_2 emissions, or (3) remain stored in the landfill.

Landfill Carbon Storage Potential

Methane emissions are not released from landfilled inorganic materials (i.e., materials that do not contain carbon such as metals and glass) or from other materials in WARM such as plastics, carpet, concrete, and tires because they do not biodegrade in measurable quantities under anaerobic conditions. Therefore, these materials do not have any landfill carbon storage potential. The carbon from petroleum-based plastics that remains in landfills is not counted as carbon storage in WARM because it is of fossil origin.

The decomposition rate of materials in landfills is affected by a number of factors, such as moisture, nutrients, temperature, and material composition. Organic refuse contains varying amounts of cellulose (the main component of all plant tissues and fibers), hemicellulose (the constituent of plant material that binds with cellulose to form the network of fibers), and lignin (the integral part of the cell wall that fills space between cellulose and hemicellulose). While cellulose and hemicellulose easily biodegrade, lignin does not. In addition, the presence of lignin can also prevent the decomposition of cellulose and hemicellulose. Materials with high lignin content (such as newspapers and branches) have higher landfill carbon storage potential than materials with lower lignin content (such as food scraps). The following table illustrates the landfill carbon storage potential of selected materials in WARM.

Landfill Carbon Storage Potential	Example Material
High	Newspapers Phonebooks Branches Dimensional Lumber Medium-density Fiberboard
Medium	Yard Trimmings
Low	Food Scraps

Conclusion

The inclusion of landfill carbon storage factors allows WARM to more accurately model the carbon flows and emissions that occur for landfilled materials from a life-cycle perspective. However, it is important to note that the landfill carbon storage factor represents one component of the net emissions from landfilling materials. Other components, such as net landfill methane emissions, transportation to the landfill, and avoided electric utility emissions from the use of landfill gas for energy contribute to the full life-cycle implications of landfilling. By including landfill carbon storage, WARM provides a more complete accounting of the GHG emissions associated with different waste management options from a life-cycle perspective.