WASTE AND CLIMATE Reducing the Impact of Waste

When it comes to addressing climate change, we normally think of greenhouse gas (GHG) emissions from power plants, cars, and heating our homes and businesses. Nearly 45% of global GHG emissions are from areas (such as industry, agriculture, and land use) that clean energy transitions cannot fully address. Sustainable materials management practices can be impactful in achieving additional GHG reductions.[1,2]

If the United States reduced and managed its waste more sustainably, the GHG savings are estimated to be 700 million metric tons of CO_2 equivalent (CO_2e) each year. This is equivalent to closing 90% of coal-fired power plants or taking 156 million passenger vehicles off the road.[3]

Momentum is building for actively addressing the benefits of more sustainable waste management in advancing climate goals - a major initiative focused on more sustainable waste management was announced at the latest international climate meeting, COP 28.[4]

> ***"This triple crisis is in effect one single crisis, a message writ large in the huge amounts of waste our economies generate."***
> Inger Andersen, refers to the triple crises of climate change, nature & biodiversity and pollution & waste during the Launch of Global Waste Management Outlook in February 2024, 6th United Nations Environment Assembly (UNEA-6), 2024.

How can we manage waste more sustainably?

Waste can be managed sustainably by following the Waste Management Hierarchy, a ranking of waste management approaches recognized by the U.S. EPA, the European Union, and the United Nations Environmental Programme. (see Figure 1).[5-7]The hierarchy prioritizes source reduction, the only approach that has no environmental impact. Next is reuse, followed by recycling, energy recovery, and lastly, landfilling for what is left over. By following the hierarchy, we are recognizing waste as a resource – enabling a reduction in our demand for virgin raw materials, lessening our dependence on fossil fuel-fired electricity, and crucially keeping materials out of landfills, and ultimately reducing GHG emissions.

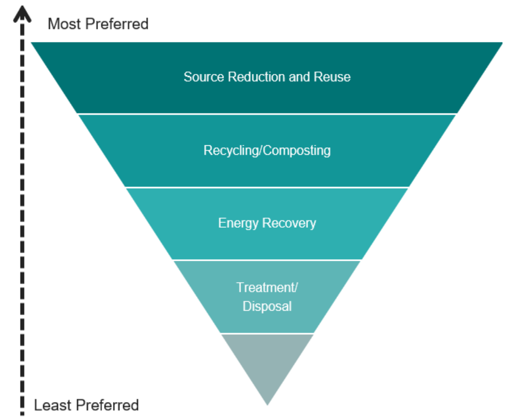

Figure 1*. U.S. EPA Waste Management Hierarchy*

In the United States, two thirds of waste generated annually is landfilled (~250 million tons).[8] In contrast, leading European countries, like Germany and Denmark, have implemented numerous policies to promote the hierarchy and divert nearly all of their solid wastes from landfills (See Figure 2). Policies aimed at landfill diversion and climbing the waste hierarchy have already led to significant reductions in GHG emissions across Europe.[9]

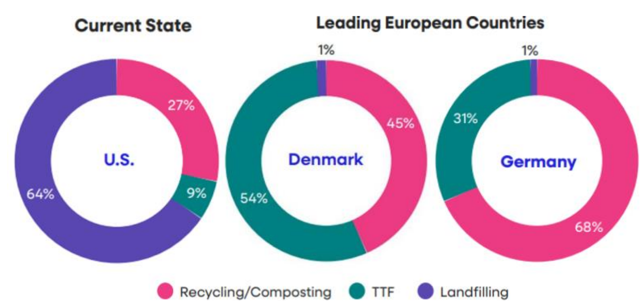

Figure 2. *Waste management practices of the U.S. and leading European countries*[10,11]

Reuse, recycle & recover

The higher tiers of the hierarchy conserve materials, energy and GHG emissions. For example:

Reduce/Reuse. Every ton of food waste reduced can save at least 4.6 tons of CO_2e relative to landfilling.[12]

Recycle. Every ton of aluminum recycled saves 45 MWh of energy and reduces GHG emissions by 10 tons of CO_2e. These reductions are critical in helping industries decarbonize. In order to meet its climate goals, the aluminum sector needs to grow the share of recycled aluminum in the market by 50% by mid-century.[13]

Recover. For waste that can't be recycled, energy recovery is a more sustainable alternative to landfilling. Energy recovery can include anaerobic digestion when the residuals are not reused as compost, processing directly at thermomechanical treatment facilities (TTF, or waste-to-energy), or conversion to an alternative engineered fuel (AEF) that be used as a fossil-fuel replacement.

AEF can help reduce GHG emissions from difficult to decarbonize industries, like cement and lime manufacturing. The Global Cement and Concrete Association estimates a need to increase AEF use ten-fold from the 1990 rate by 2050 to achieve net-zero emissions in the industry.[14]

Energy recovery reduces GHG emissions by reducing the need for fossil fuels, recovering metals for recycling, and diverting organic waste from landfills - where potent GHG methane is generated during the anaerobic decomposition process. The GHG mitigation benefits of TTFs have been recognized both domestically and internationally by the following organizations:

- European Union[15]
- Intergovernmental Panel on Climate Change (IPCC)[16]
- World Economic Forum (WEF) [17,18]
- U.S. Environmental Protection Agency[19]
- National Renewable Energy Lab[20]
- Columbia University[21] & Univ. of Buffalo scientists[22]
- Obama administration Clean Power Plan[23]
- Voluntary carbon markets[24]
- California's Solid Waste Regulator (CalRecycle)[25]
- California Air Resources Board (CARB)[26,27]
- U.S. EPA Scientists[28]
- Berkeley Law Center for Law, Energy & the Environment[29]

Why is it important to divert waste from landfills?

Landfills are a leading source of anthropogenic methane both globally and in the United States.[30,31] When biodegradable waste is placed in landfills, it breaks down anaerobically, generating methane. While many landfills have systems in place to capture and combust this methane, either via flares or for energy recovery, it remains a highly imperfect system, as landfills only capture a fraction of the gas generated. Landfill gas (LFG) escapes through leachate collection systems, around wells and penetrations, through cracks and imperfections in the surface cap, and through the cap itself. Over the life of waste in a landfill, the efficiency of these collection systems is estimated to be only **30 – 55%**, leaving roughly two thirds of methane uncollected and emitted into the atmosphere.[32-37] Furthermore, landfills do not measure their emissions. Rather, landfills use modelled emissions,[38] often leading to underestimated methane reporting.[39]

Direct measurement of landfill methane plumes (see Figure 3), via aircraft downwind of landfills, remote sensing, and satellite data, corroborate this conclusion. A recent UNEP report states landfill methane emissions are likely **underreported by a factor of 2-3x**.[40]

Landfill plume direct measurement studies continue

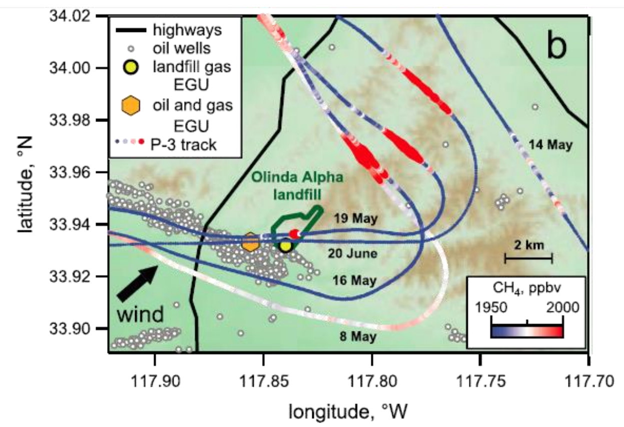

***Figure 3.** Example of landfill methane plume observations in the L.A. Basin*

to be released (Table 1). Most recently, U.S. EPA and NASA scientists published a comprehensive study in the journal *Science* that found actual emissions to be 1.4 to 2.7 times greater than those currently reported in inventories.[41] A prominent NASA study using satellite measurements found a subset of California landfills to be 'super-emitters' of methane, even with the strongest gas collection regulations in the country.[42]

These recent studies reflect a fundamental evolution in how we can measure overall landfill emissions. The existing data in WARM and the GHGRP are overwhelmingly reliant on the use of flux chambers, which have been widely criticized for small sample sizes; large uncertainty; omission of discreet point sources like cracks or system components; interference with methane transport mechanisms; and under-reporting emissions.[44-52]

Study Area	Landfill Inventory ($Gg\ CH_4/y$)	Landfill Measurement ($Gg\ CH_4/y$)	Ratio
L.A. Basin (2013)[53,a]	17.84	24.1 – 43.9	1.9x
California (2014)[54,b]	312	840	2.7x
Indianapolis (2015)[55,a]	13.9	22.5	1.6x
Indiana (2017)[56,a]	3.73	4 – 6.6	1.4x
Baltimore/DC (2018)[57]	19.6	47.3	2.4x
San Francisco Bay (2017)[58]	61.5	88.5 – 143.8	1.9x
California (2020)[59,c]	86.7	115.7	1.3x
L.A. Basin (2017)[60,a]	11.5	14.5	1.3x
LF Average			***1.8x***

Table 1. *Comparison of Measured Emissions to GHG Inventories*

[a] values are for a single landfill within respective scope
[b] values calculated from combined total for landfills/wastewater treatment
[c] sample of California landfills selected for study
[d] average from several days of measurement at single California landfill

Why the focus on methane?

While methane is already identified as the second largest contributor to global climate change,[61] its overall climate impact is much larger than previously understood as atmospheric concentrations of the GHG continue to rise. As a short-lived climate pollutant (SLCP), methane is increasingly under international scrutiny.

According to the IPCC's 6th Assessment Report, methane is over 80 times more potent over 20 years, a timeframe increasingly relevant to the timescale of global climate goals, including reaching net zero by 2050.[62]

> **"Cutting methane is the single fastest, most effective opportunity to reduce climate change risks in the near term."**
> Ilissa Ocko, former Environmental Scientist at the EDF, 2021

A United Nations Environment Programme (UNEP, 2021) report calling for methane reductions asserted that "current methane concentrations are well above those needed to achieve our 2° C target… we cannot achieve the Paris Agreement targets without immediately reducing methane along with carbon dioxide and all other climate forcing emissions."[63]

In the near-term, reducing emissions of SLCPs like methane is more effective than reducing CO_2.[64] The levels of methane mitigation needed to keep warming to 1.5° C will not be achieved by broader decarbonization strategies alone.[65] Focused strategies specifically targeting methane need to be implemented to achieve sufficient methane mitigation.

Researchers have called for alignment of climate policy goals and time horizons for GHG emission metrics.[66] In response to the growing concern about methane and other SLCPs, the 20-year GWP has been adopted by California in its *Short-Lived Climate Pollutant Reduction Strategy*,[67] NY State in its 2019 Climate Bill,[68] and New Jersey.[69] When methane is viewed from the perspective of a 20-year GWP, the climate benefits of sustainable waste management solutions by diverting waste from landfilling are even more compelling.

Methane and health risks

Reducing methane emissions has important health benefits as well, driven by decreases in ground-level ozone.[70-72]

The 2021 UNEP Global Methane Assessment estimated that for every million tons of methane reduced, approximately 1,400 premature deaths would be avoided. Globally reducing methane emissions by 134 million tons (30-35% of current anthropogenic methane emissions) would also translate to a staggering 55 *billion* hours saved in labor losses.[73]

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