LANDFILL GAS Collection Systems and Reporting

When biodegradable waste is placed in landfills, it breaks down anaerobically (in the absence of oxygen), generating methane gas. Methane is a potent short-lived climate pollutant and greenhouse gas (GHG) with a 20-year Global Warming Potential (GWP) of 81.[1-4]

While many landfills have systems in place to capture and combust methane – either in flares or engines for energy recovery – they are not perfect. Collecting a gas like methane from an operating landfill that can extend over hundreds of acres is a significant engineering and operational challenge that must be sustained for decades. As a result, landfills are the third largest source of anthropogenic methane and new data show their emissions are significantly greater than previously estimated.[5]

What is landfill gas?

Landfill gas (LFG) is generated from the anaerobic decomposition of biogenic (i.e., biological origin) materials in waste, such as food waste, paper products, yard wastes, and natural fabrics. LFG is composed of roughly equal parts methane and carbon dioxide (CO_2) and also contains non-methane organic compounds (NMOCs). NMOCs generally consist of ~170 air pollutants, including over 40 air toxins, 4 known carcinogens, and 13 probable carcinogens.[6,7]

While both methane and CO_2 are derived from biogenic sources, their climate impacts are very different. For example, if allowed to decompose aerobically on a forest floor, biogenic sources would mostly release biogenic CO_2 as part of the normal carbon cycle. In contrast, when those same materials degrade anaerobically in a landfill, they also generate methane – a far more potent GHG.

How is landfill gas collected?

LFG is typically collected from a series of vertical and horizontal wells installed through landfill cover materials and into the buried waste. These wells are designed to be operated under a negative pressure (vacuum) to collect gases and to route it to a flare for destruction or to a system that combusts the methane to recover energy. The amount of LFG and its methane composition depends on local conditions and how the LFG system is operated. For example, a stronger vacuum can be used to pull more LFG, but this can both reduce the quality of the gas for energy recovery purposes and risk pulling in oxygen from the atmosphere into the landfill, leading to the risk of landfill fires or explosions. The collection of LFG reduces emissions, and when used for energy generation, can displace the use of fossil fuels.

If landfills collect LFG, what's the issue?

Landfill operators can collect a substantial amount of gas, but it's difficult due to the size of landfills, technological and operational limitations, and the extended duration over which LFG is generated. Also, LFG is not collected during all phases of LFG generation. Current regulations allow landfill operators between 2-5 years after waste is placed in a cell to install gas collection and allow for shutdown of collection systems before gas generation is completely over. Even during normal operating conditions, LFG escapes through cracks and imperfections in the surface cap, around wells and penetrations, through leachate collection systems, and through the cap itself.

Over the life of waste in a landfill, the efficiency of landfill gas collection systems is estimated to be only **30 – 55%,** leaving roughly half of methane uncollected and emitted into the atmosphere.[8-12]

> ***"67% of landfills have emissions exceeding levels reported to the EPA, according to satellite data."***[36]
> America's Hidden Landfill Emissions, Environmental Defense Fund, September 2024

Why can't landfills collect 100% of LFG?

Methane generation varies over a landfill's lifetime and the ability collect that methane is driven by a variety of factors, including the type of collection system and cover in place. The typical gas collection efficiency of a landfill increases over its lifetime as more permanent collection infrastructure and covers are installed.

When waste is first placed in a landfill cell, it is added to the "working face" and covered daily. This "daily cover" is typically made up of soil or similarly permeable materials. The daily cover is designed to allow precipitation into the landfill to promote decomposition, reduce vermin and prevent trash getting carried off-site by wind.

When landfill cell activity decreases, an intermediate cover is placed to mitigate odors and increase the performance of the gas collection system."[13] Even with the intermediate cover, "hotspots" can occur, which are localized areas of increased methane emissions not captured by the collection system. These hotspots can be a significant source of methane emissions.

Toward the end of the life of a landfill or a major phase of its operation, a final cover is installed in preparation for closure. The final cover can consist of clay or a geomembrane cover and must be three feet thick or more.[14] This is meant as a permanent, impermeable seal atop the landfill. The greatest collection efficiencies are attained with final covers; however, emissions still occur due to leaks through surface penetrations (e.g. wells) or cracks, allowing methane to escape.

> ***"Sanitary landfills that are equipped to capture methane at best capture 50% of the methane generated."***[9]
> IPCC 5th Assessment Report.

Instantaneous vs. lifetime collection efficiency

Generally, published collection efficiency values represent an instantaneous efficiency, i.e., the estimated efficiency of a collection system at a single point in time. A *lifetime* collection efficiency, which represents the fraction of methane collected over the lifetime of waste in a landfill, is a more accurate measure of the climate impact of landfilling and is used in lifecycle modeling.[15]

Lifetime efficiencies account for several practical realities regarding LFG collection.

- Landfill gas collection systems are typically not installed when waste is first placed in the landfill, to prevent damage to the systems.
- Once the gas collection systems are in place, there is considerable delay in the installation of a final cover or cap, all the while leaving more permeable cover materials in place.
- Eventually, landfill operators are permitted to turn off their collection systems.

Figure 1 depicts the relationship between lifetime and instantaneous collection efficiencies, considering periods of no gas collection, and the variable efficiency of gas collection systems over time.

How do we know how much LFG is collected?

Over the past decade, more accurate methods have emerged that are able to measure the entire methane plume from a landfill. These methods have generally found methane emissions from landfills to be far

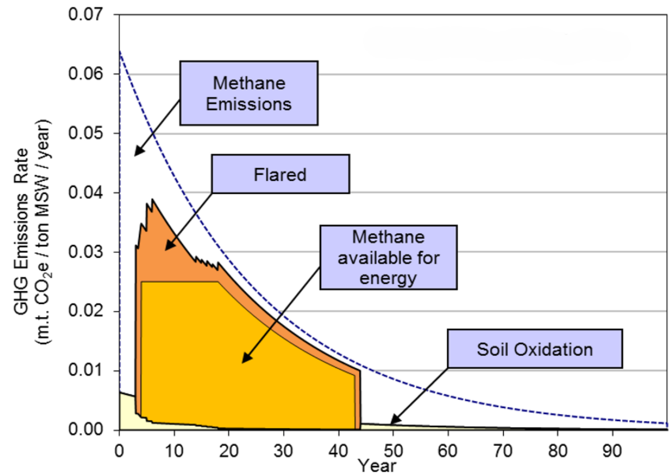

Figure 1. *LFG Lifetime Collection Efficiency Example*

greater than previously estimated.

Estimating instantaneous performance of LFG collection poses unique challenges, given the size of landfills and the variability of emissions over time. In contrast to a point source of emissions such as a stack, landfills are an area source of up to 250 acres or more. Temperature, barometric pressure, precipitation, wind speed, waste age, cover material and thickness, cover condition, and collection system operation all impact emissions and collection efficiency, making landfills a particularly variable source of emissions, temporally as well as spatially.[16,17] New data using sophisticated area source measurement methods employing aircraft and satellites and a conservative approach to developing default collection efficiencies can address these challenges.

Early published values for instantaneous collection efficiency ranged broadly from 14-99%.[18-23] Much of the early estimates on instantaneous collection efficiency were generated using flux chambers, square chambers installed on the surface of a landfill where researchers could measure methane concentrations over time.[24] Flux chambers are widely criticized for small sample sizes and consequent omission of discrete point sources like cracks, interference with methane transport mechanisms, and generally high uncertainty and likelihood of underreporting emissions. [25-31]

A little over a decade ago, as an alternative to flux chambers, the U.S. EPA's Office of Research and Development (ORD) first deployed optical remote sensing for methane plume measurement, to estimate landfill collection efficiency. This early work concluded that "the data collected does not support the use of collection efficiency values of 90% or greater as published in earlier studies."[32]

Later, the National Oceanic and Atmospheric Administration (NOAA) and university scientists measured the downwind plume of two landfills in the Los Angeles Basin via aircraft.[33] Results validated EPA's work based on a 75% collection efficiency[34] for a landfill subject to California's landfill gas rules, arguably the most stringent in North America, and 83% with the final cap in place. An increasing amount of data from similar studies using aircraft indicates landfill emissions are in fact underestimated (see Table 1). A recent UNEP report underscores this finding, which states landfill methane emissions are likely **underreported by a factor of 2-3x**.[35] A more recent analysis by the Environmental Defense Fund (EDF) using satellite landfill monitoring indicates that actual methane emission could be more than 1.6 times what was reported to the EPA.[36]

Table 1. *Comparison of measured emissions to GHG inventories*

Study Area	Landfill Inventory ($Gg\ CH_4/y$)	Landfill Measurement ($Gg\ CH_4/y$)	Ratio
L.A. Basin (2013)[37,a]	17.84	24.1 – 43.9	1.9x
California (2014)[38,b]	312	840	2.7x
Indianapolis (2015)[39,a]	13.9	22.5	1.6x
Indiana (2017)[40,a]	3.73	4 – 6.6	1.4x
Baltimore/DC (2018)[41]	19.6	47.3	2.4x
San Francisco Bay (2017)[42]	61.5	88.5 – 143.8	1.9x
California (2020)[43,c]	86.7	115.7	1.3x
L.A. Basin (2017)[44,a]	11.5	14.5	1.3x
LF Average			***1.8x***

[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

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