# SATELLITE MONITORING OF ANNUAL U.S. LANDFILL METHANE EMISSIONS AND TRENDS

This study uses satellite observations of atmospheric methane concentrations to estimate methane emissions from four large landfills in the southeastern United States over the period 2019–2023. These estimates are then compared to results from two different models used to calculate emissions under the U.S. Greenhouse Gas Reporting Program (GHGRP). The authors find large discrepancies between estimates developed using satellite monitoring data and the model-based estimates reported by landfill operators. They conclude that reported emissions, which the U.S. Environmental Protection Agency (EPA) uses to develop its national greenhouse gas inventory (GHGI), may be substantially understating actual emissions (as much as six-fold, on average, for the landfills studied). Further, a downward trend in reported emissions in recent years is likely an artifact of landfill operators choosing a favorable estimation methodology. Applying the alternative model yields the opposite result — increasing rather than declining emissions — and is more consistent with evidence from satellite monitoring.

## Context and methodology

The decomposition of organic waste under anaerobic conditions generates methane, a potent greenhouse gas. Landfills are known to be a significant source of methane, accounting for 17% of anthropogenic methane emissions in the U.S., according to EPA's national GHG inventory (EPA 2024). All operators of landfills with GHG emissions above 25,000 metric tons $CO_2$-equivalent per year are required to report methane emissions annually. For landfills that have gas collection systems in place, operators must calculate emissions in two ways: (1) based on methane recovered by the gas collection system (the recovery-first model) and (2) by applying a first-order decay rate to waste-in-place (the generation-first model). However, operators can choose which set of results to report. Operators of landfills without gas collection systems must rely on the generation-first model to report emissions.

Previous studies using aircraft and satellite observations suggest that both of these model-based estimation methods frequently understate actual emissions, such that actual landfill emissions could be about 50% higher than the totals reported to EPA and reflected in the national inventory (Cusworth *et al.* 2024, Nesser *et al.* 2024). This study provides more evidence on the question of potential underreporting of landfill methane emissions using observations collected over a period of several years by the Tropospheric Monitoring Instrument (TROPOMI), onboard the European Space Agency Sentinel-5 Precursor low-Earth orbiting satellite. The TROPOMI data provide continuous observations of global daily atmospheric methane concentrations (Lorente *et al.* 2021) and can be used to infer annual emissions and year-to-year emission trends over defined geographic areas.

For this study, Balasus *et al.* focus on four U.S. landfills that are isolated from other methane sources, as indicated by the gridded GHGI (Maasakkers *et al.* 2023), and are successfully observed by TROPOMI in all seasons and for each year. To estimate annual emissions from each landfill, the authors average the TROPOMI data across time, using a technique known as oversampling, which takes advantage of day-to-day shifts in satellite orbits to effectively increase the spatial resolution provided by the TROPOMI observations (Zhu *et al.* 2017).

## Findings and discussion

Figure 1 shows results from the TROPOMI analysis for each of the four selected landfills and compares these results to emissions estimates generated using the recovery-first and generation-first models.
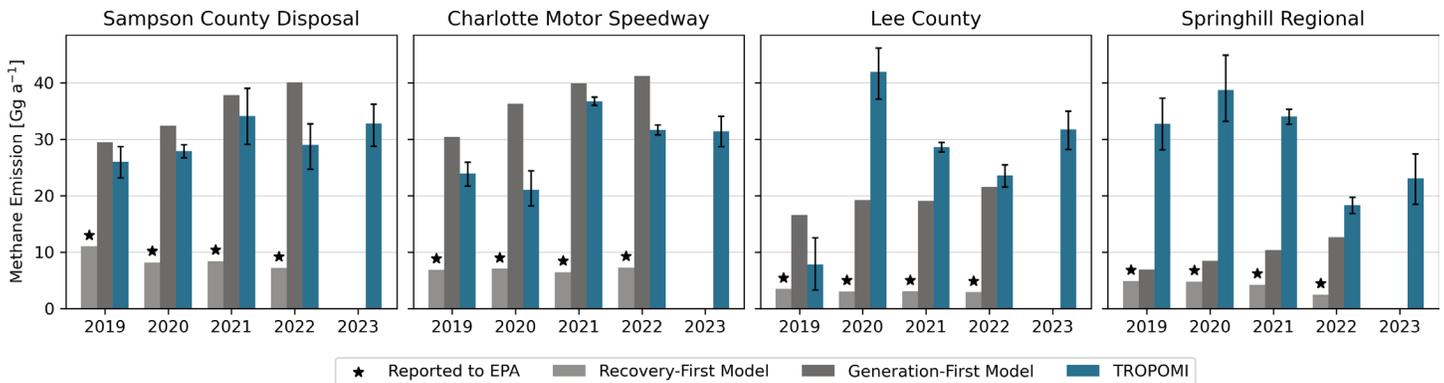


*Figure 1.* Estimates of annual methane emissions from four US landfills for the years 2019–2023. The first two bars for each year are the emissions calculated by the landfills using the recovery-first and generation-first models. The emissions they chose to report to the EPA for inclusion in the national inventory are indicated with a star. Reported emissions for 2023 are not yet available. The third bar for each year is the TROPOMI estimate with 95% confidence intervals.

Several key points emerge from this comparison:

- The recovery-first model, which was used to report emissions for all four of the landfills considered in this study, consistently produces far lower emission estimates than either the generation-first model or the TROPOMI data.

- For two of the landfills (Sampson County and Charlotte Motor Speedway), the generation-first estimates exceed or roughly align with the TROPOMI-based estimates, whereas for the two other landfills (Lee County and Springhill Regional), the generation-first estimates are consistently lower than the TROPOMI-based estimates.

- The recovery-first estimates paint a picture of flat or declining emissions since 2019, but this trend is not supported by the generation-first or TROPOMI-based estimates.

Further examination of emissions estimates from all reporting landfills in the U.S. shows that the 19% decrease in landfill emissions reported by the GHGI over 2005–2022 reflects landfill operators' increasing preference for using the recovery-first model to report emissions, rather than an actual reduction in emissions. Use of the generation-first model, by contrast, would imply an *increase* in landfill emissions over the period 2013–2022, which is more consistent with atmospheric observations. Overall, the authors estimate that landfill methane emissions in the national inventory would be 56% higher than the current estimate for 2022 if the GHGRP required use of the generation-first model (6.7 Tg a$^{-1}$ versus 4.3 Tg a$^{-1}$).

Consistent bias in the methods used to report landfill methane emissions is a significant issue for developing accurate GHG inventories and tracking emission trends. Recent amendments to the GHGRP could help resolve shortcomings of both the generation-first and recovery-first models, although large discrepancies in the results produced by these methods are likely to persist. This suggests that comprehensive atmospheric monitoring will continue to be important to verify the effectiveness of policies to reduce methane emissions from landfills and other sources.

## References

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