Jalisco Landfill Gas and Emissions Modeling Report

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CLEAN AIR TASK FORCE

Global Methane Initiative

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About

About the Clean Air Task Force

Clean Air Task Force (CATF) is a global nonprofit organization working to safeguard against the worst impacts of climate change by catalyzing the rapid development and deployment of low-carbon energy and other climate protection technologies. With 25 years of internationally recognized expertise on climate policy and a fierce commitment to exploring all potential solutions, CATF is a pragmatic, non-ideological advocacy group with the bold ideas needed to address climate change. CATF has offices in Boston, Washington D.C., and Brussels, with staff working virtually around the world. For more information, visit **www.catf.us**.

About the Global Methane Initiative

The Global Methane Initiative (GMI) is a voluntary, multilateral partnership that aims to reduce global methane emissions and advance the abatement, recovery, and use of methane as a valuable energy source in three key sectors: biogas (agriculture, municipal solid waste, and municipal wastewater), coal mines, and oil and gas systems. GMI achieves its goals by creating an international network of Partner Countries and Project Network members who represent the private sector, development banks, research and academic programs, and non-governmental organizations. GMI's Secretariat is hosted by the United States Environmental Protection Agency (U.S. EPA) which provides logistical and technical resource support. View more information about GMI at **www.globalmethane.org**.

About the Waste Methane Assessment Platform

The Waste Methane Assessment Platform (WasteMAP), a joint initiative by RMI and CATF, is an open online platform that brings together waste methane emissions data with decision support tools for stakeholders in the waste sector. The platform is supported by country engagement that involves collaboration with national and subnational governments, waste management officials, and other key decision makers to provide capacity building and technical assistance—providing a pathway to reduce solid waste methane emissions. Please visit **https://wastemap.earth/** to learn more.

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Introduction

Mexico is the second largest solid waste generator in the Latin American and Caribbean Region.

Mexico's waste sector emitted 54.3 million metric tons of carbon dioxide equivalent in 2019, with methane pollution accounting for 93% of these emissions.[1] Methane, a climate pollutant with more than 80 times the potency of carbon dioxide over its short lifetime, is emitted from the decay of organic waste in anaerobic conditions in landfills and dumpsites. Methane abatement is critical for slowing global warming in the near term.

Jalisco, a state in the western region of Mexico, is home to over 8 million people. Jalisco collects approximately 8,815 metric tons of waste each day, making it the third largest generator of municipal solid waste in the country.[2] In 2017, Jalisco's waste sector emitted over 3 million metric tons of carbon dioxide equivalent, accounting for 11% of the state's greenhouse gas emissions.[3]

To better understand emissions from the waste sector and options for mitigation, Jalisco's Ministry of Environment and Land Development (Secretaría de Medio Ambiente y Desarrollo Territorial – SEMADET, in Spanish) expressed interest in understanding the landfill gas (LFG) potential of disposal sites and selected three landfills for further investigation and modeling. Through cooperation between Clean Air Task Force (CATF) and the United States Environmental Protection Agency (U.S. EPA) on behalf of the Global Methane Initiative (GMI), the Puerto Vallarta, Mazamitla, and Tuxpan disposal sites were modeled using U.S. EPA's Mexico LFG model.

This report presents the results of that modeling and proposes opportunities for mitigating methane from solid waste disposal in the state. Section 2 discusses the Mexico LFG model and data obtained for this analysis. Section 3 presents the results of the modeling at each landfill. Finally, Section 4 reports conclusions and recommendations for next steps.

1 Gobierno de México. Secretaría de Medio Ambiente y Recursos Naturales. (2022). México: Tercer Informe Bienal de Actualización ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático. https://unfccc.int/sites/default/files/resource/Mexico_3er_BUR.pdf

2 INEGI. Censo Nacional de Gobiernos Municipales y Demarcaciones Territoriales de la Ciudad de México 2023. Tabulados básicos

3 Replicated from Jalisco's State Emission Inventory for Greenhouse Gases and Compounds for 2017. https://transparencia.info.jalisco.gob.mx/sites/default/files/RESUMEN2%20TRANSPARENCIA-%20IEEGYCEI2017.pdf

Background and Methodology

SEMADET is currently analyzing existing disposal sites in the State of Jalisco and requested assistance in understanding emissions from Los Gavilanes landfill in Puerto Vallarta, SIMAR Sur Sureste landfill in Mazamitla, and SIMAR Sur Sereste landfill in Tuxpan.

CATF and U.S. EPA worked directly with SEMADET to facilitate landfill site data collection for the modeling analysis. SEMADET was given a data input collection form with instructions on specific information required for use in the models. CATF and its local partner SIPRA conducted data validation to ensure accuracy and completeness of the submitted data with additional clarification from SEMADAT, as necessary. Model input data for the three sites are shown in Annex 2. The primary limitation of this data is the level of uncertainty associated with estimates and assumptions about a site's waste and operations (e.g., future waste tonnages, waste composition, LFG collection efficiencies to be achieved, and landfill fire impacts). Frequent data collection via on-site surveys of operations and facilities, waste characterization studies, and standardized reporting can help minimize data limitations.

The U.S. EPA's Mexico LFG Model[4] was used to estimate LFG potential at these sites. It can be used to estimate LFG generation rates at landfills and potential LFG recovery rates for landfills that have, or plan to have, gas collection and control systems in Mexico.

The Mexico LFG Model is an Excel® spreadsheet model that calculates LFG generation by applying a first order decay equation. It requires the user to input site-specific data for landfill opening and closing years, waste disposal rates, landfill location, and to answer several questions regarding the past and current physical conditions of the landfill. It includes default values for waste composition, methane generation rate (k), and potential methane generation capacity (L_0) for each state and estimates LFG collection efficiency based on user input. Default values were developed using data on climate, waste characteristics, and disposal practices in Mexico (based on 2008 data), and the estimated effect of these conditions on the amounts and rates of LFG generation.

Annual waste tonnages disposed at each site, from the operational start year through the projected year of closure, were applied as model inputs to calculate annual LFG and methane generation over a 50-year forecast period. The Mexico LFG Model was used to estimate the annual LFG collection rate that could be achieved after an active gas extraction system is installed and LFG recovery begins at each landfill.

Once the methane potential was estimated, options for methane mitigation were explored, including:

1. Use of LFG for electricity generation

Recovering LFG from landfills for electricity generation results in a productive source of energy while also mitigating methane emissions from LFG that would alternatively be uncaptured or simply flared. Common technologies used to generate electricity from LFG include internal combustion engines, gas turbines, and microturbines. Site characteristics such as LFG flow rate, regional electricity costs, and LFG quality determine project feasibility and are discussed in Annex 1, Table A3.

2. Direct use of the LFG

It may be feasible to use the collected LFG on-site for operational processes or heating, or it could be transported via pipeline to nearby users if economically feasible. Common on-site applications include boilers, process heaters, infrared heaters, and leachate evaporation. For direct use of LFG, the quality of gas dictates available technology options, with some [e.g., direct injection into a pipeline, conversion into compressed natural gas (CNG) or liquified natural gas (LNG)] requiring extensive processing and purification prior to distribution and sale. See Table A2 in Annex 1 for further details.

[4] The model was developed by SCS Engineers under contract to U.S. EPA's Landfill Methane Outreach Program in 2009.

3. Flaring of the LFG

Collecting LFG and using a flare for combustion provides emissions reductions, odor control, and mitigation of subsurface LFG issues (e.g., fires, worker safety) at landfill sites. Combustion of LFG destroys methane and converts it into carbon dioxide thus, resulting in net GHG emissions reductions given methane's higher global warming potential. Flaring can provide methane emissions mitigation at sites which are not feasible for landfill gas to energy (LFGE) projects, however sufficient LFG flow rates are necessary for optimal flare combustion and efficiency. Enclosed flares can have a methane destruction efficiency of 98-99%;[5] however, in practice flare efficiencies are often lower as flares may not be lit, due to a variety of reasons including maintenance, or operating at suboptimal conditions. Table A1 in Annex 1 has further details.

4. Soil or Biocover

Adding or improving the soil/biocover at landfill sites can be a standalone mitigation solution or done in conjunction with the above mitigation options. It presents a low cost and simple means of decreasing fugitive LFG flows and reducing emissions. By using materials such as soil, clay, sand, tarps, or purpose-built covers, fresh waste materials are separated from the outside environment and atmosphere. Daily and/or intermediate cover as a management practice also improves the efficiency of LFG collection for flaring, direct use, or electricity generation.[6] Biocovers are manufactured landfill top covers that optimize the environmental conditions for the oxidation of methane.[7] The mitigation potential of a biocover is dependent on the physical and chemical properties of its materials as well as the environmental conditions of the site.[8]

Collecting LFG for electricity generation or direct use provides economic benefits and can reduce facility operating costs (e.g., on-site electricity or heat generation) in addition to methane emissions reductions. According to Mexican regulations, these are the preferred options for destroying and utilizing methane generated by landfills.[9] While each project context is unique, general LFGE project size recommendations can be found in Annex 1, Table A4. Flaring and landfill biocovers, also recognized as LFG controls in the Mexican regulations, present methane mitigation options that may be implemented where other treatment methods are not feasible—both reduce emissions and can improve landfill operational safety. While flaring LFG does not provide the economic benefits of utilization, it is preferred to passively venting LFG into the atmosphere—the current practice at all three disposal sites examined in this study.

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5 U.S. EPA. (2011). Available and Emerging Technologies for Reducing GHG Emissions from Municipal Solid Waste Landfills. https://www.epa.gov/sites/default/files/2015-12/documents/landfills.pdf

6 Global Methane Initiative. (2012) International Best Practices Guide for Landfill Gas Energy Projects, pg. 18. https://www.globalmethane.org/documents/toolsres_lfg_IBPGcomplete.pdf

7 UN Environment Programme. (n.d.) UN Climate Technology Centre & Network: Biocovers of landfills. https://www.ctc-n.org/technology-library/solid-waste/biocovers-landfills

8 CCAC (2023). Scaling up underfinanced SLCP mitigation solutions: Driving innovation and technology in the waste sector. https://www.ccacoalition.org/sites/default/files/resources/files/TEAP%20Policy%20Brief_15Jan2024.pdf

9 Secretaría de Gobernacíon. (2021). NOM-083-SEMARNAT-2003, Especificaciones de protección ambiental para la selección del sitio, diseño, construcción, operación, monitoreo, clausura y obras complementarias de un sitio de disposición final de residuos sólidos urbanos y de manejo especial. https://www.dof.gob.mx/nota_detalle.php?codigo=5617899&fecha=10/05/2021#gsc.tab=0

Results

Los Gavilanes Landfill, Puerto Vallarta

Data used in the Mexico LFG Model for each final disposal is shown in Annex 2: Jalisco Sites Data Input Forms. The key inputs and assumptions for the Los Gavilanes Landfill used in the Mexico LFG Model that largely define the projected LFG generation and recovery include the following:

- Waste disposal started in 2012 and is projected to end in 2030. About 2 million metric tons of waste have been disposed at the landfill through early 2024. A total of 3.58 million metric tons is expected to be accumulated by the time of closure in 2030.
- The disposed waste consists of approximately 40% food waste, 12% garden waste, 5% paper, and 11% other organic wastes from multiple categories. The remaining 31% consists of inorganic materials, including 13% plastics.
- The landfill has a history of fires which reportedly had a moderate impact over approximately 70% of the landfill area. Under these assumptions, the model applies a 47% discount to the methane productivity (L_0 value) of waste disposed at the landfill, meaning the model assumes that 47% of the organic matter was consumed by fires and will be similarly impacted in the future. The model uses a conservative estimate by carrying forward impacts from past fires and it should be noted that LFG generation could be higher than estimated if fires are avoided at this site in the future.
- It was assumed that the LFG collection would begin in 2026 and 53% collection efficiency could be achieved by the collection system.

Model Results

Model results show LFG generation increasing to a maximum of 1,379 m^3/hour in 2031 before declining. LFG recovery is projected to increase from 597 m^3/hour in 2026 to a maximum of 731 m^3/hour in 2031, before declining after the landfill closes. A graph of the model output is shown in Figure 1.

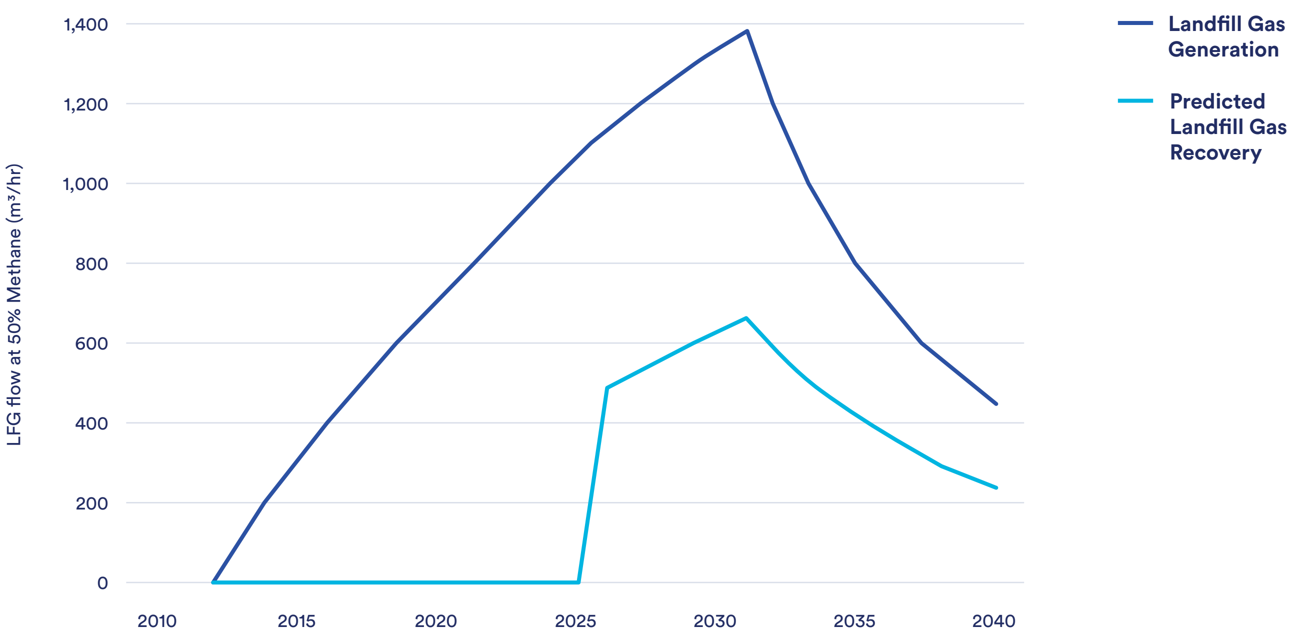
Methane Utilization Potential

Model results show there are multiple options to address methane production from the Los Gavilanes Landfill:

1. **LFG for electricity generation.** The site has the potential to produce enough methane to support a 1-megawatt (MW) electricity generation project for approximately 7 years (2026-2032), after which the LFG recovery rates will likely be insufficient to fuel the facility.
2. **Direct use of LFG.** Direct use of medium British thermal unit (Btu) LFG in industrial facilities is an option if such facilities exist within a few miles of the landfill. However, there is not enough LFG to support a renewable natural gas (RNG) project, which requires many years of sustained flows of at least 1,500 to 2,000 m^3/hour.
3. **Flaring of the LFG.** The LFG can be collected and combusted in a flare, reducing methane emissions from the landfill by about 50% and achieving 80% to 90% of the emissions reduction that would have occurred with a methane utilization project, such as in options 1 and 2 above. Using a 100-year Global Warming Potential[10] (GWP) to convert emissions of methane to carbon dioxide equivalent (CO_2e), cumulative emission reductions over a 15-year period (2026-2040) total about 640,000 metric tons CO_2e from methane collection and combustion, and about 753,000 metric tons CO_2e if cover soils achieve 20% oxidation of uncollected methane. Further, using a 20-year GWP, cumulative emissions reduction over a 15-year period (2026-2040) total about 1.9 million metric tons CO_2e from methane collection and combustion, and about 2.2 million metric tons CO_2e if cover soils achieve 20% oxidation of uncollected methane.

[10] GWP values from the Intergovernmental Panel on Climate Change's (IPCC) sixth assessment report were used. A value of 27 was used for the 100-year GWP, and a value of 79.7 for the 20-year GWP. IPCC. (2021). Climate Change 2021: The Physical Science Basis. Working group 1 Contribution to the Sixth Assessment Report of the IPCC. https://www.ipcc.ch/report/ar6/wg1/

Figure 1: Landfill gas generation and recovery projection for the Los Gavilanes Landfill in Puerto Vallarta, Jalisco



SIMAR Sur Sureste Landfill, Mazamitla

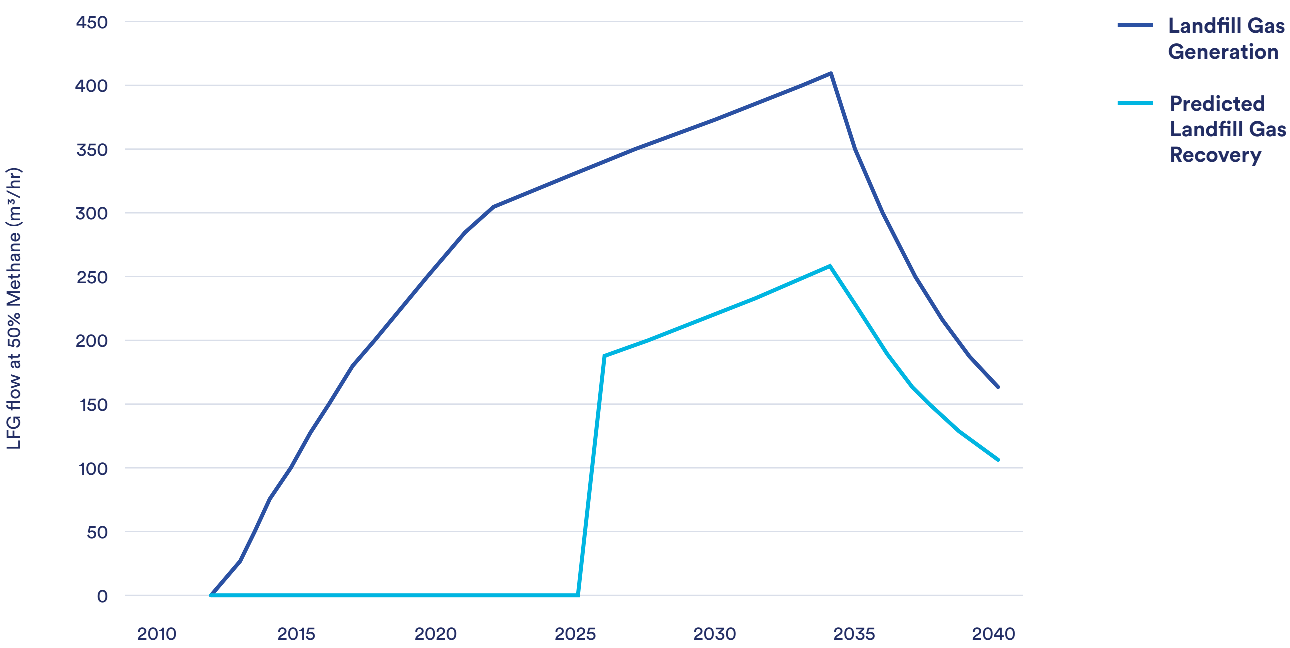
The key inputs and assumptions for the Mazamitla SIMAR Sur Sureste Landfill used in the Mexico LFG Model that largely define the projected LFG generation and recovery include the following:

- Waste disposal started in 2012 and is projected to end in 2033 after 606,878 metric tons of waste have accumulated. There are about 310,000 metric tons of waste in place at the landfill as of early 2024.
- Disposed wastes consist of approximately 65% food waste, 2% garden waste, 6% paper, and 9% other organic wastes from multiple categories. The remaining 18% of waste consists of inorganic materials, including 9% plastics.
- It was assumed that the LFG collection would begin in 2026 and a maximum of 65% collection efficiency could be achieved after the landfill closes in 2033 (the model value calculated based on user-defined site characteristics). Because the landfill's small annual waste accumulation limits initial LFG well installation and is likely to inhibit efficient LFG collection, it was assumed that the collection efficiency would be 55% when the system starts up in 2026 and will incrementally increase each year until after the landfill closes and a final cover is installed, allowing 65% collection efficiency to be achieved.

Model Results

Model results show LFG generation increasing to a maximum of 407 m^3/hour in 2034. LFG recovery is projected to increase from 187 m^3/hour in 2026 to a maximum of 256 m^3/hour in 2034, before declining after the landfill closes. A graph of the model outputs is shown in Figure 2 below.

Figure 2: Landfill gas generation and recovery projection for the SIMAR Sureste Landfill in Mazamitla, Jalisco



Methane Utilization Potential

The Mexico LFG model results show that the Mazamitla SIMAR Sur Sureste Landfill has limited potential to produce sufficient methane to support utilization projects, yet there are a few mitigation options:

1. **Direct use of LFG.** The only feasible utilization option is the direct use of medium Btu LFG in industrial facilities, if any exist within a few kilometers of the landfill.
2. **Flaring of the LFG.** Alternatively, LFG could be collected and flared, reducing methane emissions from the landfill by over 50 percent and achieve emission reductions that total 248,000 metric tons CO_2e over a 15-year period (2026-2040), using a 100-year GWP. The emission reductions are estimated to total 732,000 metric tons CO_2e over a 15-year period (2026-2040), using a 20-year GWP.
3. **Soil or Biocover**
   a. The Model does not produce estimates of methane oxidation, but it is expected that the installation of a soil cover without a gas collection system could oxidize about 10% of methane emissions, which would total about 16,000 metric tons CO_2e emissions reduction (GWP-100) during a 15-year period (2026-2040); emissions reductions are estimated to total about 47,000 metric tons CO_2e using GWP-20.
   b. With a biocover, and no LFG collection, up to 25% oxidation and 40,000 metric tons CO_2e emissions reduction could be achieved in 15 years (GWP-100); using GWP-20, emission reductions from the biocover are estimated to total 117,500 metric tons CO_2e in 15 years.
   c. With a gas collection system achieving up to 65% collection efficiency, oxidation of uncollected methane is more efficient and could reach about 20% with a soil cover and up to 50% with a biocover. This oxidation would result in additional emission reductions of about 32,000 to 80,000 metric tons CO_2e over the 15-year period (GWP-100). Using GWP-20, methane oxidation would increase total 15-year emission reductions by about 94,000 to 235,000 metric tons CO_2e.

SIMAR Sur Sureste Landfill, Tuxpan

The key inputs and assumptions for the Tuxpan SIMAR Sur Sureste landfill used in the Mexico LFG model that largely define the projected LFG generation and recovery include the following:

- Waste disposal started in 2012 and is projected to end in 2025 after 251,740 metric tons of waste have accumulated. There are about 215,000 metric tons of waste in place at the landfill as of early 2024.
- Disposed wastes consist of approximately 65% food waste, 2% garden waste, 6% paper, and 9% other organic wastes from multiple categories. The remaining 18% of waste disposed consists of inorganic materials, including 9% plastics.
- It was assumed that LFG collection would begin in 2026 and a 55% collection efficiency could be achieved, before increasing to a maximum of 64% collection efficiency in 2027 after the landfill installs a final cover.

Model Results

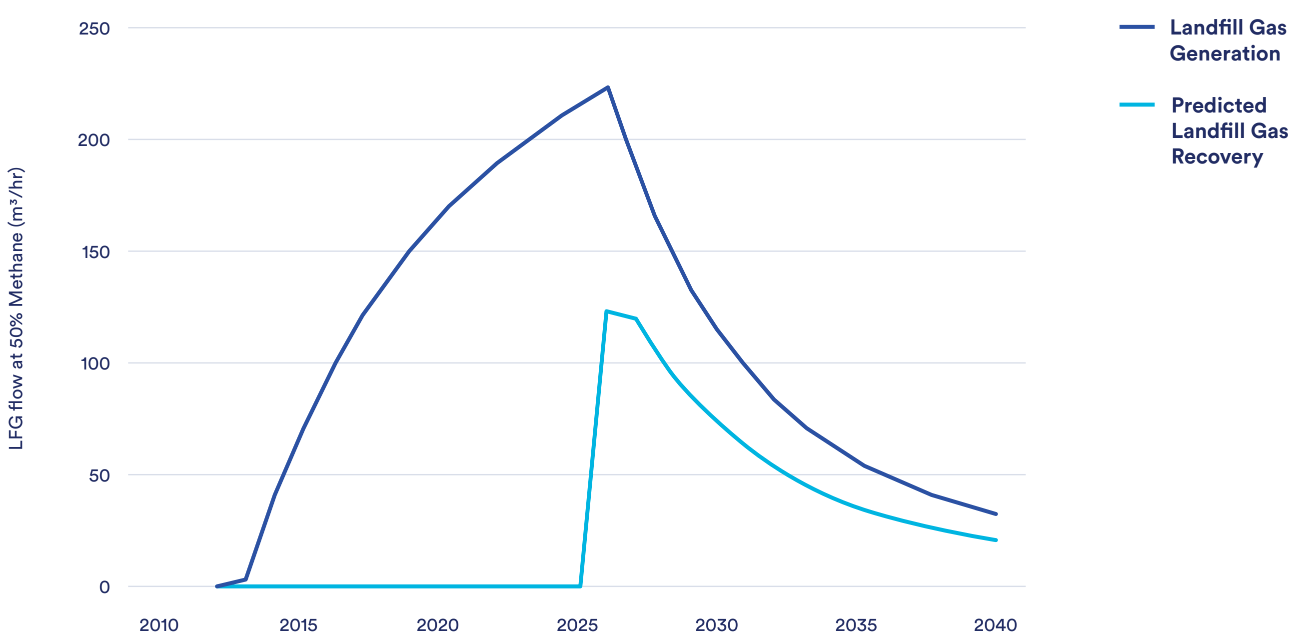
Model results show LFG generation increasing to a maximum of 223 m^3/hour in 2026. LFG recovery is projected to be 122 m^3/hour in 2026, and to decline afterwards due to declining LFG generation. A graph of the model outputs is shown in Figure 3 below.

Methane Utilization Potential

Model results show that the Tuxpan SIMAR Sur Sureste Landfill has very limited potential to produce methane to support utilization projects or LFG flaring but could reduce emissions with the use of a soil cover.

1. **Direct use of LFG.** Direct use of medium Btu LFG in industrial facilities may be a feasible utilization option, if any exist within a few kilometers of the landfill.
2. **Flaring of the LFG.** Collecting and combusting the LFG in a flare will provide minimal amounts of methane emissions reduction due to the small and declining LFG generation rates.
3. **Soil or Biocover.** Although the Model does not produce estimates of methane oxidation, we expect that the installation of a soil cover or biocover could reduce 10 to 25 percent of methane emissions without a gas collection system. This would result in an estimated 12,000 to 30,000 metric tons CO_2e abatement between 2026 and 2040 (GWP-100). Using GWP-20, installing soil or biocovers would reduce emissions by about 34,000 to 87,000 metric tons CO_2e over the same period.

Figure 3: Landfill gas generation and recovery projection for the SIMAR Sur Sureste Landfill in Tuxpan, Jalisco



Conclusions

Four methane mitigation solutions were evaluated for each landfill based on their projected LFG generation. The table below summarizes the feasibility for these different project types by site.

To proceed with one or more of these options, SEMADET will need to conduct detailed feasibility studies to determine the economic viability of the project(s), best end use of the LFG, and investigate potential sources of financing. SEMADET could consider using the electricity generated at the Los Gavilanes landfill onsite to offset operating costs of the facility. It is recommended that SEMADET improve the collection of relevant information from landfills for more accurate modeling of LFG; better data will yield improved estimates of the generation of LFG and potential for gas recovery. Below are some of the categories of information that can be improved:

- Landfill operations data
- Localized and recent waste composition data
- Information on incidents in the landfill, including fires, slope failures, cover failures
- Localized LFG direct usage demand (factories, re-fueling stations, heavy industry)

Further, Jalisco could consider additional actions to improve waste management and mitigate methane in the state. Improving onsite operational practices, such as ensuring proper compaction of the waste, and improving daily and intermediate soil cover, impact emissions and potential generation and collection rates of LFG. In addition, Jalisco could focus on diverting organic waste from landfills in the state and treating it via composting or anaerobic digestion technologies. Both reduce methane emissions and public health impacts from landfills while creating revenue sources from the sale of compost and heat or energy from biogas. The U.S. EPA has developed several tools (e.g., Solid Waste Emission Estimation Tool, OrganEcs, Anaerobic Digestion Screening Tool) to assist local governments in assessing the feasibility and impacts of diverting organics from landfills that could be used to investigate these options.

Table 1: Summary of LFG project feasibility by site

	Los Gavilanes Landfill, Puerto Vallarta	SIMAR Sureste Landfill, Mazamitla	SIMAR Sur Sureste Landfill, Tuxpan
LFGE	1 MW LFGE project feasible from 2026-2032	Not feasible	Not feasible
Direct-Use	Medium Btu LFG pipeline (if end-user facilities are nearby)	Medium Btu LFG pipeline (if end-user facilities are nearby)	Medium Btu LFG pipeline (if end-user facilities are nearby)
Flaring	Flaring to reduce methane emissions (approximately 50%)	Flaring to reduce methane emissions (approximately 50%)	Not feasible
Soil or Biocover	Improve LFG collection efficiency; reduce emissions by increased methane oxidation	Improve LFG collection efficiency; reduce emissions by increased methane oxidation	Improve LFG collection efficiency; reduce emissions by increased methane oxidation

ANNEX 1

LFG Capture and Utilization Resources

The tables below provide a summary overview of several LFG capture, destruction, and utilization options. Note that LFG collection systems are highly dependent on landfill site features and vary in their configurations, efficiency, and local regulatory requirements.

Table A1: LFG Flaring Technology Considerations

Technology	Advantages	Disadvantages	Components Required
LFG collection with flaring	Continued methane mitigation when energy recovery is not feasible or desired. Reduces odors and mitigates emissions at open and closed landfills. More than 99% of methane can be destroyed under optimal conditions.[11]	Initial and ongoing costs required to install, operate, and maintain the collection system and flare. Sufficient methane content and quantities must be available to support stable combustion. Additional costs for supplemental propane may be required at sites with lower gas levels.	Wells and well heads, flares, pipe gathering system, condensate knockout system, blower and skid equipment, and data logger/ thermocouple kit for monitoring. Engineering, permitting, well drilling and site surveys also incur costs.

[11] Methane collection efficiency will vary depending on wellfield coverage, condition of the infrastructure and landfill cover type. U.S. EPA. (2011). Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Municipal Solid Waste Landfills. https://www.epa.gov/sites/default/files/2015-12/documents/landfills.pdf.

LFG can be used as a source of alternative energy, either directly at the site for process energy, or externally via pipelines, RNG sales, and onsite electricity generation sold to the grid. In the tables below, Direct-Use LFG and LFGE technologies are summarized to provide context to SWM planners and landfill operators on the advantages and disadvantages of each technology.

Table A2: Summary of Direct-Use LFG Technologies[12]

Technology	Advantages	Disadvantages	LFG Treatment Requirements
Medium-Quality LFG			
Boiler, dryer, process heater	Can utilize maximum amount of recovered gas flow. Cost-effective. Limited condensate removal and filtration treatment is required. Does not require large amount of LFG and can be blended with other fuels.	Cost is tied to length of pipeline; energy user must be nearby.	Need to improve quality of gas or retrofit equipment.
Infrared heater	Relatively inexpensive. Easy to install. Does not require a large amount of gas. Can be coupled with another energy project.	Seasonal use may limit LFG utilization.	Limited condensate removal and filtration treatment is required.
Leachate evaporation	Good option for landfill where leachate disposal is expensive.	High capital costs.	Limited condensate removal and filtration treatment is required.
High-Quality LFG			
Pipeline-quality gas	Can be sold into a natural gas pipeline.	Increased cost that results from tight management of wellfield operation needed to limit oxygen and nitrogen intrusion into LFG.	Requires extensive and potentially expensive LFG processing.
CNG or LNG	Alternative fuels for vehicles at the landfill or refuse hauling trucks, and for supply to the general commercial market.	Increased cost that results from tight management of wellfield operation needed to limit oxygen and nitrogen intrusion into LFG.	Requires extensive and potentially expensive LFG processing.

12 U.S. EPA, Landfill Methane Outreach Program. (2021). Landfill Gas Energy Cost Model (LFGcost-Web) User's Manual. https://www.epa.gov/sites/default/files/2021-04/documents/lfgcost_web_v3.5_usersmanual_mar2021.pdf.

Table A3: Summary of LFGE Technologies[13]

Technology	Advantages	Disadvantages	LFG Treatment Requirements
Internal combustion engine	High efficiency compared with gas turbines and microturbines. Good size matches the gas output of many landfills. Relatively low cost on a per kW installed capacity basis when compared with gas turbines and microturbines. Efficiency increases when waste heat is recovered. Can add/remove engines to follow gas recovery trends.	Relatively high maintenance costs. Relatively high air emissions. Economics may be marginal in countries with low electricity costs.	At a minimum, requires primary treatment of LFG; for optimal engine performance, secondary treatment may be necessary.
Gas turbine	Economies of scale, because the cost per kW of generating capacity drops as gas turbine size increases and the efficiency improves as well. Efficiency increases when heat is recovered. More resistant to corrosion damage. Low nitrogen oxides emissions. Relatively compact.	Efficiencies drop when the unit is running at partial load. Requires high gas compression. High parasitic loads. Economics may be marginal in countries with low electricity costs.	At a minimum, requires primary treatment of LFG; for optimal engine performance, secondary treatment may be necessary.
Microturbine	Need lower gas flow. Can function with lower percent methane. Low nitrogen oxides emissions. Relatively easy interconnection. Ability to add and remove units as available gas quantity changes.	Economics may be marginal in countries with low electricity costs.	Requires extensive primary and secondary treatment of LFG.

13 U.S. EPA. Landfill Methane Outreach Program. (2021). Landfill Gas Energy Cost Model (LFGcost-Web) User's Manual.

Table A4 below presents some general project sizing estimations which can be used to understand common thresholds for LFGE project types. Site and region-specific context should always be considered during project planning.

Table A4: LFGE Project Sizing Considerations[14]

LFG Energy Project Type	Project Size Estimates
Direct Use (boiler, process heat, etc.)	680 to 5,100 m^3/hr LFG
Boiler Retrofit	Less than or equal to 5,100 m^3/hr LFG
RNG Processing Plant	1,700 to 10,195 m^3/hr LFG
On-site CNG Production and Fueling Station	85 to 1,020 m^3/hr LFG
Standard Turbine-Generator Sets	Greater than 3 MW
Standard Reciprocating Engine-Generator Sets	800 kW and greater
Microturbine-Generator Sets	30 to 750 kW
Small Reciprocating Engine-Generator Sets	100 kW to 1 MW
Combined Heat and Power (CHP) Reciprocating Engine-Generator Sets	800 kW and greater
CHP Turbine-Generator Sets	Greater than 3 MW
CHP Microturbine-Generator Sets	30 to 300 kW

[14] U.S. EPA. Landfill Methane Outreach Program. (2021). Landfill Gas Energy Cost Model (LFGcost-Web) User's Manual.

ANNEX 2

Jalisco Sites Data Input Forms

Below are data used in the Mexico LFG Model for each final disposal site. Sources of the data, and any alterations made by the CATF and GMI teams are indicated below.

Los Gavilanes Landfill, Puerto Vallarta

General	Value	Sources & Notes
Landfill Name	Los Gavilanes	
City	Puerto Vallarta	
State	Jalisco	
Site-specific waste composition data? (Y/N)	Y	
Year opened	2012	SEMADET
Annual disposal (at this site) in 2022 or most recent year (tons)	216,372	SEMADET
Year of disposal estimate entered above	2022	SEMADET
Projected or actual closure year	2030	SEMADET
Estimated average historical growth in annual disposal (%) (site-specific if known, general if unknown)	1.5%	Population growth rate in Guadalajara
Type of site: Unmanaged disposal site, engineered/ sanitary landfill, or semi-aerobic landfill	Sanitary landfill	SEMADET
Average landfill depth (m)	9	SEMADET

Site Fire Details	Value	Sources & Notes
Has the site been impacted by fires? (Y/N)	Y	SEMADET
If a fire occurred, what % of landfill area was impacted?	70	SEMADET
If a fire occurred, how severe was it? (1=low impact, 2=medium impact, 3=high impact)	2	SEMADET

LFG Details	Value	Sources & Notes
Does the site have a (active) landfill gas collection system in place? Or does the site vent gas (passive system)?	Passive vent system	SEMADET
Year of LFG collection system start-up:	2026	Assumption for modeling
Percent of waste area with wells	75	Assumption for modeling
Percent of waste area with final cover	60	Assumption based on data provided by SEMADET
Percent of waste area with intermediate cover	20	Assumption based on data provided by SEMADET
Percent of waste area with daily cover	13	Assumption based on data provided by SEMADET
Percent of waste area with no soil cover	7	Assumption based on data provided by SEMADET
Percent of waste area with clay or synthetic liner	100	SEMADET
Is waste compacted on a regular basis? (Y/N)	Y	SEMADET
Is waste delivered to a focused tipping area? (Y/N)	Y	SEMADET
Does the landfill experience leachate surface seeps or surface ponding? (Y/N)	Y	SEMADET
If yes to above, does this occur only after rainstorms? (Y/N)	Y	SEMADET

Annual Disposal Estimates	Tonnage Estimate (metric ton)	Sources & Notes
2012	120,848	SEMADET
2013	127,422	SEMADET
2014	134,349	SEMADET
2015	141,653	SEMADET
2016	149,358	SEMADET
2017	157,479	SEMADET
2018	166,042	SEMADET
2019	175,072	SEMADET
2020	184,591	SEMADET
2021	194,629	SEMADET
2022	205,214	SEMADET
2023	216,372	SEMADET

Waste Category	Percent Composition	Sources & Notes
Food Waste	40.36	SEMADET. (2022). Jalisco Reduce, Programa Estatal de Gestión Integral de Residuos.
Paper/Cardboard	5.31	
Garden/ Green Waste (includes small branches, prunings, leaves, grass)	11.69	
Wood (includes large branches, stumps, lumber)	1.97	
Rubber, Leather, Bones, Straw	0.27	
Textiles	2.01	
Toilet Paper	5.42	
Other – Organics	0.25	
Diapers (20% organic, 80% inorganic)	7.13	
Metal	1.54	
Construction & Demolition Waste	0.86	
Glass and Ceramics	3.72	
Plastic	12.99	
Other – Inorganic	6.48	
Total	**100**	

SIMAR Sur Sureste Landfill in Mazamitla

General	Value (Write-In)	Sources & Notes
Landfill Name	Simar Sureste	
City	Mazamitla	
State	Jalisco	
Site-specific waste composition data? (Y/N)	Yes	
Year opened	2012	SEMADET
Annual disposal (at this site) in 2022 or most recent year (tons)	27,165.71	SEMADET
Year of disposal estimate entered above	2022	SEMADET
Projected or actual closure year	2033	SEMADET
Estimated average historical growth in annual disposal (%) (site-specific if known, general if unknown)	1.5%	Population growth rate in Guadalajara
Type of site: Unmanaged disposal site, engineered/ sanitary landfill, or semi-aerobic landfill	Sanitary landfill	SEMADET
Average landfill depth (m)	10 m	SEMADET

Site Fire Details	Value (Write-In)	Sources & Notes
Has the site been impacted by fires? (Y/N)	N	SEMADET
If a fire occurred, what % of landfill area was impacted?	N/A	
If a fire occurred, how severe was it? (1=low impact, 2=medium impact, 3=high impact)	N/A	

LFG Details	Value (Write-In)	Sources & Notes
Does the site have a (active) landfill gas collection system in place? Or does the site vent gas (passive system)?	PASSIVE SYSTEM VENTILLATION	SEMADET
Year of LFG collection system start-up:	2026	Assumption for modeling
Percent of waste area with wells	75	Assumption for modeling
Percent of waste area with final cover	70	Assumptions based on data provided by SEMADET
Percent of waste area with intermediate cover	15	Assumptions based on data provided by SEMADET
Percent of waste area with daily cover	15	Assumptions based on data provided by SEMADET
Percent of waste area with no soil cover	0	Assumptions based on data provided by SEMADET
Percent of waste area with clay or synthetic liner	100	SEMADET
Is waste compacted on a regular basis? (Y/N)	Y	SEMADET
Is waste delivered to a focused tipping area? (Y/N)	Y	SEMADET
Does the landfill experience leachate surface seeps or surface ponding? (Y/N)	N	SEMADET
If yes to above, does this occur only after rainstorms? (Y/N)	N/A	

Annual Disposal Estimates	Tonnage Estimate (metric tons)	Sources & Notes
2012	11,611.13	SEMADET
2013	22,583.82	SEMADET
2014	22,119.43	SEMADET
2015	25,413.62	SEMADET
2016	26,778.56	SEMADET
2017	26,582.19	SEMADET
2018	27,494.5	SEMADET

Annual Disposal Estimates	Tonnage Estimate (metric tons)	Sources & Notes
2019	29,295.64	SEMADET
2020	30,789.30	SEMADET
2021	30,443.42	SEMADET
2022	27,165.71	SEMADET

Waste Category	Percent Composition	Sources & Notes
Food Waste	65	Assumptions for modeling. Adapted from the report: SIMAR Sureste, 2021. Informe de Actividades 2021, page 43.
Paper/Cardboard	6	
Garden/ Green Waste (includes small branches, prunings, leaves, grass)	2	
Wood (includes large branches, stumps, lumber)	0	
Rubber, Leather, Bones, Straw	0	
Textiles	3.3	
Toilet Paper	5	
Other – Organics	0	
Diapers (20% organic, 80% inorganic)	2.5	
Metal	2	
Construction & Demolition Waste	0	
Glass and Ceramics	3	
Plastic	9	
Other – Inorganic	2.1	
Total	**100**	

SIMAR Sur Sureste Landfill in Tuxpan

General	Value (Write-In)	Sources & Notes
Landfill Name	SIMAR SUR SURESTE	
City	TUXPAN	
State	Jalisco	
Site-specific waste composition data? (Y/N)	Yes	
Year opened	2012	SEMADET

General	Value (Write-In)	Sources & Notes
Annual disposal (at this site) in 2022 or most recent year (tons)	20, 000	SEMADET
Year of disposal estimate entered above	2023	SEMADET
Projected or actual closure year	2025	SEMADET
Estimated average historical growth in annual disposal (%) (site-specific if known, general if unknown)	1.5%	Population growth rate in Guadalajara
Type of site: Unmanaged disposal site, engineered/ sanitary landfill, or semi-aerobic landfill	Sanitary landfill	SEMADET
Average landfill depth (m)	10	SEMADET

Site Fire Details	Value (Write-In)	Sources & Notes
Has the site been impacted by fires? (Y/N)	Y	SEMADET
If a fire occurred, what % of landfill area was impacted?	20	SEMADET
If a fire occurred, how severe was it? (1=low impact, 2=medium impact, 3=high impact)	1	SEMADET

LFG Details	Value (Write-In)	Sources & Notes
Does the site have a (active) landfill gas collection system in place? Or does the site vent gas (passive system)?	Passive venting system	SEMADET
Year of LFG collection system start-up:	2026	Assumptions for modeling
Percent of waste area with wells	75	Assumptions for modeling
Percent of waste area with final cover	75	Assumptions for modeling
Percent of waste area with intermediate cover	12	Assumptions for modeling
Percent of waste area with daily cover	8	Assumptions for modeling
Percent of waste area with no soil cover	5	Assumptions for modeling
Percent of waste area with clay or synthetic liner	100	SEMADET
Is waste compacted on a regular basis? (Y/N)	Y	SEMADET
Is waste delivered to a focused tipping area? (Y/N)	Y	SEMADET
Does the landfill experience leachate surface seeps or surface ponding? (Y/N)	N	SEMADET
If yes to above, does this occur only after rainstorms? (Y/N)	N/A	SEMADET

Annual Disposal Estimates	Tonnage Estimate (metric tons)	Sources & Notes
2012	1,900	SEMADET
2013	17,900	SEMADET
2014	18,100	SEMADET
2015	18,350	SEMADET
2016	18,690	SEMADET
2017	18,740	SEMADET
2018	18,900	SEMADET
2019	19,250	SEMADET
2020	19,480	SEMADET
2021	19,610	SEMADET
2022	19,890	SEMADET
2023	20,010	SEMADET

Waste Category	Percent Composition	Sources & Notes
Food Waste	65	Assumptions for modeling. Adapted from the report: SIMAR Sureste, 2021. Informe de Actividades 2021, page 43.
Paper/Cardboard	6	
Garden/ Green Waste (includes small branches, prunings, leaves, grass)	2	
Wood (includes large branches, stumps, lumber)	0	
Rubber, Leather, Bones, Straw	0	
Textiles	3.3	
Toilet Paper	5	
Other – Organics	0	
Diapers (20% organic, 80% inorganic)	2.5	
Metal	2	
Construction & Demolition Waste	0	
Glass and Ceramics	3	
Plastic	9	
Other – Inorganic	2.1	
Total	**100**	