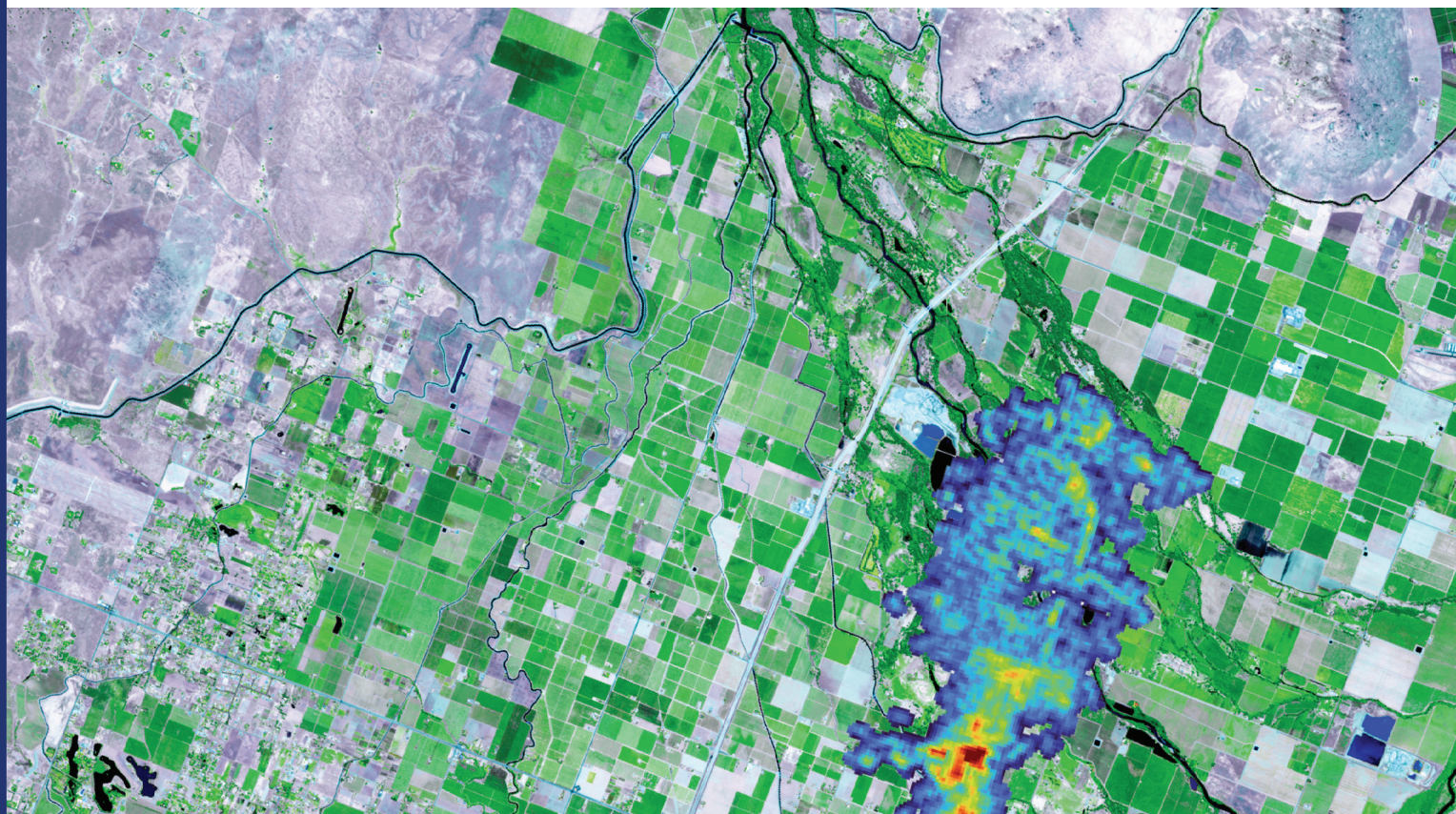
GHGSAT™

TRENDS IN GLOBAL & U.S. LANDFILL METHANE EMISSIONS

A Data-Driven Guide for Policymakers & Industry Operators



EXECUTIVE SUMMARY

For international institutions focused on reducing methane emissions, the waste management sector has drawn increased global attention in recent years. This is for good reason: research from the U.S. Environmental Protection Agency, for example, estimates that **landfills are the third-largest source of human-related methane emissions in the United States**[1]. In reality, their prevalence is likely even more significant than estimated: scientists at Harvard University have found that methane emissions from landfills are up to 51% higher than even the EPA estimates.[2] GHGSat data further confirms this trend.

Because methane has a warming effect roughly 80 times stronger than carbon dioxide over a 20-year period, reducing its levels in the atmosphere can have a swift impact on the climate. In the near-term, every ton of methane reduced will be equivalent to over **100 tons of carbon dioxide reduced over the subsequent five years.**

Methane emissions at landfills are not unexpected: they stem from organic matter like food waste naturally breaking down over time. It's this decomposition process that creates most of the methane as a byproduct of landfill operations.

However, just because methane emissions are expected does not mean that they cannot be mitigated. Pioneering landfill operators have developed gas capture systems to trap and collect methane, and reuse it in a variety of ways, from selling it back to local power grids, powering on-site operations, or converting it to natural gas. These systems are a win-win as they generate additional revenue for landfill operators while also protecting the environment, ensuring clean air and water for local communities.

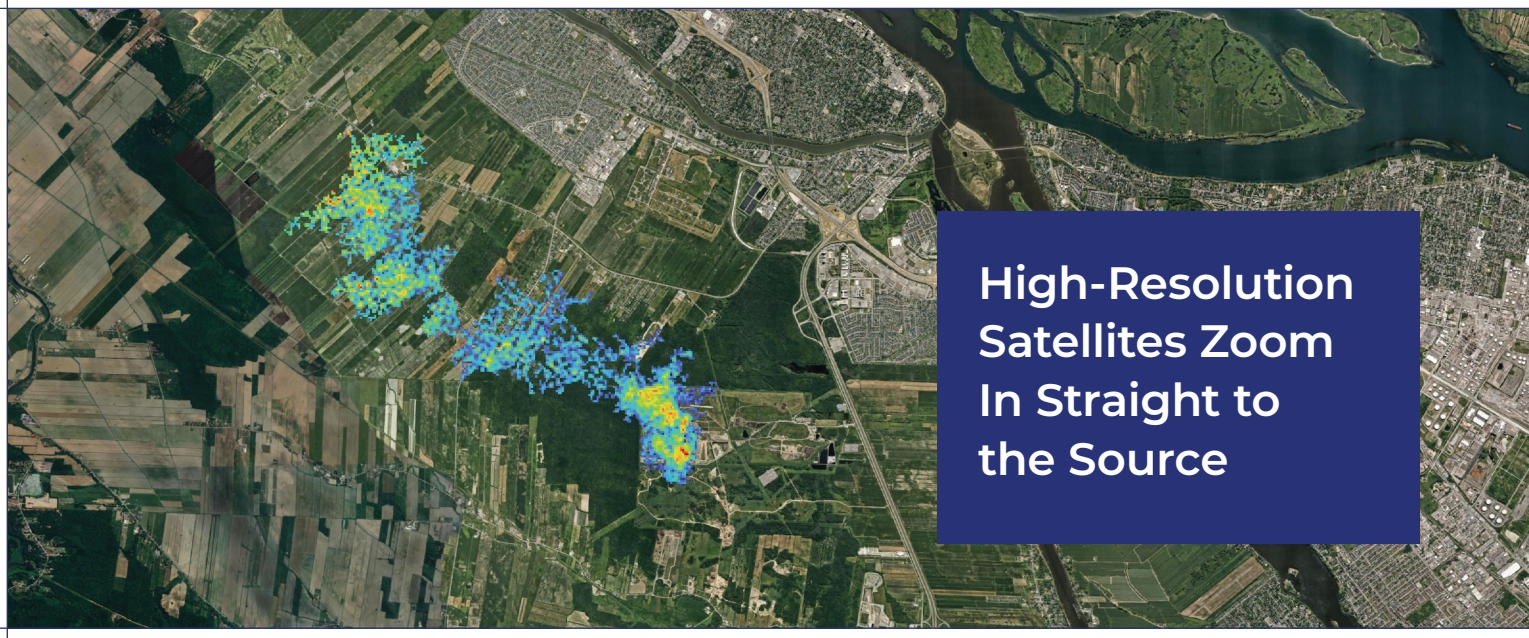
[1] *U.S. Environmental Protection Agency. (n.d.). Basic information about landfill gas. EPA. Retrieved February 15, 2025, from* https://www.epa.gov/lmop/basic-information-about-landfill-gas
[2] *Burrows, L. (2024, May 1). EPA underestimates methane emissions from landfills, urban areas. Harvard John A. Paulson School of Engineering and Applied Sciences. Retrieved February 15, 2025, from* https://seas.harvard.edu/news/2024/05/epa-underestimates-methane-emissions-landfills-urban-areas

Building these systems effectively, however, requires **data that quantifies the methane, and pinpoints its location**. Various technologies are now available to quantify and detect methane emissions, but with an ability to trace emissions to their source at a frequent cadence, high-resolution satellites have emerged as a vital piece of the puzzle.

GHGSat's constellation of high-resolution satellites, alongside its fleet of aircraft, monitor industrial sites around the world, including landfills, at a near-daily frequency, detecting **leaks as small as 100kg/hour**, and providing unprecedented detail on where emissions stem from and how much methane is being emitted.

Drawing on GHGSat's robust catalogue of facility-level emissions data **reveals insights about the global prevalence of methane emissions from landfills, as well as characteristics that are correlated with higher emissions**, so that policymakers and operators can design effective mitigation strategies.

This report highlights findings around the global prevalence of waste management methane emissions, and then zooms in to identify the characteristics of landfills associated with higher detected emissions.



High-Resolution Satellites Zoom In Straight to the Source

KEY TAKEAWAYS

Landfill methane emissions comprise a significant portion of the global picture. Landfills are also more persistent sources of methane than other sectors, which means a given emission is more likely to be observed multiple times upon revisit.

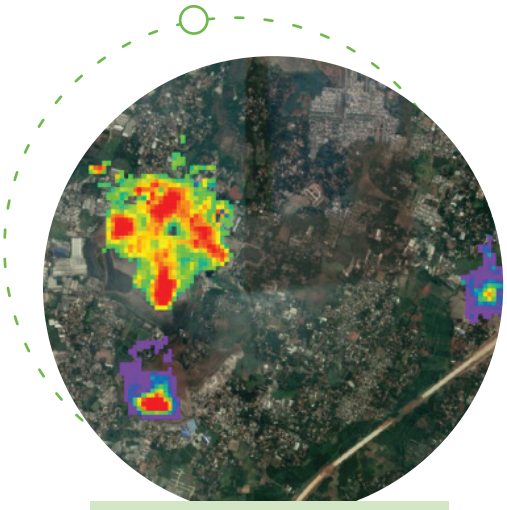
There is significant discrepancy between measured and reported methane emissions. In a pilot analysis of 13 landfills, GHGSat data indicated that nine out of the 13 reported significantly lower emissions than what was directly measured, by a factor ranging from just over one to nearly seven, indicating that models and estimates alone do not provide an accurate picture of emissions.

Across the United States, average source rates vary across regions and states, with the Southeast emerging as the region with the highest emissions. GHGSat data indicated large fluctuations in average source rates across states, with higher emissions in the Southeast—all states with a hotter and wetter climate. However, additional factors can also contribute to this result, such as regulatory practices or waste composition.

Landfills tend to emit the most methane when they have been in operation for 20 to 60 years. Based on this data, this time horizon would be the most fruitful for landfill methane gas capture systems, and one to prioritize for emissions reduction efforts.

These insights are critical for both industry operators and policymakers. For governments and regulators, **a detailed understanding of emissions locations and trends allows for data-driven, effective policy.**

Detecting and mitigating landfill methane also presents an opportunity for industry operators: to **transform methane emissions into additional revenue** via gas capture, ensure on-site energy security, and contribute to a clean environment for all at the same time, demonstrating that positive impacts for local communities and revenue generation goals are not at odds. Accurate and robust data is foundational for these efforts.



Multiple plumes detected
Jakarta, Indonesia

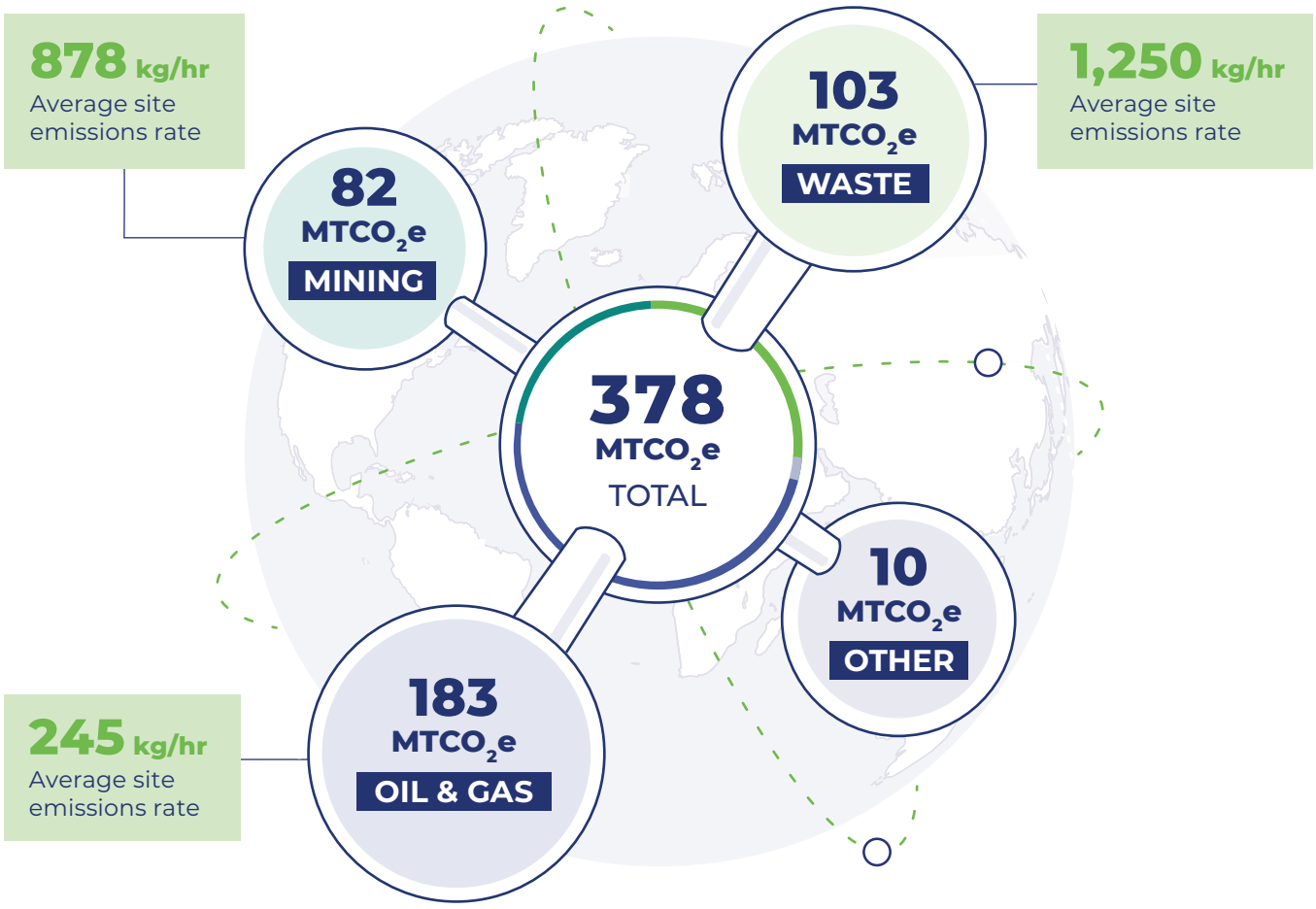
TRENDS ACROSS GLOBAL & U.S. LANDFILL METHANE EMISSIONS

Despite their significant contribution to the total amount of methane in the atmosphere, landfill emissions have often been overlooked in traditional monitoring frameworks.

GHGSat's emissions-monitoring technologies provide unparalleled insight into landfill emissions, tracing emissions to a 25-meter area, to illuminate the sources of methane emissions around the world and quantify the scope of the challenge.

GHGSat Global Emissions from the Waste Sector in 2023

FIGURE 1 **GHGSat's 2023 Methane Emissions Data Summary**



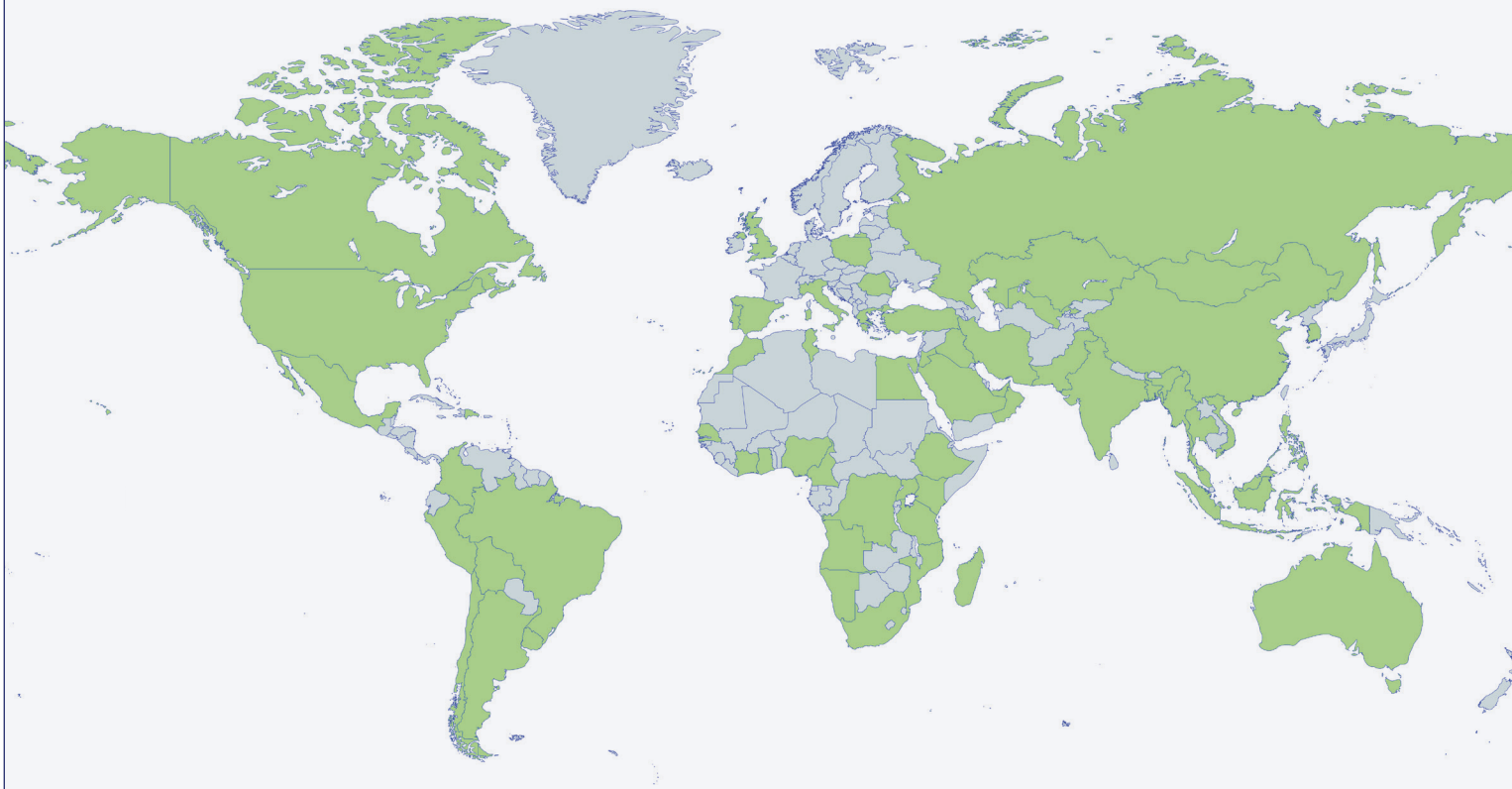
Globally, the waste sector accounted for **27% of all methane emissions detected by GHGSat in 2023** *(Figure 1)*. The waste sector exhibited the highest average source rate, at **1,250 kg/hr, and the highest persistence rate, at 69 percent**. This means that compared to other sectors, detected emissions from landfills were larger and more likely to be observed repeatedly across multiple satellite passes.

This high persistence rate, observed across both developed and developing regions, highlights the widespread challenge of managing diffuse and complex methane sources from landfills.

Landfill methane emissions were detected across six continents and 64 different countries *(Figure 2)* in 2023, providing a comprehensive view of landfill emissions worldwide and revealing distinct regional trends.

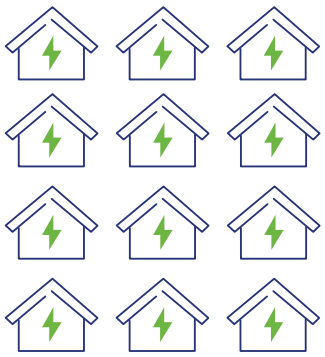
In North America and Asia, detected emissions for each reached nearly 1 $MTCO_2e$, with the two regions together accounting for over 50% of sector emissions measured in 2023. Meanwhile, in South America, **nearly 85% of detected emissions originated from the waste sector**, underscoring the need for concerted mitigation efforts in these regions.

FIGURE 2 **Countries with Detected Waste Sector Emissions in 2023**



U.S. LANDFILL METHANE EMISSIONS

Focusing specifically on the United States, **GHGSat detected more than 810,000 tons of methane emissions** from the waste management sector in 2023, equivalent to the emissions stemming from the annual electricity use of more than 4.7 million homes.



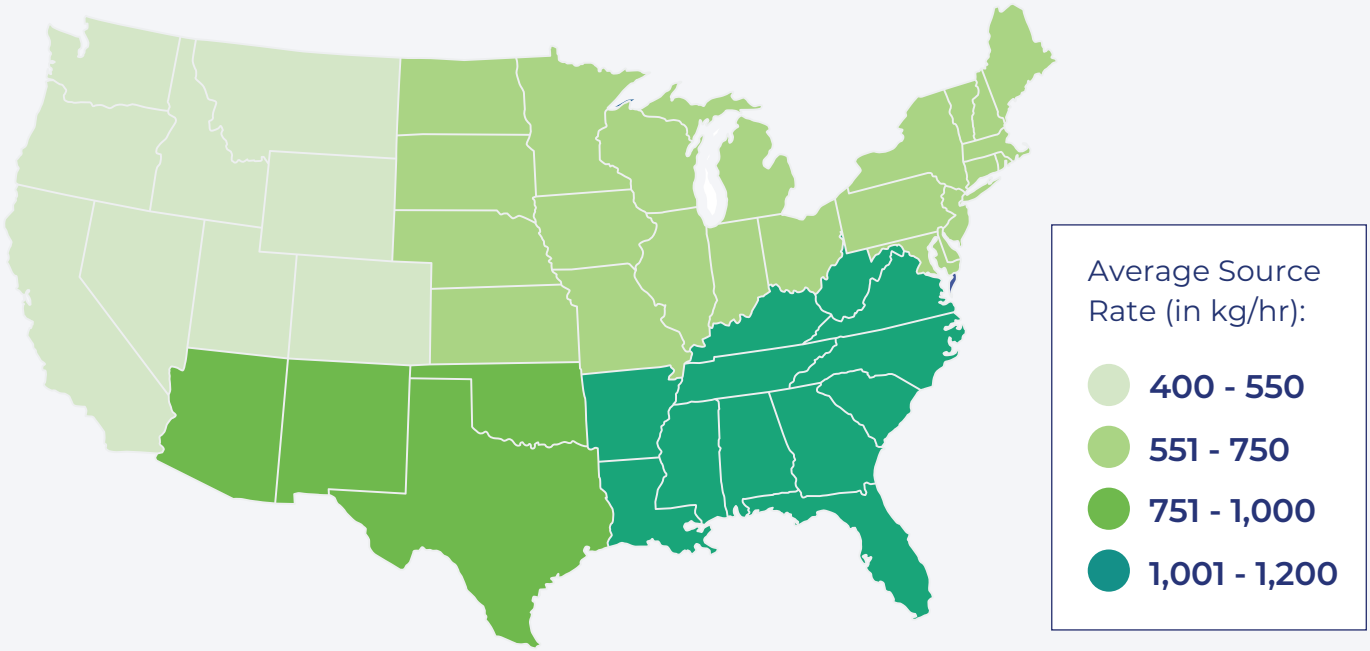
4.7M

Emissions detected equivalent to the annual power use of 4.7M+ homes.

This total was derived from standard methodologies for calculating site-level emissions inventories that takes factors such as null observations, error rates, persistence rates, and more, into account.

GHGSat's extensive dataset enables comparisons of **average source rates across regions** *(Figure 3)*. The Southeast exhibited higher emissions than any other region, likely related to its hotter and wetter environment. Additional meteorological factors, including wind patterns and atmospheric pressure, may also influence emissions. Beyond weather, factors like waste composition and landfill-specific characteristics also play a role. Further research is necessary to identify which of these factors contribute most significantly to the region's higher methane emissions.

FIGURE 3 **Site Source Rates - Regional Averages**



At the state level, similar variations in average source rates were observed, likely driven by a combination of climate, different waste management practices, landfill design, and state-specific policies. Preliminary analysis of state-level data showed that states with **more conservative waste management policies exhibited higher emissions.**

Conversely, states with more forward-thinking practices, such as food waste diversion regulations in **California, New Jersey, New York, New Hampshire, and Oregon, recorded lower average methane emissions from landfills.**

Further analysis is needed as the regional variations are difficult to disentangle from other factors, such as environment, landfill characteristics, and waste composition.

Together, however, these trends highlight the potential impact of targeted action at both regional and state levels.

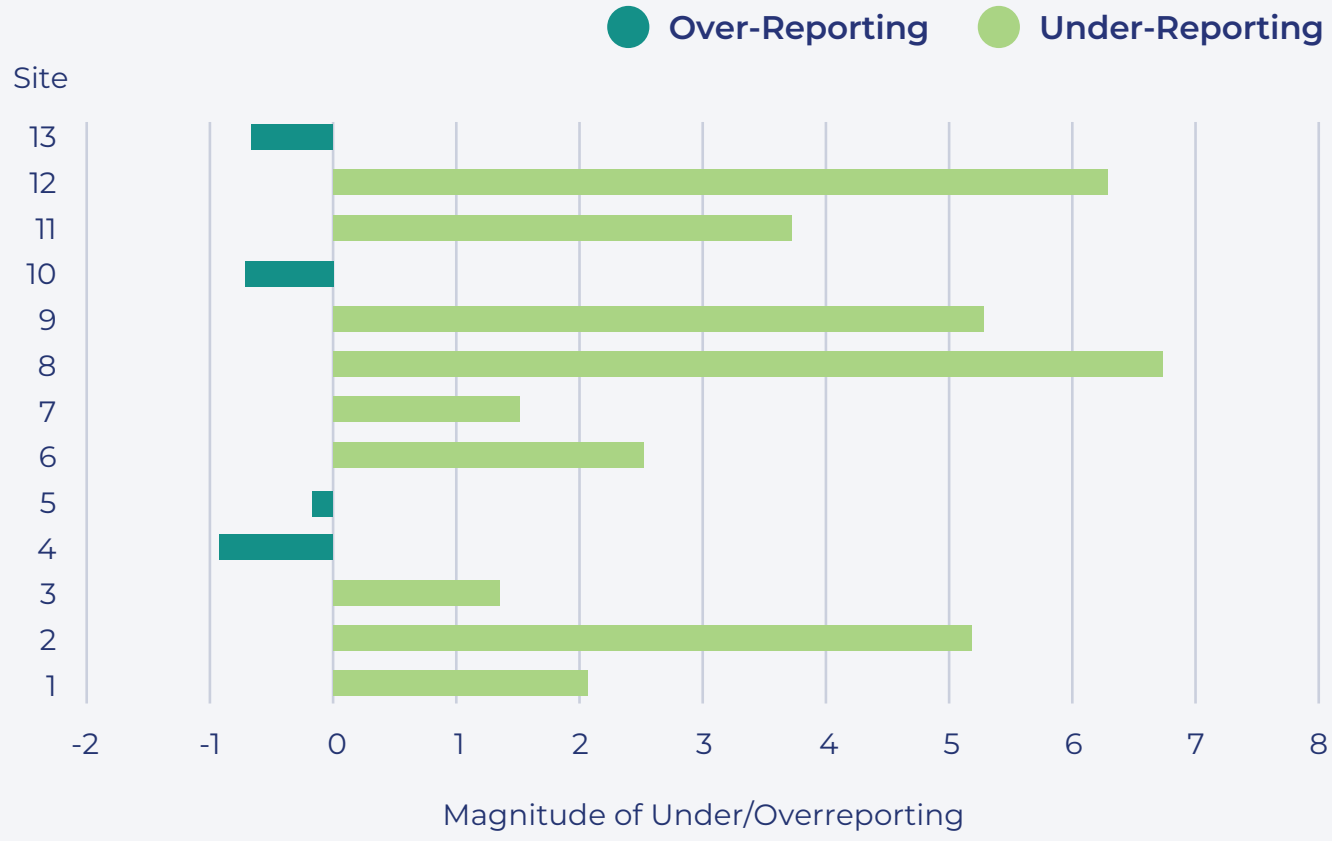
DISCREPANCIES BETWEEN MEASURED AND REPORTED EMISSIONS

Another major finding from GHGSat's 2023 data was a significant discrepancy between measured and reported methane emissions. *(Figure 4)*. In a comparison of sites that had more than 20 GHGSat observations to the reported emissions submitted to the EPA's Greenhouse Gas Reporting Program, nine out of 13 sites reported methane emissions which were significantly lower than those measured, with discrepancies ranging from just over 1x to close to 7x. Overreporting was rare, with only four sites doing so by a small margin.

These findings highlight that self-reported and modelled data are insufficient to provide an accurate picture of methane emissions.

Direct measurements are crucial for understanding the true impact of methane and for supporting policies and monitoring frameworks based on real-world data—particularly as the regulatory environment for the waste management sector is shifting significantly, which will be outlined in the next section.

FIGURE 4 **Discrepancies Between Measured & Reported Emissions at 13 Sites Across the U.S.**



RELATIONSHIP BETWEEN LANDFILL AGE & DETECTED EMISSIONS

Policymakers seeking to design impactful regulatory policy require an understanding of the characteristics of landfills with the highest emissions, so they can ensure regulation is targeted appropriately.

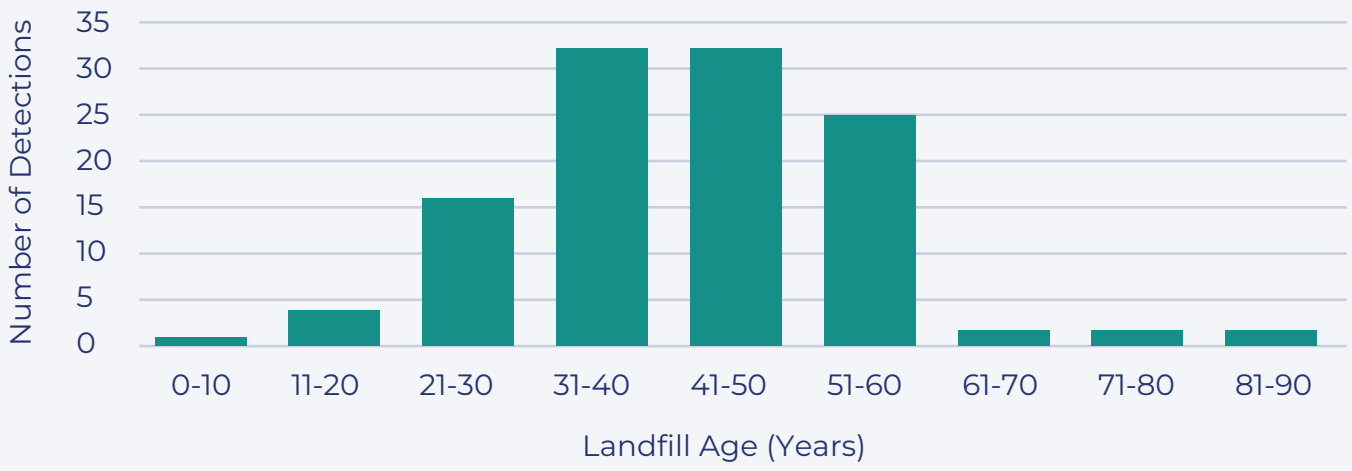
For landfill operators, investment into gas capture systems that can collect the methane emitted from the organic matter, and transform it into energy products, is a cornerstone of a methane mitigation strategy that also can create a new revenue stream. To justify this investment however, operators need a clear picture of their methane emissions: data to build a business case.

With accurate data that quantifies emissions and identifies their sources, landfill operators are equipped to right-size their investment in a gas capture system—no guessing or estimates of their return on investment required.

In this analysis, data from GHGSat's satellite constellation provides this ground truth. By comparing GHGSat's methane detections with U.S. Environmental Protection Agency data on landfill age, a link was identified. GHGSat data confirms a relationship between the age of a landfill and its methane emissions.

Fewer emissions were detected from newer landfills, those in operation for eight years or less. Intuitively, this makes sense, as newer landfills likely have less organic matter in the landfill to decompose and release methane. Notably, the data identifies an inflection point at approximately 20 years in operation, which lasts until a landfill has been operational for 60 years, marking an optimal period to prioritize for gas capture. For policymakers, there is the potential to make the biggest impact in the overall level of methane produced by the landfill if regulations prioritize landfills in this operational age bracket.

FIGURE 5 **2023 Detected Emissions by Landfill Age**



Drawing on GHGSAT data can also support analysis of the revenue potential from methane gas capture systems. This estimate leveraged GHGSat's facility data of methane emissions across five sites. Assuming a 50% methane capture efficiency, based on annual average emissions rates, and based off natural gas pricing information as of January 11th, 2025 (3.650$/mmBTU.), the revenue potential for landfills across Georgia, Texas, Utah, California, and Alabama was calculated. Each site demonstrated significant revenue potential: **capturing landfill methane could generate over $1M per site annually.**

FIGURE 6 **Estimated Revenue Potential from Methane Gas Capture (2023)**

DIVING INTO THE REGULATORY LANDSCAPE

Tackling Emissions from Waste Has Risen on the Global Agenda

This confirmed prevalence of methane emissions from the waste management sector begs the question: **what action is being taken at the global scale to address it?** Regulatory efforts have accelerated in recent years. More broadly, methane has held a place on numerous government agendas since the launch of the Global Methane Pledge (GMP) at COP26 in Glasgow in 2021. However, much of the emphasis has been on reducing emissions from the oil and gas industry, due in part to the relative ease in addressing them as well as their strong contribution to the total compared to other sectors.

That changed with an initial initiative in 2023 at COP28: Lowering Organic Waste Methane (LOW-Methane), which seeks to **lower annual emissions from the waste sector by 1 million tons by 2030.**

This initiative set the stage for a stronger commitment at COP29, where more than **30 member countries signed a declaration on Reducing Methane from Organic Waste**. The signatories to this statement account for nearly half of the global emissions from organic waste, and include the COP29 host Azerbaijan, Türkiye, Morocco, the United States, and Israel, among others.

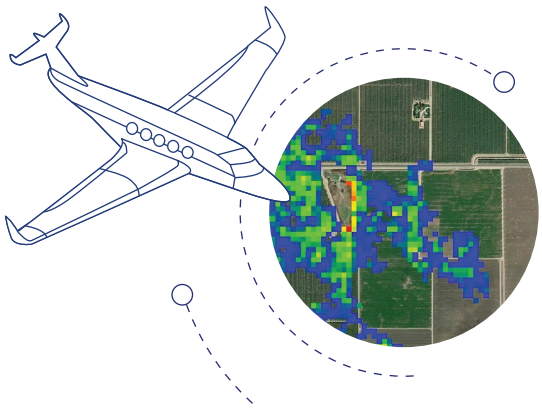
Of note, Russia also signed on to this declaration, which is striking given that it has refrained from signing on to the broader GMP.

The declaration lays out several objectives, including the promotion of interventions that prevent food loss in the value chain, such as when food is damaged or spoils in transit (pre-consumer), and integration of circular practices, such as composting. It also emphasizes the value of increasing international cooperation, unlocking finance for methane reduction projects, and using observation-based techniques for a more accurate understanding of methane emissions.

The declaration further encourages action towards better design of nationally determined contributions (NDCs), recommending improved quantification of emissions targets and the establishment of measurable activities and policies in support of these objectives at both the national and sub-national levels.

Regulations Provide a Lever for Action...

Such policies already exist in varying levels of development across key markets. While there are voluntary efforts underway across various industrial sectors to tackle methane emissions globally, some markets have clearly defined regulations in place to spur action. Well-crafted policies and regulations can serve as valuable tools, providing operators with greater certainty and stability for investments that can lead to higher efficiency in operations and new revenue streams, as in the case of renewable natural gas.

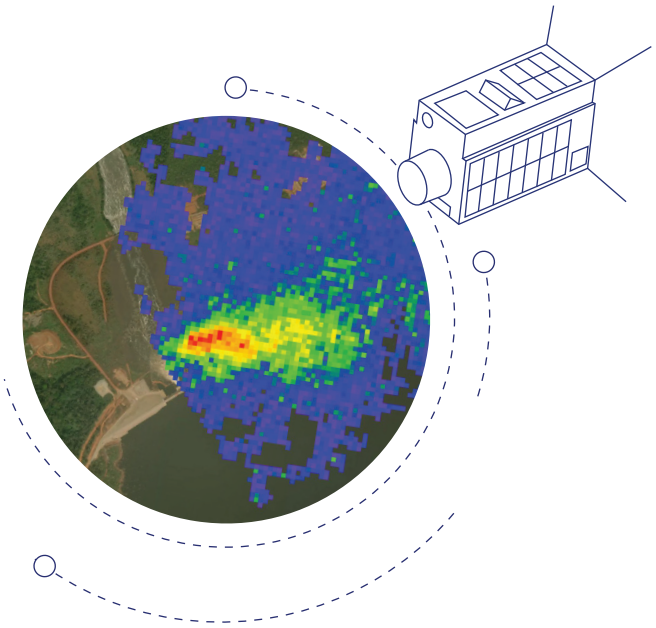


Several countries and regions that are signatories to this declaration, such as Canada, Japan, the EU, and the US, have been active in either adopting and/or drafting policies to reduce emissions from the waste sector. Canada, the EU, and Japan have clear regulations in place, with certain EU member countries having further raised the profile of this issue in their policymaking, such as Spain through its “Circular Spain 2030” strategy.

In terms of expected draft policies, new regulations around methane emissions from the waste sector at the federal level in the U.S. were widely anticipated leading up to 2025. However, the recent change in administration has brought some uncertainty to this timeline.

Nevertheless, regulatory movement continues at the state level in the U.S. Several states have chosen to draft, and enforce, more stringent policies around certain aspects of waste management emissions, such as landfill gas (LFG) capture thresholds and organic waste bans. California was an early adopter of tighter LFG requirements, while Washington state has been the most recent state to sign on through its 173-408 WAC rule, which went into effect in May 2024.

This rule includes several requirements pertaining to other topics, such as monitoring and reporting.



Regarding organic waste bans, Connecticut, Massachusetts, and Vermont have led the charge, enacting food waste bans in 2014, with California and Rhode Island following shortly thereafter. New York, New Jersey, Maryland, and New Hampshire have also joined this effort. These state-level efforts have been met with mixed results, but a recent study has identified Massachusetts as a success story, thanks to its combined availability of food diversion infrastructure, simplicity of regulatory language, low compliance cost, and enforcement[3]. Recent GHGSat observations support this finding.

Further revealing the complex nature of the US regulatory landscape, there are several municipalities that have enacted their own rules and regulations around food diversion, with New York City one of the most recent cities to roll out a curbside organic waste collection program.

[3] *Fiorentia Zoi Anglou et al. ,Of the first five US states with food waste bans, Massachusetts alone has reduced landfill waste.Science385,1236-1240(2024).DOI:*10.1126/science.adn4216

...Though the unique characteristics of regions, sites preclude a one-size-fits-all approach

Extending this example beyond US borders, where waste sites range from small, open dumpsites to large, highly sophisticated, engineered landfills, the patchwork of policies and site characteristics becomes even more complicated, highlighting the inability for operators in the waste industry to uniformly adopt a one-size-fits-all approach to emissions management. However, this uniqueness is where facility-level data from GHGSat provides critical value: **frequent, precise emissions measurements that capture the true picture of methane emissions on the ground.**

CONCLUSION

The availability of precise, accurate data and frequent monitoring through satellite and aircraft technologies like GHGSat's has ushered in a new understanding of the prevalence of landfill emissions.

While the validation that methane emissions from landfills are widely underestimated is disheartening, the data also points towards reasons for future optimism: with a more informed understanding of the sources and amount of methane that stems from landfills, industry operators and policymakers can **make better-informed strategic decisions to capture methane at its source**, transforming it into a revenue stream and mitigating its impact on local communities.

Notes on Satellite Data

This analysis was developed using GHGSAT's facility-level methane emissions data from its constellation of high-resolution satellites. Satellite technology has some coverage limitations, such as being affected by cloud cover or available daylight. GHGSat's detected emissions include an error rate for greater transparency in scientific measurements. While the annualized site numbers above have been adjusted for persistence rates using an established methodology, individual emission error rates have been excluded from these calculations. More broadly, given the historic challenges of quantifying diffuse sources of methane emissions, academic and scientific research is underway, including between GHGSAT and Flux Lab, for example, to rigorously validate measurements of diffuse sources.

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