Challenging the belief that landfill has higher net CO2 emissions than waste-to-energy incineration or composting

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Abstract
Landfill is generally believed to have higher greenhouse gas emissions than composting or waste-to-energy. The EU Landfill Directive requires nations to progressively divert biodegradable waste away from landfill. Waste disposal in landfill is at the bottom of its Waste Hierarchy. Many nations also ban landfilling of plastic. These policies may inadvertently increase global warming by increasing incineration. In Europe, Waste-to-Energy (WTE) incineration emits 72,000,000 tonnes of fossil CO2 a year, increasing yearly. Landfill methane is now generally captured. Nations that directly measure landfill gas emissions (the UK, Ireland and USA) now report about 65- 75% landfill gas recovery; the average for California is 79%. It is now almost always used to generate electricity. When burnt it does not emit fossil CO2. Landfill is a carbon sink, sequestering about half of the organic carbon deposited in it, long-term, like peat. This reduces the global flux of CO2.
Keywords: landfill emissions, waste-to-energy, Waste hierarchy, composting

1. Introduction

Landfill was in the past a significant source of greenhouse gas emissions. In recent years, however, landfill gas recovery has increased to about 65% or higher in countries that directly measure methane generation and recovery. The EU now uses 85% of recovered landfill gas for energy. Much of the unrecovered methane is oxidised by soil microbes. Landfill is also a carbon sink. This study questions the assumption that net emissions from well-managed landfill are still higher than those from Waste-to-energy incineration (WTE) and aerobic composting. It aims to quantify and compare them.

2. Method

Default factors from the Intergovernmental Panel on Climate Change (IPCC 2006) Guidelines for National Greenhouse Gas Inventories were used to calculate typical emissions from composting, landfill and carbon storage. WTE emissions and electricity output data are from the US EPA WARM model (2018). The IPCC default factors were checked to ensure their accuracy. An extensive literature study was conducted to find reliable, objective studies. Waste component data is from 2018 National Inventory reports to the UNFCCC.

COMPOSTING: The IPCC composting emission factors were compared to figures from Amlinger et al (2008); Hellebrand (1997) and recent data from the EU (UBA 2014, Ademe 2012). Indoor composting plants, with oxygen pumped through the waste and nitrogen scrubbers to clean waste gas, have very low emissions but if composting or curing is conducted outdoors the IPCC factors appear reasonably accurate. Seceral nations have b based their "country-specific"composting emission factors othe Austrian Amlinger study, which claims emissions from well-made composting should be no higher than 20-65 kg CO2-e/tonne fresh waste. We found however that emissions from six of the 12 Amlinger experiments were above 65 kgCO2/tonne, and some experiments were conducted in freezing conditions. The IPCC factors appear more accurate for general use.

Table 1. Gross and Net CO2-e emissions after offsets
Unit is kg of CO2-e per tonne of fresh municipal waste (or green waste for composting)

Emissions source	Gross	Net
Compost: CH_4 and N_2O Offset: soil-carbon storage	172.5	**168**
Landfill: CH_4 emissions		
Gas recovery 82%	202.5	**-126.5**
Gas recovery 70%	337.5	**12.5**
Gas recovery 60%	450	**132**
Gas recovery 0	1125	**850**
Offsets: stored carbon; electricity		
WTE: Fossil CO2 Offset: electricity output	550	**373**

Carbon storage in composted soil: Smith et al (2001) claimed significant long-term carbon storage in compost-amended agricultural soil, but this appears to be incorrect. Scientists Jenkinson & Rayner (1977) at Rothamsted Research Farm directly measured decomposition of organic material in agricultural soil: 97.7% of the added organic carbon was gone within four years.
Smith et al also assumed that composting would reduce synthetic nitrogen fertiliser use, and net emissions. But synthetic fertiliser is very concentrated. We found the quantity of compost needed to replace it would emit more

CO2-e than the fertiliser itself. Having cleared away incorrect assumptions we calculated net composting emissions as about 168 kg CO2-e/tonne of garden waste.

LANDFILL: We found municipal waste in the EU and USA contained about 150 kg of degradable carbon, producing some 50 kg of CH4 per tonne but avoiding 275 kg/tonne due to carbon storage. Wang et al (2011) found minimal CH4 emissions from timber and none at all from some types of pine and eucalypt. About 90% of the carbon was stored. Wood contains about 45% carbon (IPCC 2006) so landfill avoids more than a tonne of CO2-e emissions per tonne of wood buried. The IPCC (2006) landfill emission factors were checked and found to be conservative, overestimating potential emissions and underestimate sinks. They are widely accepted, but real landfill emissions may be less than those shown above.

WTE INCINERATION: This is seen as clean, renewable energy, replacing harmful fossil fuel, but the energy required to generate electricity comes mostly from fossil fuels: plastics and synthetic rubber etc. The carbon intensity of WTE in the EU and USA was almost as high as for coal-fired power - double the average for electricity in the EU which emits only about 296 kg CO2-e/MWh. Organic waste is also burnt in WTE. It emits CO2, which would have been avoided if the waste were landfilled.

The US EPA regards the energy saved by recycling steel from incinerator ash as an offset against WTE emissions. We found recycling rates were no higher for WTE than for the rest of the USA. The recovered steel is reportedly contaminated with copper. We did not include this offset.

3. Results and Conclusion

Results are shown in Table 1 above. They show that well-managed landfill emits only 12.5 to 132 kg of CO2-e/tonne of waste; less than composting or WTE. When landfill gas recovery is very high, as in California, net emissions from landfill are negative: that is landfill removes more CO2-e emissions from the atmosphere than it creates. This means that current policies such as the EU Landfill Dirctive, the Waste Hierarchy and the ban on landfilling of plastic in some countries are counterproductive. Instead of enforcing an unflexible Waste Hierarchy, nations should be allowed to make their own decisions based on their own waste composition. The hierarchy below prioritises climate change control

Waste
avoidance
Reuse & Recycling
Landfill: rot-resistant wood
LF: mixed waste, gas capture>70%
Anaerobic digestion; aerobic composting
Landfill with <60% gas recovery, or flaring of the gas
Composting as waste disposal, when the compost is not used
WTE including plastic; landfill, nogas capture; open burning; dumping

Figure 1. A new waste hierarchy to control climate change

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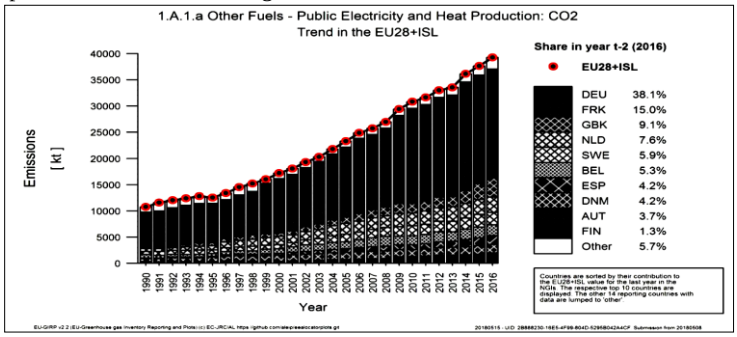

Figure 2. Fossil CO_2 output from waste-to-energy electricity and heat production in the EU
Source: EU Greenhouse Gas Inventory Report for the EU28 and Iceland to the UNFCCC (2019)