ECONOMIC IMPACT ANALYSIS

(Final Analysis)

Item Title: **Regulation Number 31: Control of Methane Emissions from Municipal Solid Waste Landfills**

Meeting Date: **August 20-22, 2025**

ISSUE

During the 2019 and 2023 legislative sessions, Colorado's General Assembly adopted legislation setting statewide GHG emissions reduction goals of 26% by 2025, 50% by 2030, 65% by 2035, 75% by 2040, and net-zero by 2050, as compared to 2005 levels. Statewide GHG pollution is defined as "the total net statewide anthropogenic emissions of carbon dioxide [(CO_2)], methane [(CH_4)], nitrous oxide [(N_2O)], hydrofluorocarbons [(HFCs)], perfluorocarbons [(PFCs)], nitrogen trifluoride [(NF3)], and sulfur hexafluoride [(SF6)] expressed as carbon dioxide equivalent [(CO2e)] calculated using a methodology and data on radiative forcing and atmospheric persistence deemed appropriate by the commission."[1] In February 2024, Colorado released the Greenhouse Gas (GHG) Pollution Reduction Roadmap 2.0, which identifies reducing methane emissions from landfills as a near-term action needed to help achieve the statutory statewide GHG reduction goals.

Municipal solid waste (MSW)[2] landfills in Colorado produced 1.445 million metric tons of CO2e in 2020[3]. As a potent greenhouse gas, the release of methane from landfills contributes to climate change. Capturing and destroying this methane will help to address the rising challenge of climate change and help the state achieve its GHG reduction goals. Because landfill gas also contains toxic compounds and ozone precursors, better managing and

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1 § 25-7-103(22.5), C.R.S.

2 Municipal solid waste (MSW) includes wastes like durable goods, nondurable goods, containers, packaging, food scraps, yard trimmings, and miscellaneous inorganic wastes from various sources. MSW excludes industrial process wastes, automobile bodies, municipal sludge, and combustion ash. The anaerobic decomposition of organic materials found in MSW produces landfill gas (LFG), which comprises approximately 50 to 55 percent methane and 45 to 50 percent carbon dioxide, with less than 1 percent non-methane organic compounds and trace amounts of inorganic compounds. The methane released from landfills is a potent greenhouse gas that is 28 to 36 times more effective than carbon dioxide in trapping atmospheric heat and contributing to climate change.

3 Waste Workbook: 2023 CO GHG Inventory

reducing emissions from landfills would also have a beneficial impact on the health and well-being of communities near MSW landfills[4].

Targeting both MSW landfills that have gas collection and control systems (GCCS) as well as those that do not, the proposed rule aims to reduce methane emissions from MSW landfills. Specifically, based on waste in place and the associated methane generation rate of a landfill, the proposed rule requires the owners or operators of 18 MSW landfills in Colorado that do not currently have a GCCS to install a GCCS or conduct surface emissions monitoring (SEM) to determine if a GCCS must be installed. The proposed rule also requires all owners or operators of MSW landfills with a GCCS and those that will have to install one to monitor their landfill's surface emissions and GCCS for leaks, among other performance measurements. 11 landfills in Colorado that currently have a GCCS under U.S. EPA requirements, 2 active landfills with a voluntary GCCS not subject to U.S. EPA requirements, and the landfills that will have to install a GCCS, are expected to use tighter spacing in conducting surface emission monitoring of their landfill with the goal of better identifying and remediating potential leaks that may be occurring at the landfill. This EIA describes the various compliance options and associated costs, as well as the expected benefits from implementing the proposed rule.

REQUIREMENTS FOR ECONOMIC IMPACT ANALYSIS (EIA)

Section 25-7-110.5(4)(a), C.R.S. sets forth the requirements for the initial and final Economic Impact Analysis, as stated below:

> Before any permanent rule is proposed pursuant to this section, an initial economic impact analysis shall be conducted in compliance with this subsection (4) of the proposed rule or alternative proposed rules. Such economic impact analysis shall be in writing, developed by the proponent, or the Division in cooperation with the proponent and made available to the public at the time any request for hearing on a proposed rule is heard by the commission. A final economic impact analysis shall be in writing and delivered to the technical secretary and to all parties of record five working days prior to the prehearing conference. If no prehearing conference is scheduled, the economic impact analysis shall be submitted at least ten working days before the date of the rule-making hearing. The proponent of an alternative proposal will provide, in conjunction with the Division, a final economic impact analysis five working days prior to the prehearing conference. The economic impact analyses shall be based upon reasonably available data. Except where data is not reasonably available, or as otherwise provided in this section, the failure to provide an economic

[4] Methane emissions from municipal solid waste landfills are managed through two primary methods: containment and capture. Containment involves the use of materials such as soil, compacted clay, geomembranes, bio-covers, or other surface covers to prevent the gas from escaping. Capture is achieved by installing and operating gas collection and control systems. These systems typically comprise vertical wells and, in some instances, horizontal trenches that are embedded within the waste. These wells are connected to header pipes, which direct the gas to a pump or blower station. The application of vacuum pressure by a pump or blower draws the gas towards a control device where it is flared.

> impact analysis of any noticed proposed rule or any alternative proposed rule will preclude such proposed rule or alternative proposed rule from being considered by the Commission. Nothing in this section shall be construed to restrict the Commission's authority to consider alternative proposals and alternative economic impact analyses that have not been submitted prior to the prehearing conference for good cause and so long as parties have adequate time to review them.

Per Section 25-7-110.5(2), C.R.S., the requirements of Section 25-7-110.5(4) shall not apply to rules which: (1) adopt by reference applicable federal rules; (2) adopt rules to implement prescriptive state statutory requirements where the AQCC is allowed no significant policy-making options; or, (3) adopt rules that have no regulatory impact on any person, facility or activity.

Section 25-7-110.5(4)(c), C.R.S., further provides that

> The proponent and the division shall select one or more of the following economic impact analyses. The commission may ask the affected industry to submit information with regard to the cost of compliance with the proposed rule, and, if it is not provided, it shall not be considered reasonably available. The economic impact analysis required by this subsection (4) shall be based upon reasonably available data …

For the purposes of this Economic Impact Analysis, the Division has chosen methodology as set forth in § 25-7-110.5(4)(c)(III), C.R.S.

DISCUSSION

Based on the data available to the Division at this time, the Division provides the following information relating to the proposed Regulation Number 31.

A) Identifies the industrial and business sectors that will be impacted by the proposal; and

B) Quantifies the direct cost to the primary affected business or industrial sector; and

C) Incorporates an estimate of the economic impact of the proposal on the supporting business and industrial sectors associated with the primary affected business or industry sectors.

A) Identify the industrial and business sectors that will be impacted by the proposal

The proposed rule may require additional MSW landfills in Colorado to install and operate a GCCS, among other requirements, to achieve methane emission reductions. The proposed rule will affect both landfills that have a GCCS and landfills that do not yet have a GCCS. Landfills that have a GCCS to comply with federal regulations are expected to incur additional costs because of the tighter monitoring pattern that will be required when conducting SEM and increased frequency of performance testing the GCCS. These landfills are also required to expand their GCCS earlier than they would be required to under federal regulations. All owners or operators of MSW landfills covered by the proposed rule will be required to report the amount of waste at their landfill at least once. If the landfill is active, annual waste-in-place reporting is required. If the amount of waste-in-place exceeds 450,000 tons, an owner or operator must calculate the methane generated from the landfill and possibly incur costs associated with installing and operating a GCCS. The costs of the different elements of the rule are discussed in the sections below.

Businesses that supply services and equipment to landfills are also expected to be affected by this rule. This includes local engineers, consultants, construction firms, equipment vendors, technicians, and utilities that will be involved in performing site assessment, design, drilling, piping, construction, and operation of the GCCS. Engineers and technicians will have increased opportunities for conducting monitoring and reporting activities. Businesses that supply parts and raw materials used to make the GCCS and SEM equipment used in complying with this rule will also be affected by the proposed rule as they will likely see increased demand for new equipment such as piping, pump or blower station, and gas control devices. This will have a cascading effect on industries upstream of the equipment manufacturers that will see a corresponding increased demand for their products and services. The number of jobs supported by these investments is discussed in Section C.

Landfill owners/operators might pass on the cost of compliance to waste collectors in terms of higher tipping fee. Households may see a slight increase in waste collection fees resulting from higher tipping fees charged by landfills to waste disposal companies. Section B contains the estimated potential average yearly increase in waste collection fees per household.

Businesses and households whose interests are affected by climate change will also be impacted by the proposed rule. While this rule might lead to a slight increase in tipping and waste collection fees, by reducing the emissions of greenhouse gases and other air pollutants, this rule will prevent a considerable amount of damage from climate change and benefit such businesses and households. The emission savings and the resulting avoided cost of climate change are discussed in the section below.

B) Quantify the direct cost to the primary affected business or industrial sector

The proposed rule involves reporting requirements such as waste-in-place and methane generation rate reports, as well as requirements for tighter-spaced surface emission monitoring and potentially the installation and operation of a GCCS. Some landfills that already have a GCCS installed are expected to be subject to the tighter space surface emission monitoring requirements and earlier expansion of the GCCS. Landfills that do not have a GCCS installed and meet or exceed certain thresholds would be subject to reporting, tight-space surface emission monitoring requirements, as well GCCS installation requirements. The types of compliance options, corresponding costs, and their applicability are discussed below.

i. Costs of waste-in-place and methane generation rate reporting

MSW landfills are required to report the total amount of solid waste placed in the landfill, or waste-in-place, estimated in tons. If waste-in-place is reported above 450,000 tons the methane generated by the landfill or the methane generation rate, should be calculated and reported. Completing and filing these reports will involve labor costs for hiring an environmental engineer/technician. The annual cost associated with completing each report is $4,840. This cost figure is based on the estimated number of hours needed to complete the reports and the hourly rate for completing them by an environmental engineer/technician that comes from cost estimates for the MSW landfill methane reduction rule promulgated by the Oregon Environmental Quality Commission[5]. Because the cost analysis was done in 2021, the 2025 equivalent of the figure is estimated using the Consumer Price Index (CPI) inflation calculator from the Bureau of Labor Statistics (CPI Inflation Calculator).

Table 1. Costs for Waste-in-Place and Methane Generation Rate Reports

Proposed Requirement	Lump Sum Cost, 2021$	Adjustment factor	Adjusted cost, 2025$[6]
Annual waste-in-place Report	$4,000	1.21	$4,840
Annual GCCS reporting	$4,000	1.21	$4,840
Annual methane generation rate report	$4,000	1.21	$4,840

[5] APCD_EIA_EX-002 (Oregon_Landfill Methane Rules_Staff Report).

[6] In developing this rule, the Division did not perform individual site assessments for all affected landfills and prepare comprehensive design plans and their corresponding cost estimates. The cost estimates are based on average or typical costs for the operations or actions necessary to comply with the proposed regulation and informed in part by similar regulations and cost estimates used in other states implementing comparable regulations. Given that the numbers presented are average or typical cost figures, the actual costs to a given landfill may be lower or higher than estimated. However, the Division expects that the total cost to all affected landfills will be consistent with the stated estimates.

80 landfills are expected to submit a waste-in-place report in 2026. This number is expected to be 49 by 2027 since closed landfills must only submit a one-time waste-in-place report. 36 landfills in 2026 and 35 landfills in 2027 are expected to file methane generation reports, with that number being 34 in 2030[7]. While the 13 landfills with GCCSs are expected to submit semi-annual and annual reports, based on reporting requirements for operating a GCCS, starting in 2026 and continue to do so through 2050 in the cost analysis, 18 additional landfills are expected to submit semi-annual and annual reports starting in 2029. The present value of the cost associated with these reports is $3.74M.

ii. Costs for conducting surface emission monitoring (SEM) and gas collection and control system (GCCS) leak monitoring at MSW landfills

If the calculated methane generation rate is greater than or equal to 664 metric tons (732 tons) per year but less than 1,814 metric tons (2,000 tons) per year, the owner or operator of the MSW landfill must either install and operate a GCCS or complete quarterly SEM using an approved monitoring method to determine if a GCCS must be installed. Owners or operators of MSW landfills with a GCCS installed also have to perform quarterly SEM to help ensure the GCCS is properly controlling emissions from the landfill and leak monitoring of the GCCS components. All SEM must be conducted using 25-foot spacing on the surface of the landfill. The tighter spaced SEM is expected to lead to increased detection of leaks and corrective action(s) to address them, resulting in greater capture and destruction of methane.[8]

ii.a. EPA Method 21

In completing SEM and GCCS leak monitoring, landfill owners/operators can either contract an engineering or consulting firm that owns the required equipment to perform the task, or purchase the required equipment, if available for sale, incurring this cost as a one-time capital expenditure and spend only on the labor required to complete the SEM and leak monitoring. Table 2 below shows the typical number and type of equipment involved in performing SEM and leak monitoring based on EPA Method 21, which is an allowable monitoring method under the proposed rule, and the associated costs. This includes the calibration of monitoring devices and the downloading of monitoring data from the data

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[7] Larimer County is constructing a new landfill that was issued a construction permit for an enclosed flare. For the purpose of the EIA, only costs from reporting waste-in-place are attached to the new North Larimer County Landfill.

[8] Eastern Research Group, Analysis of Surface Exceedances from California Landfills under the New Source Performance Standards and the California Landfill Methane Rule (pg.2): Estimates from ERG show that exceedances on average were 180% more frequent with 25 feet spacing, using data from SCS Engineers.
SCS Engineers, A Comparison of Monitoring Results For California Landfills under the New Source Performance Standards and the California Landfill Methane Rule (pg.12): Analysis from SCS Engineer show that exceedances are more frequent per acre with 25 feet spacing.
Both available at: https://www.regulations.gov/document/EPA-HQ-OAR-2003-0215-0233

logger. These costs are based on information obtained from the California Air Resources Board (CARB) for their landfill methane rule and adjusted to a 2025-dollar value[9] [10].

The sub-sections below Table 2 describe the costs associated with using SEM options other than EPA Method 21.

Table 2. EPA Method 21 Equipment and Costs			
Monitoring equipment	Number	Cost per item	Total cost[11]
Portable Organic Vapor Analyzers	3	$7,450	$22,350
Calibration System	1	$4,470	$4,470
Vacuum Measuring Devices	3	$1,490	$4,470
Portable Oxygen Analyzers	3	$5,215	$15,645
Spare Parts	1	$745	$745
Tools	1	$1,490	$1,490
Datalogging Systems	3	$7,450	$22,350
Total			**$71,520**

For a landfill operator that makes a one-time investment in Method 21 equipment and pays only for monitoring labor costs, the first-year cost includes the equipment cost and labor cost. For the subsequent years, the only cost incurred is the labor cost of monitoring. The labor costs are related to the Engineering/Monitoring technician staff's time. This cost is based on information obtained from the CARB for their landfill methane rule and adjusted to a 2025-dollar value.

[9] CARB STAFF REPORT: INITIAL STATEMENT OF REASONS FOR THE PROPOSED REGULATION TO REDUCE METHANE EMISSIONS FROM MUNICIPAL SOLID WASTE LANDFILLS, May 2009

[10] The cost estimates, including the hourly rates, are adjusted to the proposed rule using the cost involved in completing the task on a per-acre basis.

[11] Id. The equipment purchase capital cost after the cost figures were adjusted for inflation.

Table 3. EPA Method 21 Labor Cost			
Labor need	**Cost/hour/acre***	**Adjustment factor****	**Adjusted cost/hour/acre**
Engineering/Monitoring technician staff time	$48.76	1.49	$73

***** Labor cost/hour/acre data from CARB 2009 (see footnote 8).

****** Adjustment factor for converting 2009$ to 2025$ based on consumer price index data obtained from the Bureau of Labor Statistics (CPI Inflation Calculator)

ii.b. EPA OTM-51 Drone-based SEM - Sniffer Robotics

Sniffer Robotics offers an unmanned aerial system (UAS) or drone (SnifferDrone) to perform SEM following EPA Method 21 for MSW landfills, which is known as OTM-51. This monitoring method is included in the Other Test Method (OTM) category on EPA's Air Emission Measurement Center (EMC) website and is a broadly applicable alternative test method approved for SEM at MSW landfills for compliance with federal air pollution regulations. OTM-51 may also be used for SEM under the proposed rule.

Sniffer Robotics only offers their SnifferDrone for SEM at an MSW landfill on a contractual basis and provided information that performing SEM at 25-foot spacing, as required under the proposed rule, costs approximately $10,000 per monitoring event at a 100-acre landfill[12]. Performing SEM at 100-ft spacing, as required under federal air pollution regulations, costs approximately $5,000 per monitoring event at a 100-acre landfill. The incremental cost associated with shifting from 100-foot spacing to 25-foot spacing for SEM is $20,000 per year. However, there are significant efficiency gains from using the SnifferDrone with the tighter monitoring spacing and when the size of the landfill being monitored is larger. For example, for EPA Method 21 and handheld TDLAS (see subsection ii.c. below), shifting from 100-foot to 25-foot spacing means a quadrupling of the SEM cost, but it is only doubled when using the SnifferDrone. In terms of landfill size, performing SEM using Method 21 or a handheld TDLAS at a 100-acre landfill is 10 times as costly as performing SEM at a 10-acre landfill. With the SnifferDrone, the cost increase is less than that.

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[12] This cost covers expenses for preplanning, labor, upload of data to cloud, mobilization/demobilization, generating and delivering reports digitally, and access to a dashboard service that allows users to see measurements at every discrete point and generate an exceedance map to facilitate comparison of performance across measurement events. The vendor only contracts service and does not sell the equipment. As such, capital costs associated with this equipment cannot be estimated.

ii.c. Handheld tunable diode laser absorption spectroscopy (TDLAS) device

Landfill owners/operators can also use handheld methane-specific TDLAS devices to conduct SEM and GCCS leak monitoring. Based on communications with Ecotec and Xplorobot, which are two companies that supply handheld TDLAS devices that could be used at MSW landfills, the annual cost of conducting SEM and leak monitoring using a handheld TDLAS at an MSW landfill that is 100 acres in size ranges from $25,000 to $34,000. The following subsection describes the cost figures in more detail.

Ecotec

Size, terrain, and environmental conditions affect the time needed to conduct SEM and GCCS leak monitoring at an MSW landfill. Hiring a contractor to perform quarterly SEM using 25-foot spacing and GCCS leak monitoring with a handheld TDLAS at a landfill that is 100 acres in size is expected to cost $25,600 per year. This figure does not include travel, lodging, and out-of-pocket costs for the contractor.

Alternatively, instead of contracting the monitoring duties, landfill owners/operators can make a one-time purchase of the Gazoscan handheld TDLAS instrument from Ecotec for $19,950. Added costs associated with this option include the labor and data logging costs associated with performing the monitoring. If the landfill owner/operator uses Ecotec's data logging software, the MSW landfill owner/operator would incur an additional cost of $30 per month or $360 per year. The Gazoscan has a useful lifetime of 10 years[13]. The landfill owner/operator is also expected to incur a one-day in-person training cost of $800, which consists of a classroom review and field application. Additional costs will be incurred for travel and other expenses involved in attending this in-person training course. If the landfill owner/operator chooses to train more than one person, the cost of in-person training would increase proportionally.

Xplorobot

Xplorobot estimates that performing quarterly SEM using 25-foot spacing and GCCS leak monitoring at a 100-acre landfill using its handheld TDLAS would cost $34,000 per year. This cost would cover labor, digital reporting, digital emission geotags, emission quantification, and access to the digital reporting dashboard offered by Xplorobot. Xplorobot does not yet have an exact cost for the purchase of their handheld TDLAS as they are shifting the technology to be used with the addition of a smartphone as a visualization and tracking tool.

iii. Costs for installing/upgrading GCCS

Various factors, including the depth and number of installed wells, affect the total cost associated with installing and operating a GCCS. If the elevation of compacted waste at a landfill is high, costs tend to rise because well depths will need to be increased. A higher

[13] February 6, 2025 email communication with Ecotec.

number of installed wells also means higher cost[14]. Because of these factors, the GCCS design and corresponding cost that apply to one site may be different than another site. However, based on comparable regulations proposed and adopted by other states, industry data, and EPA cost estimates for implementing a GCCS at a landfill, the typical cost per acre for installing a GCCS is expected to be $40,050, while upgrading an existing GCCS[15] costs $26,600 per acre. The operation and management (O&M) cost, which is incurred yearly, costs $6,740 per acre.

Table 4. Capital and O&M costs associated with installing/upgrading a GCCS

Types of costs involved	Estimated cost/acre
Install New GCCS (initial)[16] [17]	$40,050
Upgrade GCCS (initial)	$26,600
Operations and Maintenance (yearly)	$6,740

[14] If the landfill gas is used to generate energy, the revenue from the sale of that energy could offset operational costs. The Division's analysis does not consider this potential revenue and associated incremental cost.

[15] Landfills that do not have a GCCS will need to install a GCCS. Landfills that are equipped with open flares will need to upgrade to enclosed flares, which tend to be more expensive, but they provide greater control of combustion conditions, allow for stack testing, and might achieve slightly higher combustion efficiencies (higher methane destruction rates) than open flares. They can also reduce noise and light nuisances. The cost figures are quoted in 2025$. LFG Energy Project Development Handbook, Chapter 7: Best Practices for Landfill Gas Collection System Design and Installation. This analysis assumes one well per acre. Landfills in more wet climates may require more collectors for the same area of coverage of gas collection (pg.7). Data on Colorado landfills shows that the average number of wells per acre is lower than one, suggesting that the cost such landfills incur will be less than the cost assumed in this EIA.

[16] Costs for upgrading/installing new GCCS are calculated using Landfill Gas Energy Cost Model (US EPA: (LFG Energy Project Development Handbook, Chapter 4: Project Economics and Financing) and Maryland's Landfill methane rule workbook (Technical Support Document - Control of Methane Emissions from MSW Landfills - Final w appendices.pdf). The per-acre cost is adjusted to 2025$ using CPI inflator. This cost item includes expenses associated with site assessment, design and installation of collection and control systems, which include enclosed flaring system featuring stack, control panel, flame arrester, safety shutoff valve, flow meter, and chart recorder. The GCCS cost also makes allowances for propane pilot gas system, transportation, and sales tax. Flaring costs are incorporated into these estimated capital and O&M costs.

[17] Maryland's industry estimate for GCCS puts the expected per acre cost for a new GCCS between $37K to $66.5K in 2025$ (Technical Support Document - Control of Methane Emissions from MSW Landfills - Final w appendices.pdf).

MSW landfills with an existing GCCS that operate an enclosed flare are expected to meet the proposed regulation's requirements without incurring additional installation or upgrade costs. As with the capital costs, landfills with an existing GCCS and enclosed flares or combustion devices are expected to meet the proposed regulation's requirements without incurring additional GCCS operation and management costs[18] except for the cost associated with an increased frequency of performance testing of the control device and tighter spacing for performing SEM. For landfills that will need to install a new GCCS or upgrade to an enclosed flare or combustion device, O&M costs are considered a compliance cost because these costs were either previously not incurred or were incurred at a lower level in the case of utilizing open flares.

After the installation/upgrading of a GCCS, if the surface emission monitoring shows an exceedance, the landfill is expected to incur costs to mitigate the emissions. A $75/acre average cost is assumed for the owner/operator of an MSW landfill to cover repair work. This figure is based on CARB data on landfill cover repair cost allowances as quoted in landfill closure plans submitted by regulated MSW landfills[19].

Performance testing

The enclosed flare must be installed, calibrated, operated and maintained in accordance with the manufacturer's instructions and specifications and operated within the parameter ranges established during the most recent performance. This test is estimated to require 2 hours per week by an environmental engineer to track the required information and 20 hours to compile a report for submission. At a $119 per hour rate for an environmental engineer, this requirement, adjusted for inflation, is expected to cost $15,172[20].

iv. Early installation of horizontal gas collectors

When municipal solid waste is initially placed in a landfill, it undergoes an aerobic decomposition stage with oxygen, during which time little methane is produced. Typically, within a year, anaerobic conditions develop, and methane-producing bacteria start to decompose the waste and generate methane. The GCCS pipes or wells that typically collect this methane are usually installed after an area of the landfill where waste has been in place

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[18] This analysis is an estimate of the incremental cost of the proposed regulation measuring the costs to an affected landfill resulting from compliance actions required by the proposed regulation. These costs do not include the normal cost of operation that are encountered without the proposed regulations' requirements, including capital and operation costs incurred by MSW landfills that voluntarily operate GCCS or costs associated with compliance with preexisting federal requirements.

[19] CARB STAFF REPORT: INITIAL STATEMENT OF REASONS FOR THE PROPOSED REGULATION TO REDUCE METHANE EMISSIONS FROM MUNICIPAL SOLID WASTE LANDFILLS, May 2009

[20] See, APCD_EIA_EX-004 (Washington Landfill Methane Rules Final Regulatory Analysis) This cost figure is based on cost estimates for the MSW landfill methane reduction rule promulgated by the Washington Department of Ecology. The 2025 equivalent of the figure is estimated using the Consumer Price Index (CPI) inflation calculator from the Bureau of Labor Statistics (CPI Inflation Calculator). https://apps.ecology.wa.gov/publications/SummaryPages/2402010.html

for several years. The U.S. EPA requires landfills to collect gas where initial waste has been in place for 5 years or more. Installing collection pipes earlier than usual, including installing horizontal collection pipes in the active areas of the landfill as waste is being placed, can help to increase the amount of methane that is collected and destroyed over time.[21]

Installing a horizontal well can cost $7,500 per horizontal well, including a 100-foot run of piping, gravel, and labor[22,23]. The piping can be a 6-inch PVC or HDPE pipe placed in a shallow trench. For an MSW landfill that has an active collection system, starting gas collecting while the landfill cell is still accepting waste can achieve a 35% gas recovery[24].

For the landfills that have GCCS, the average filled-in area across those landfills has increased by 33 acres between 2000 and 2024. Assuming the same trend continues, meaning that the number of acres wherein horizontal collectors will be installed increases by 33 acres per year, the discounted cost associated with this measure between 2029 and 2050 is expected to be $3.7 million.

For landfills that are regulated by federal requirements, the proposed rule also requires landfills to install GCCS earlier than they would under those requirements. Because landfills regulated by federal requirements would have installed the GCCS under those requirements, the cost from installing the GCCS is not considered as an incremental cost that is resulting from the proposed rule. However, having to do so earlier results in loss of time-value of money. Two scenarios were created, one for installing GCCS by the time federal regulations require such an investment and another for installing GCCS by the proposed rule, so as to compare the net present value of the costs and to evaluate the implication of installing GCCS

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21 EPA, Quantifying Methane Emissions from Landfilled Food Waste, 2023 (pg.4): The U.S. estimates that 61% of methane generated by landfilled food waste is not captured by collection systems and released to the atmosphere due the decay rate of food waste. available at: https://www.epa.gov/system/files/documents/2023-10/food-waste-landfill-methane-10-8-23-final_508-compliant.pdf

22 August 27, 2024, email communication with Nicole Neff, Director of Environmental Attributes, LoCI Controls

23 Whereas such wells also do not require specialized drilling equipment and crews as compared to vertical wells, which can be installed in active areas if extended or connected to a central manifold, horizontal wells can be sacrificial as they are subject to being crushed and twisted as the waste is filled above. Horizontal collectors also have the advantage of not disrupting landfill operations as substantially as vertical wells because they are placed at or below the surface of a lift (layer) of waste and they allow landfills to start collecting landfill gases earlier than they would if they relied only on collection systems installed after the area is capped, minimizing the amount of methane emitted from landfills. Once the active filling moves from this area, a landfill owner/operator will install a vertical collection well from the top to continue and supplement the gas collection from the horizontal. If the verticals intersect the horizontal, it can act as an extension and increase the radius of influence of the vertical well, as the vacuum will also run through the path of least resistance and extend into the horizontal gravel and piping. LFG Energy Project Development Handbook, Chapter 7: Best Practices for Landfill Gas Collection System Design and Installation

24 https://www.researchgate.net/publication/239998633_Handbook_for_the_design_construction_operation_monitoring_and_maintenance_of_a_passive_landfill_gas_drainage_and_biofiltration_system#pf14

earlier than federal requirements. The results show that the net present value of the cost under the proposed rule is higher than the cost from doing so by federal requirement timeline, showing a net additional cost of $1.7M.

v. Biofilters and Biocovers

Biofilters and biocovers that utilize organic materials, such as compost or woody mulch, can be applied to or used at MSW landfills to oxidize methane emission. These emission control mediums rely on bacteria to metabolize and remove organic and odorous vapor phase pollutants from gas streams. They also have the advantage of not generating secondary gaseous pollutants from their activity, such as nitrogen oxides (NOx) and oxides of sulfur (SOx) that gas combustion devices produce, as their emissions or byproducts are limited to carbon dioxide (CO2) and water vapor.

Specifically, a biocover is a type of cover that is typically composed of a gas dispersion layer situated below a methane oxidation layer placed over deposited solid waste at a landfill that enhances methane oxidation into CO2 before venting to the atmosphere. The gas dispersion layer consists of a permeable material such as gravel, broken glass, or sand. It functions to evenly distribute the fugitive landfill gas (LFG) to the methane oxidation layer and effectively remove excess moisture. The methane oxidation layer, typically made of compost or other organic materials, converts the methane into CO2 (URS, 2008). Fugitive LFG filters through the biocover and is oxidized. Biocovers can be used as stand-alone technology or in combination with an active GCCS.

Biofilters may be enclosed within a vessel or container and equipped with a cover to prevent precipitation from infiltrating the filter and can be installed at landfills with and without a GCCS and in sections of a landfill that are no longer linked to a GCCS. Biofilters are often installed to replace a gas control device at an MSW landfill relying on the existing gas collection system to route LFG to the biofilters. LFG can be passively routed to a biofilter or biocover, or the landfill owner/operator can install or operate a blower to help the gas flow through the biofilter. For landfills without an active gas collection system, methane oxidation rates with biofilters can range from 10% in areas without final cover to 35% in areas with final cover[25]. A biocover employing a large volume of aged compost can oxidize up to 35% or 40% of the methane in the LFG passing through it[26].

[25] U.S. EPA. Documentation For Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM). Management Practices Chapters. November 2020. https://www.epa.gov/sites/default/files/2020-12/documents/warm_management_practices_v15_10-29-2020.pdf.

[26] CalRecycle (formerly the California Integrated Waste Management Board). Technologies and Management Options for Reducing Greenhouse Gas Emissions from Landfills. April 2008. https://www.waste.ccacoalition.org/document/technologies-and-management-options-reducing-greenhouse-gas-emissions-landfills

Biofilter oxidation rates can vary and depend on the physical and biological characteristics of the filter material[27,28]. Biofilter efficiencies for methane oxidation can also fluctuate over time due to various factors, including their condition, maintenance, and local weather conditions. Factors such as biofilter age, moisture content, organic content, oxygen levels, and temperature can also influence microbial activity, which in turn impacts oxidation performance. To maintain optimal conditions and ensure consistent methane oxidation, biofilters may need regular replacement and conditioning.

Biofilter costs depend on location, landfill characteristics, treatment goals, availability of biofilter media, and labor costs. Based on four biofilter projects, including two that represent actual biofilter installations and two that represent hypothetical biofilter installations at MSW landfills, Geosyntec Consultants estimates that the average cost for biofilters is $1,586[29] [30] per acre, with the lower and upper bound costs from the sample being $1,125 and $2,133 per acre, respectively.

One example of an actual biofilter project is the Jefferson County Landfill in the State of Washington, where 14 biofilters were installed in 2020 at a total cost of less than $10,000.[31] However, the biofilters' media and materials were not included as part of the total cost since the landfill's owner/operator provided these for the project through existing resources.

An EPA study puts the cost for biocovers at $67,200[32] per acre for biocover used for final cover at landfills. However, if a soil final cover is used at a landfill, it will have a greater thickness than an intermediate cover, which increases the cost. Under Colorado's solid waste

[27] Abichou, Tarek. Florida State University. FAMU-FSU College of Engineering. Our Experience with Methane Emissions and Methane Oxidation in Landfill Applications. Presented to Air and Waste Management Association. March 30, 2021.

[28] CalRecycle. Biocovers at Landfills for Methane Emissions Reduction Demonstration. October 2010. https://www.yolocounty.org/home/showpublisheddocument/31494/635787934907730000.

[29] These cost figures do not include costs associated with demonstrating the biofilter performance. If biofilter size needs to be increased, that will represent an additional cost.

[30] APCD_EIA_EX-003 (Email correspondence, on the 5th of June, with Peter Bannister, Principal Engineer, Geosyntec Consultants, Inc.)

[31] January 22, 2025 email communication from Al Cairns, Solid Waste Manager, Jefferson County Department of Public Works (WA); https://www.epa.gov/lmop/apply-biofilters-or-biocovers; https://jeffersoncountysolidwaste.com/wp-content/uploads/2023/04/JCSWF-Current-State-Condition-Report-Card_03222023.pdf

[32] This figure is quoted in 2024$, updated from 2011, when the cited EPA document was published: U.S. EPA. Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Municipal Solid Waste Landfills. June 2011. https://www.epa.gov/sites/default/files/2015-12/documents/landfills.pdf.

regulations, intermediate cover must only be one foot of earthen or other suitable material placed over solid waste.[33]

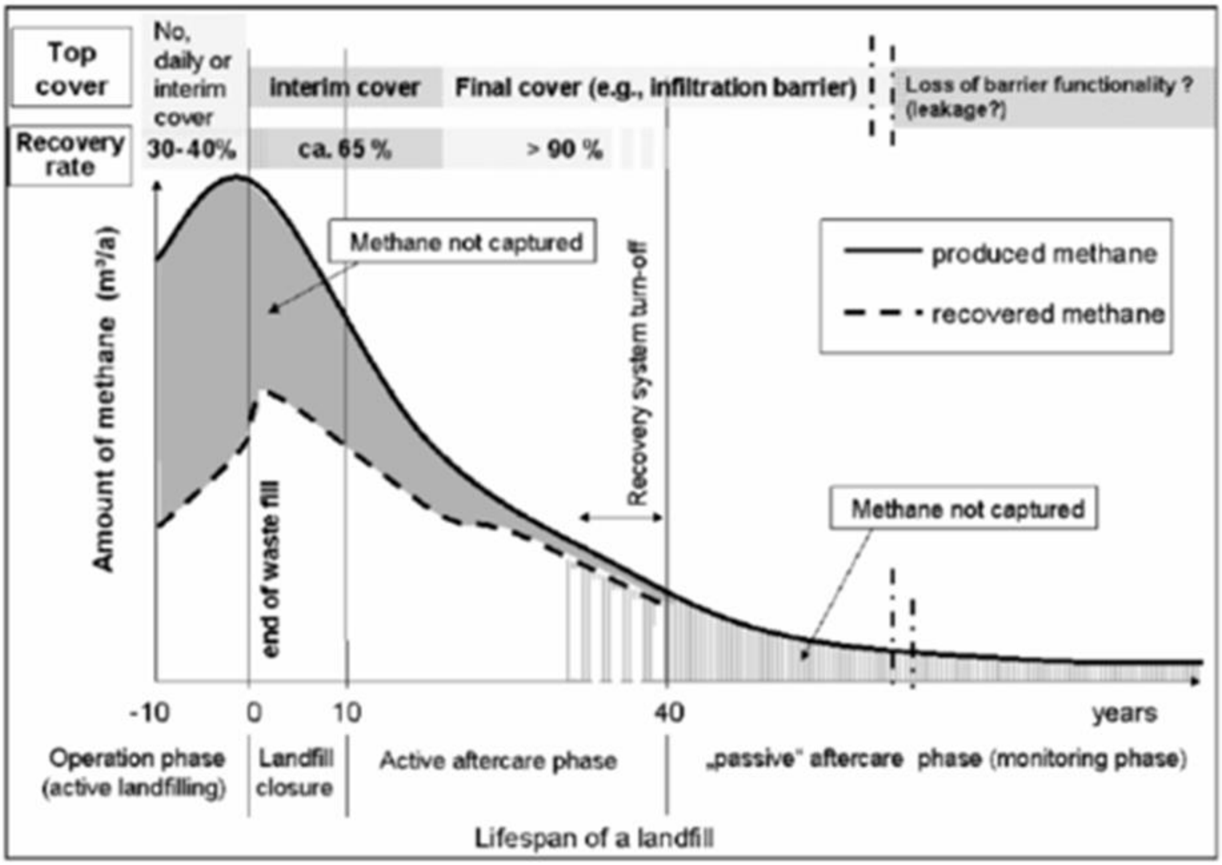

Figure 1: Amount of methane that is produced versus recovered over the lifetime of the landfill relative to when the GCCS is installed[34]

vi. Summary of cost items

The annual cost per landfill for waste-in-place, methane generation, and annual compliance reports is $4,840 each. For a landfill that is approximately 102 acres, which is the average acreage of the landfills that already have GCCS and those expected to install one, the annual

[33] 6 CCR 1007-2, Part 1, https://drive.google.com/file/d/1nV3TG7KEqCFH9eqKGFGV06mh_vT41lR0/view

[34] The figure shows that active gas extraction technologies and practices that are implemented only after landfill is closed fail to capture a significant portion of the total landfill gas that is generated. The figure shows that a considerable amount of methane is generated and released into the atmosphere both before one reaches the end of the waste deposition phase, where active collection systems are typically installed, and long after the gas recovery system has been removed. Source:https://www.researchgate.net/publication/239998633_Handbook_for_the_design_construction_operation_monitoring_and_maintenance_of_a_passive_landfill_gas_drainage_and_biofiltration_system#pf14

cost of SEM, assuming EPA Method 21 is used, is $31,348. The cost of installing a GCCS over the 895 acres of filled-in area across the 18[35] landfills that do not yet have GCCS, which is a figure that is expected to increase by an average of 10 acres per year, is $42.4 million, with the operation and management cost being $109.2 million. Dividing the total cost by the number of landfills that do not yet have GCCS, the average landfill that did not have a GCCS before this rule will have spent $2M to install a GCCS and $5.2M on operation and management by 2050.

Taking the average incremental cost for conducting SEM between Xplorobot and SnifferDrone, at an average annual increased cost of $22,500/landfill for the 13 landfills with an existing GCCS, the incremental cost from the tighter SEM pattern is expected to lead to $292.500 per year and a discounted value of $4.55 million between 2029-2050.

For landfills that do not yet have a GCCS, the SEM cost is based on each landfill being an average size of 50 acres with a $75 per acre labor cost, SEM performed quarterly, and an equipment cost of $71,500 with a 10-year useful lifetime.The present value of the cost of equipment and labor by the end of the useful lifetime of the equipment is $186.7K, putting the average yearly cost at $18.6K for SEM at a landfill. By 2050, the cost associated with SEM equipment using EPA Method 21 is expected to cost $2.3M, and the labor cost for conducting the SEM is expected to be $4.7M for all landfills that will have to install a new GCCS and perform SEM as a result of this rule.

Horizontal collectors are expected to cost $7,500 per well. Given that the average filled-in area across those landfills with GCCS has increased by 33 acres per year between 2000 and 2024 and assuming the same trend continues, the discounted cost associated with this measure between 2029 and 2050 is expected to be $3.7 million[36].

Given the number of landfills that will be covered by the rule, performance tests across all the landfills are expected to cost $358,422 per year in present value terms, or $15,172 per year per landfill. Although some landfills might become eligible to do performance testing once every three years depending on the test results, to be conservative and avoid underestimating cost, the per year cost is assumed to apply to all the landfills for each of the years where cost figures are modeled.

Out of the 13 landfills that already have a GCCS, either voluntarily or because of applicable federal requirements, 4 landfills have enclosed flare systems, representing 1,363 acres of the 2,566 total acres for the 13 landfills. If all open flares are upgraded, given the average per

[35] This number is expected to be 19 in 2031, 20 in 2032, and 21 in 2034 as three more additional landfills are expected to trigger the threshold limit at the said years.

[36] This analysis involves applying the given cost year over year and applying a discounting factor such that the time value of money is properly accounted. For a given discount rate ‘r’, the present value of future streams of costs incurred in future year ‘n’ can be calculated by using the formula Present Value = (Future Value)/$(1 + r)^n$.

acre cost of $26,600, the present value of the expected flare upgrading cost across these landfills is expected to be $28.9M[37]. If all open flares are upgraded, except for currently installed backup or secondary flares, the present value of expected flare upgrading cost across the 7 affected landfills is expected to be $23.3M.

Since the timing and extent of the shift from GCCS to biofilters is not yet known, the operation and management cost associated with GCCS is assumed to apply in the cost modeling timeframe even for years where the GCCS has been retired and the landfill operator has shifted towards using biofilters. The O&M cost of GCCS is higher than the expected per-acre cost of implementing biofilters. This approach avoids underestimation of cost.

Using a 2.5% discount rate, between 2029 and 2050, the total cost of compliance, including reporting, early installation of horizontal collectors and GCCS, is $209.6M. Given the total of $209.6M, the average per year cost in the modeling timeframe from 2029 to 2050 is expected to be $9.52M.

Projections from Colorado State Demographic Office show that the average population size of the counties served by those landfills between 2029-2050 is expected to be 2.6M households. Given the cost figure from above, the average cost per household per year is expected to be $3.66.This analysis assumes that the landfills pass on the entirety of the compliance cost and serves as the higher-end estimate of the rule's impact on affected households.[38] However, based on the experience of other states with existing landfill methane rules in place, the rule is not expected to lead to higher tipping fees[39]. As such, the effect on household waste collection fees from the rule is expected to be minimal.

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[37] Only a few landfills with open flares are expected to upgrade to enclosed flares in 2029. The cost analysis assumed that all landfills with open flares would upgrade to enclosed flares by 2029. For landfills that have to upgrade after 2029, the cost of doing so, given the time value of money, is lower than what is estimated in this analysis. As such, the actual cost incurred by landfills is likely to be lower than what is quoted in this EIA. The cost incurred to upgrade from open to enclosed flares is also quoted for landfills that have one well per acre. The average number of wells per acre in the landfills with open flares is 0.37, substantially lower than 1. By applying the cost figure as if landfills have one well per acre overestimates the cost of compliance quoted in this EIA. The same also applies to the cost of installing GCCS. This analysis assumes that landfills will have one well per acre. The average number of wells per acre for landfills that already have a GCCS is less than 0.4. If landfills that do not have GCCS and will have to install one and even landfills that have GCCS and will expand the system continue to have such a low number of wells per acre, the estimated cost of installing GCCS in this EIA is likely going to overestimate by the same proportion as the number of wells per acre is lower than 1.

[38]The estimated affected households by county include those served by landfills with a current GCCS and those that do not yet have a GCCS. Households located in Bloomfield, Boulder, Denver, and Douglas county were included. Whereas, there are not active MSW landfills in these counties, household waste will likely be sent to impacted landfills. Tipping fees are also expected to impact commercial properties such as offices and hotels.

[39] A review of the average tipping fees in California and Oregon after those states adopted landfill methane rules found that there was not a large and consistent type of increase in tipping fee resulting from the adoption of landfill methane rules, with tipping fee in California increasing by $5 and tipping

The Colorado Energy Office (CEO) has a Clean Air Grant (CAP) program that provides financial assistance to eligible applicants for projects aimed at reducing air pollution from industrial and manufacturing facilities, including MSW landfills. CEO announced that applications for the final round of CAP grants opened on July 9, 2025, and informed owner/operators of MSW landfills that are parties to the Regulation 31 rulemaking of this. If a CAP grant is awarded to to help cover a portion of the cost to install a GCCS at an MSW landfill, it can reduce the total cost burden faced by a landfill owner/operator to comply with the rule, as well as the amount of cost that may be passed onto households served by the landfill.

vii. Benefits - Emission reductions achieved and the avoided cost of climate change

MSW landfills vary in size, deposited waste composition, type of cover, topography, surrounding area's geological characteristics, and local climate. These factors affect both the rate of landfill gas production and its duration.

To assess the amount of emission reduction achieved, projected methane emissions were conducted using EPA HH-1 and HH-5 methodologies using facility reported data from Colorado APCD Regulation 22 Greenhouse Reporting records. Waste acceptance rates, waste composition as a % of weight, emission factors, oxidation factor, and other facility data from each landfill is assessed. For reporting year 2010 and onwards, the updated emission factors were retroactively used respective to the waste option reported in the corresponding year[40]. The latest waste acceptance and waste compositions for reporting year 2024 were kept as constant for projecting waste acceptance rates in 2025-2050. If a landfill exceeded its reported design capacity, that landfill was deemed closed and waste acceptance was changed to 0. Similarly, once closed, the oxidation factor of 0.35 was used to adjust for final cover.

Both 75% and 69%, which is the average collection efficiency reported in Colorado for 2024, collection efficiency and 99% destruction efficiency levels were used to estimate emission reductions for reporting years 2029-2050. Methane emission reductions were calculated by taking the difference of the projected HH-5 value, which is the amount of methane that would have been emitted post oxidation, and the sum of uncollected and uncontrolled methane, which is the amount of methane that still might be emitted after installing a GCCS. Emission reductions were assessed per landfill and then totaled taking into account delays of having to install a GCCS based on reaching the methane generation rate.

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fee in Oregon decreasing by $14. The most important factors that affected tipping fees were the cost of motor vehicles, fuel, labor, and negotiated contracts between landfills and haulers. [ANALYSIS OF MSW LANDFILL TIPPING FEES – 2023 | EREF]

[40] 5 CCR 1001-26 REGULATION NUMBER 22 COLORADO GREENHOUSE GAS REPORTING AND EMISSION REDUCTION REQUIREMENTS, Part A Greenhouse Gas Reporting. Unless otherwise indicated, any incorporation by reference of provisions of Title 40, Part 98, of the Code of Federal Regulations (CFR) are to the edition effective as of January 1, 2025. https://www.sos.state.co.us/CCR/GenerateRulePdf.do?ruleVersionId=11724&fileName=5%20CCR%201001-26

For the scenario with a 75% collection efficiency, by 2050, this rule is expected to reduce emissions by 12.53 million tons of CO_2e. For the scenario with a 69% collection efficiency, by 2050, this rule is expected to achieve the emission of 11.28 million tons of CO_2e. The emission reductions achieved by this rule will prevent considerable costs from climate change. Using a 2.5% discount rate, the avoided cost of climate change resulting from the implementation of this rule is estimated to range from $1.11B to $1B for the 75% and 69% collection efficiency, respectively[41].

Using tighter spacing of 25 feet for conducting SEM leads to higher manual cost as compared to using wider spacing of 30 meters (approximately 100 feet) as is currently federally required. The Division completed analysis on the costs and benefits associated with using tighter SEM spacing as compared to using a wider spacing. For the eleven landfills required to conduct SEM, two landfills with a voluntary GCCS not required to conduct SEM, and projected 18 landfills expected to install a GCCS, on average, using a tighter spacing for SEM will lead to the detection and destruction of an additional 1,432 metric tons of methane, or 40,105 metric tons of CO_2e per year[42] [43]. Colorado MSW landfills' semi-annual reports were reviewed for surface emissions monitoring exceedances reported. Analysis of emissions reduction of tighter spacing included SEM exceedances labeled as "surface" or identified from walking path maps. 122 surface exceedances were detected between Q1 2023 through Q4 2024. However, only 119 exceedances between 500-5414 ppmv, excluding three outliers,were included in the analysis. Emission reductions from surface exceedances were estimated assuming 1095.5 ppmv, the average concentration of 119 surface exceedances, detections would be remediated to 199 ppmv and verified at the 10 day re-monitoring period. By 2050, the total benefit from the additional emission reduction is worth $62.96M while the incremental cost from doing so is $4.5M. This shows that the incremental benefit from requiring tighter spacing in SEM is higher than the incremental cost resulting from this specific requirement.

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[41] This avoided cost is estimated using the social cost of carbon (SCC), which ascribes value to the economic, health, and environmental damages caused by carbon emissions on a per-ton basis. Using the latest SCC values, which are provided by the Interagency Working Group (IWG) on Social Cost of Greenhouse Gases (IWG 2021). The SCC values are quoted in 2020$. The 2025$ is determined by multiplying the 2020$ value by the consumer price index (CPI Inflation Calculator).

[42] See, APCD_EIA_EX-001, (Daily emissions per day from surface exceedances derived from EIP analysis (APCD_EIA_EX-001, pg. 16) which assumed 101 days of emissions per surface exceedance, 91 days between monitoring periods and 10 days for re-monitoring confirmation). The analysis assumed that there would be 5 detections at 500 ppmv per quarter for each additional landfill that meet the proposed requirements to install a GCCS . (pg. 18)

[43] ERG estimated, on average, 180% more exceedances above 500 ppmv were detected using CARBS's 25 foot spacing. Additional emissions from tighter spacing were assumed to be 500 ppmv.
ERG, Analysis of Surface Exceedances from California Landfills under the New Source Performance Standards and the California Landfill Methane Rule (2015). pg. 2., available at:
https://downloads.regulations.gov/EPA-HQ-OAR-2003-0215-0233/content.pdf

Independent study by the Environmental Integrity Project (EIP) shows that, for an assumed collection efficiency of 75%, the installation of GCCS in landfills that do not currently have this system will have a climate benefit worth $851M[44], slightly lower than the Division's estimated impact of $1.03[45]B. The same analysis shows that, for an assumed collection efficiency of 69%, the installation of GCCS in landfills that do not currently have this system will have a climate benefit worth $783M by 2050, which is lower than the Division's estimated impact of $921M.

The rule also envisions that the lag between the time the threshold is reached and the GCCS is installed is reduced from 30 months to 21 months, and that the time allowed for expansion of the GCCS into areas of the landfill with new waste is reduced from 2-5 years to 1 year. EIP's assessment of the proposed changes on landfills that already have GCCS, assuming a 75% collection efficiency, is estimated to reduce emissions by 4.4M metric tons of CO_2e by 2050. Using the 2.5% discount rate, this benefit is valued at $303M. For the 69% collection efficiency scenario, the emission reduction that is achieved is estimated to be 4.1M metric tons of CO_2e, which is worth $278M by 2050.

While the combustion of the landfill gas at 75% collection efficiency, such as through flares, to control methane is expected to lead, on average, increased emissions of particulate matter (PM) 2.5, sulfur dioxide (SO_2), and NO_x by 11.5, 10.4, and 25.8 short tons per year, respectively, the use of GCCS is expected to lead to the destruction of volatile organic compounds (VOCs) that would have been released into the atmosphere from landfills.[46] Analysis performed by the Division shows that the installation of GCCS is expected to reduce landfill VOC emissions, on average, by 97.3 short tons per year. [47]Comparable results are shown for the scenario where 69% collection efficiency is assumed. The expected average yearly emissions for this scenario are 10.6, 9.5, and 23.8 short tons for (PM) 2.5, sulfur dioxide (SO_2), and NO_x, respectively. For the 69% collection efficiency, the emission of VOCs is expected to decrease by 89.5 short tons per year.

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[44] The same adjustment for inflation is made to these figures as the climate benefit figures reported above.

[45] This figure and the figure for the 69% collection efficiency differ from the climate benefit values quoted above because these figures are the results that apply only to the installation of GCCS and do not include the additional emission reduction achieved by using tighter spacing in conducting SEM.

[46] Analysis used Updated 2024 AP-42 Ch. 2.4. Table 2.4-5 EMISSION FACTORS FOR SECONDARY COMPOUNDS EXITING CONTROL DEVICES for PM and NO_x. For SO_2, AP-42 Ch.2.4 ver. 11/98 based on 46.9 ppm concentration for total reduced sulfur.

[47] Analysis converted CH_4 to NMOC using either Tier 2 results, 956 ppmv, or 2420 ppmv and 39% or 85% VOC as a percentage of NMOC based on what is listed on a landfill's APEN or latest 8 year rolling average of PCS acceptance. AP 42 Table 2.4-5 Emission Factors for NMOC, as hexane (VOC) was used as a conservative approach accounting for VOC emissions from combustion.

The rule is also expected to reduce emissions of hazardous air pollutants (HAPs), on average, by 42.9 and 39.5 short tons per year for the 75% and 69% collection efficiency levels, respectively[48]. The list of reduced HAPs and air toxics includes benzene, methylene chloride, hydrogen sulfide, and mercury, among several others. These pollutants are known to cause serious health effects, including cancer, reproductive problems, birth defects, and damage to the respiratory, immune, and nervous systems[49]. By reducing the emissions of these air pollutants, this rule will help to minimize the public's exposure to these compounds and the resulting adverse health impacts.

Sensitivity analysis

The Division completed a sensitivity analysis for the benefits and costs associated with this rule. Such analysis is useful in testing if and by how much the overall assessment of cost effectiveness would change when certain changes are made to the assumptions that are made in the initial analysis.

For this purpose, the Division assessed what the overall cost effectiveness would be, as measured by the overall benefit-to-cost ratio, if the assumed cost of compliance was higher than what is assumed in the initial analysis. Scenarios were created where the cost figures were increased by a net change equal to 50%, 100%, 150%, and 200%. Given that these figures are net changes, a 200% scenario is the same as assuming the initial cost is multiplied by 3, shown by the last column in Table 5 as the '3X higher' scenario.

Typically a scenario is created for analysis wherein only one cost item is increased at a time while the other cost items are assumed to be the same as what is assumed in the initial model. For this analysis, however, the Division increased all the cost items at the same time. Even for the extreme scenario where the cost of compliance is multiplied by a factor of 3 and all cost components are multiplied by 3 instead of only select cost items being multiplied by 3, the results of the sensitivity analysis show that the overall benefit-to-cost ratio is still above 1, meaning that for each dollar incurred as a cost of compliance, the benefit from doing so is more than $1. This result shows the rule is cost effective and would remain so even if certain elements of the analysis ended up being higher than what was assumed in the analysis.

[48] Estimated HAPs reductions were estimated using AP-42 Table 2.4-1 DEFAULT CONCENTRATIONS FOR LFG CONSTITUENTS. Compounds listed as HAPS in LandGEM. Co-Disposal values for benzene and toluene were only used if listed on a facility's APEN.

[49] Health and Environmental Effects of Hazardous Air Pollutants | US EPA

Table 5. Results of a sensitivity analysis				
Collection efficiency	Cost items in the scenario increased from their assumed initial value to be			
	1.5X higher	2X higher	2.5X higher	3X higher
69% collection efficiency	1 to 3.18	1 to 2.39	1 to 1.91	1 to 1.59
75% collection efficiency	1 to 3.54	1 to 2.65	1 to 2.12	1 to 1.77

* The ratios are measures of cost effectiveness. 1 to 3.18 means that for each dollar incurred as cost, there will be benefits worth $3.18.

This analysis also takes a conservative approach regarding the emission reductions that are achieved. Whereas the cost includes costs both for landfills that have GCCS and those that do not, the benefits considered only considers the emission savings achieved by the landfills that do not have GCCS. The additional emission savings achieved by the rule from landfills that have GCCS is not included. If that benefit is included in the analysis, the benefit-to-cost ratio would be even higher.

Whereas some cost items such as source testing can see a step-down to where they are incurred every three years based on test results, the analysis assumed that these costs will be incurred every year. Such an approach has the effect of overestimating the cost of compliance. Under an alternative approach, where cost step-downs are considered, the benefit-to-cost ratio would be even higher to where it shows that the benefit from implementing this rule is higher than what it is estimated to be in this analysis.

C) Incorporate an estimate of the economic impact of the proposal on the supporting business and industrial sectors associated with the primary affected business or industry sectors

Compliance with the rule is expected to lead to both direct and indirect economic impacts. Specifically, the installation and upgrading of GCCS will have direct economic impacts in terms of supporting jobs for local engineers, construction firms, equipment vendors, and utilities on account of the opportunities created to perform a site assessment, and design, drilling, piping, construction, and operation of a GCCS. Conducting monitoring and reporting activities also creates job opportunities for environmental engineers and technicians. While some of the jobs supported are temporary and occur in the construction phase, the operation of the GCCS supports longer-term jobs.

The spending by landfill owners/operators is also expected to have an indirect effect on companies that supply the parts and raw materials used to make the GCCS and SEM equipment used in complying with this rule. Specifically, the increase in demand for new equipment such as piping, pumps or blower stations, and control devices where the collected methane from landfills is flared increases the demand for input required to produce those equipment. Industries supplying material to the equipment manufacturers will see increased demand for their products, as well as being able to support more jobs on account of the increased demand for their products. This creates an indirect effect on related businesses.

The direct and indirect impacts will also have induced effects on the local economies where these landfills are located. Lodging and meals for workers supporting compliance with the rule, for instance, will boost the local economy through an induced effect.

The investment by landfill owners/operators will circulate within the local economy, providing direct, indirect, and induced economic benefits. Using the applicable multipliers, between 2029 and 2050, analysis shows that the investment by landfill owners/operators will support 482 direct jobs and 1,630 indirect jobs.

Table 5: Number of jobs supported by the investments made by landfill owners/operators in complying with the rule

Industry	**Direct jobs multiplier**	**Jobs per $1M in final demand**[50]		
		Supplier jobs	**Induced jobs**	**Total, indirect**
General purpose machinery manufacturing	2.3	4.6	3.3	7.8
Expected cost of compliance, $209.6M	482	961	689	1,630

[50] Updated employment multipliers for the U.S. economy | Economic Policy Institute

SUMMARY AND CONCLUSION

By requiring MSW landfills that do not have a GCCS to install one and by tightening the SEM monitoring pattern, between 2029 and 2050, this rule will lead to the capture and destruction of 11.28 and 12.53 million metric tons of CO_2e for the 69% and 75% collection efficiency levels, respectively. The emission reductions achieved by this rule will prevent considerable costs from climate change. Using a 2.5% discount rate, the avoided cost of climate change resulting from the implementation of this rule is estimated to be worth $1B and $1.11B for the 69% and 75% collection efficiency levels, respectively.

The annual cost per landfill for waste-in-place, methane generation, and annual compliance reports is $4,840 each. For a landfill that is approximately 102 acres, the annual cost of SEM, assuming EPA Method 21 is used, is $31,348. The cost of installing a GCCS over the 895 acres of filled-in area across the 18 landfills that do not yet have GCCS, an area that is expected to increase by an average of 10 acres per year, is $42.4 million, with the operation and management cost being $109.2 million. Using a 2.5% discount rate, between 2029 and 2050, the total cost of compliance, including reporting, early installation of horizontal collectors, and GCCS, is $209.6 million.

While the combustion of landfill gas is expected to lead to increased emission in PM 2.5, SO_2, and NOx by 11.5, 10.4, and 25.8 short tons per year, respectively, the use of GCCS is expected to lead to the destruction of 97.3 short tons per year of volatile organic compounds (VOCs) and 42.9 short tons per year of HAPs that would have been released into the atmosphere. Comparable results are shown for the scenario where 69% collection efficiency is assumed. The expected average yearly emissions for this scenario are 10.6, 9.5, 23.8, and 89.5 short tons for (PM) 2.5, sulfur dioxide (SO_2), NOx, and VOC, respectively. The rule is also expected to reduce emissions of hazardous air pollutants (HAPs) by 39.5 short tons per year for the 69% collection efficiency levels. By reducing the emissions of these air pollutants, this rule will help to minimize the public's exposure to these compounds and the resulting adverse health impacts.

This investment by landfill owners/operators will circulate within the local economy and create direct, indirect, and induced economic impacts. Using the applicable multipliers, between 2029 and 2050, analysis shows that the investment by landfill owners/operators is expected to support 482 direct jobs and 1,630 indirect jobs. Whereas some of these jobs will take place directly at the landfills, others will be jobs in the supply chain responsible for producing the pipes and other equipment that constitute GCCS.

The effect of the rule on tipping fee, which is the amount paid by waste collection companies to landfill owners/operators, and household waste collection fees, which is the amount paid to waste collection companies for collecting waste, is expected to be minimal. Even if landfill owners/operators were to pass on all the compliance costs to households they serve, the potential upper-end increase in the average yearly cost for waste collection as a result of an increase in tipping fees is expected to be $3.66 per household.

Given the climate benefits, which are valued at $1.11B and $1B for the 75% and 69% collection efficiency, the benefit-to-cost ratio is expected to be 5.3 and 4.77 for the 75% and 69% collection efficiency levels, respectively. This shows that for each dollar incurred as cost, there will be benefits worth $5.3 and $4.77 for the 75% and 69% collection efficiency levels respectively. These results show that the rule is cost effective. The cost per ton of CO_2e removed ranges from $16.84 to $18.73 for the 75% and 69% collection efficiency levels, respectively. The cost per ton of CO_2e reduced for similar rules in other states ranges from $6 to $25, putting the expected compliance cost in the middle of that range.
