Landfill Project Protocol

Collecting and Destroying Methane from Landfills

Version 5.0 for Public Comment

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Abbreviations and Acronyms

ACF	Actual cubic feet
BAU	Business as usual
CAA	Clean Air Act
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
CH_4	Methane
CNG	Compressed natural gas
CO_2	Carbon dioxide
EG	Emission Guidelines
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
LFG	Landfill gas
LFGE	Landfill gas-to-energy
LMOP	Landfill Methane Outreach Program
LNG	Liquefied natural gas
Mg	Mega gram (1,000,000 grams or one tonne, or “t”)
MMg	Million mega grams
MSW	Municipal solid waste
N_2O	Nitrous oxide
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NG	Natural gas
NMOC	Non-methane organic compounds
NPV	Net Present Value
NSPS	New Source Performance Standards
NSR	New Source Review
PSD	Prevention of Significant Deterioration
QA/QC	Quality Assurance/Quality Control
RCRA	Resources Conservation and Control Act
Reserve	Climate Action Reserve
SCF	Standard cubic feet (60°F and 1 atm)
tCO_2e	Metric ton of carbon dioxide equivalent
VOC	Volatile organic compound
WIP	Waste in place

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1 Introduction

The Climate Action Reserve (Reserve) Landfill Project Protocol provides guidance to account for and report greenhouse gas (GHG) emission reductions associated with installing a landfill gas collection and destruction system at a landfill.

The Climate Action Reserve is an environmental nonprofit organization that promotes and fosters the reduction of greenhouse gas (GHG) emissions through credible market-based policies and solutions. A pioneer in carbon accounting, the Reserve serves as an approved Offset Project Registry (OPR) for the State of California's Cap-and-Trade Program and plays an integral role in supporting the issuance and administration of compliance offsets. The Reserve also establishes high quality standards for offset projects in the North American voluntary carbon market and operates a transparent, publicly-accessible registry for carbon credits generated under its standards.

Deleted: As the premier carbon offset registry for the North American carbon market, the Climate Action Reserve works to ensure environmental benefit, integrity and transparency in market-based solutions that reduce greenhouse gas (GHG) emissions. It establishes high quality standards for carbon offset projects, oversees independent third-party verification bodies, issues carbon credits generated from such projects and tracks the transaction of credits over time in a transparent, publicly-accessible system. By facilitating and encouraging the creation of GHG emission reduction projects, the Climate Action Reserve program promotes immediate environmental and health benefits to local communities, allows project developers access to additional revenues and brings credibility and value to the carbon market. The Climate Action Reserve is a private 501c(3) nonprofit organization based in Los Angeles, California.¶

Project developers that install landfill gas capture and destruction technologies use this document to register GHG reductions with the Reserve. This protocol provides eligibility rules, methods to calculate reductions, performance-monitoring instructions, and procedures for reporting project information to the Reserve. Additionally, all project reports receive annual, independent verification by ISO-accredited and Reserve-approved verification bodies. Guidance for verification bodies to verify reductions is provided in the Verification Program Manual and the corresponding Landfill Project Verification Protocol.

This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification of GHG emission reductions associated with a landfill project.[1]

Project developers must comply with all local, state, and federal municipal solid waste (MSW), air and water quality regulations in order to register GHG reductions with the Reserve. To register GHG reductions with the Reserve, project developers are not required to take an annual entity-level GHG inventory of their MSW operations.

[1] See the WRI/WBCSD GHG Protocol for Project Accounting (Part I, Chapter 4) for a description of GHG accounting principles.

2 The GHG Reduction Project

2.1 Background

Most MSW in the United States is deposited in landfills, where bacteria decompose the organic material. A product of both the bacterial decomposition and oxidation of solid waste is landfill gas, which is composed of methane (CH_4) and carbon dioxide (CO_2) in approximately equal concentrations, as well as smaller amounts of non-methane organic compounds (NMOC), nitrogen (N_2), oxygen (O_2) and other trace gases. If not collected and destroyed, over time, this landfill gas is released to the atmosphere. In the United States, the Environmental Protection Agency (EPA) has concluded that landfills are the largest source of anthropogenic emissions of CH_4, accounting for 16 percent of total CH_4 emissions.[2] However, the solid waste industry has made significant efforts to reduce their GHG emissions, with an almost 40% reduction in CH_4 emissions since 1990.[4]

There is considerable uncertainty regarding the actual amount of fugitive methane emissions from landfills. Therefore, this protocol does not address fugitive landfill methane emissions. Instead, it addresses the methane that is captured and destroyed in excess of any regulatory requirements. Landfill operations that utilize bioreactor technologies are not eligible to use this protocol, as it is unclear what effects the bioreactor may have on the baseline fugitive methane emissions and the timing of their release from the landfill.

2.2 Project Definition

For the purpose of this protocol, the GHG reduction project is defined as the collection of methane gas from one or more specified cells at an eligible landfill, and the destruction of such methane gas in one or more eligible destruction devices. The expansion of an existing GCCS to a new cell or cells can optionally be included within an existing landfill project or submitted as a new project. If an individual cell is to be considered as a new project, it must be engineered in such a way that LFG cannot migrate between that cell and other landfill cells. Where a single landfill contains multiple cells, across multiple landfill projects, those projects may share common destruction devices, provided the flow of methane from each project is metered separately.

Qualifying destruction devices may include utility flares, enclosed flares, engines, turbines, microturbines, boilers, pipelines, leachate evaporators, kilns, sludge dryers, burners, furnaces, or fuel cells. An eligible landfill is one that:

1. Is not subject to regulations or other legal requirements requiring the destruction of methane gas; and
2. Is not a bioreactor, as defined by the U.S. EPA: "a MSW landfill or portion of a MSW landfill where any liquid other than leachate (leachate includes landfill gas condensate) is added in a controlled fashion into the waste mass (often in combination with recirculating leachate) to reach a minimum average moisture content of at least 40 percent by weight to accelerate or enhance the anaerobic (without oxygen) biodegradation of the waste"[5]; and

[2] U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016, EPA-430-R-18-003 (April 2018).
[4] Ibid, *Table 7-3: CH4 Emissions from Landfills (MMR CO2 Eq.).*
[5] 40 CFR 63.1990 and 40 CFR 258.28a.

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Deleted: over the past 20 years.[3]
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Deleted: an eligible qualifying device for destroying
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3. Does not add any liquid other than leachate into the waste mass in a controlled manner.

Captured landfill gas may be destroyed onsite or transported for offsite use. Regardless of how project developers use the captured landfill gas, for the project to be eligible to register with the Reserve under this protocol, the ultimate fate of the methane must be destruction.[6]

Deleted: or used to power vehicles

Landfill gas collection and destruction systems typically consist of wells, pipes, blowers, caps and other technologies that enable or enhance the collection of landfill gas and convey it to a destruction technology. At some landfills, a flare will be the only device where landfill gas is destroyed. For projects that utilize energy or process heat technologies to destroy landfill gas, such as turbines, reciprocating engines, fuel cells, boilers, heaters, or kilns, these devices will be where landfill gas is destroyed. Most projects that produce energy or process heat also include a flare to destroy gas during periods when the gas utilization project is down for repair or maintenance. Direct use arrangements which entail the piping of landfill gas to be destroyed by an industrial end user at an offsite location are also an eligible approach to destruction of the landfill gas. For instances of direct use, agreements between the project developer and the end user of the landfill gas (i.e., an industrial client purchasing the landfill gas from the project developer), must include a legally binding agreement to assure that the GHG reductions will not be claimed by more than one party. Direct use project developers must also be able to identify the specific destruction technology at the receiving end of the pipeline.

Projects that utilize landfill methane for energy generation may avoid GHG emissions associated with fossil fuel combustion. However, under this protocol such projects do not receive credit for fossil fuel displacement. Although the Reserve does not issue CRTs for fossil fuel displacement, it strongly supports using landfill methane for energy production.

2.3 The Project Developer

The "project developer" is an entity that has an active account on the Reserve, submits a project for listing and registration with the Reserve, and is ultimately responsible for all project reporting and verification. Project developers may be landfill owners, landfill operators, GHG project financiers, utilities, or independent energy companies. The project developer must have clear ownership of the project's GHG reductions. Ownership of the GHG reductions must be established by clear and explicit title, and the project developer must attest to such ownership by signing the Reserve's Attestation of Title form.[7]

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[6] It is possible that at some point landfill gas may be used in the manufacture of chemical products. However, given that these types of projects are few, if any, these projects are not addressed in this protocol.
[7] Attestation of Title form available at http://www.climateactionreserve.org/how/program/documents/.

3 Eligibility Rules

Projects that meet the definition of a GHG reduction project in Section 2.2 must fully satisfy the following eligibility rules in order to register with the Reserve.

Eligibility Rule I:	Location	→	*U.S. and its tribal lands and territories*
Eligibility Rule II:	Project Start Date	→	*No more than 6 months prior to project submission*
Eligibility Rule III:	Additionality	→	*Meet performance standard*
		→	*Exceed legal requirements*
Eligibility Rule IV:	Regulatory Compliance	→	*Compliance with all applicable laws*

3.1 Location

Under this protocol, only projects located at landfills in the United States and its tribal lands and territories are eligible to register with the Reserve.[8]

3.2 Project Start Date

The project start date shall be defined by the project developer, but must be no more than 45 days after landfill gas is first destroyed in a project destruction device, regardless of whether sufficient monitoring data are available to report reductions. The start date is defined in relation to the commencement of methane destruction, not other activities that may be associated with project initiation or development.

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To be eligible, the project must be submitted to the Reserve no more than six months after the project start date.[9] Projects may always be submitted for listing by the Reserve prior to their start date. For projects that are transferring to the Reserve from other offset registries, start date guidance can be found in the Program Manual.

3.3 Project Crediting Period

The Reserve will issue CRTs for GHG reductions quantified and verified using this protocol for an initial crediting period of ten years following the project start date. However, the Reserve will cease to issue CRTs for GHG reductions if at any point landfill gas destruction becomes legally required at the landfill. If an eligible project has begun operation at a landfill that later becomes subject to a regulation, ordinance, or permitting condition that would call for the installation and operation of a landfill gas control system, the Reserve will issue CRTs for GHG reductions achieved up until the date that the landfill gas control system is legally required to be operational.

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The project crediting period begins at the project start date regardless of whether sufficient monitoring data are available to verify GHG reductions. Projects will be eligible to apply for a second crediting period, provided the project meets the eligibility requirements of the most current version of the protocol at the time of such application. If a project developer wishes to apply for eligibility under a second, 10-year crediting period, they must do so no sooner than six months before the end date of the initial crediting period.

Deleted: is available to verify GHG reductions.

[8] Refer to Appendix A for information on the performance standard analysis supporting application of this protocol in the United States.
[9] [insert footnote defining when a project is considered "submitted"]

A project may be eligible for a second crediting period even if the project has failed to maintain continuous reporting up to the time of applying for a second crediting period, provided the project developer elects to take a zero-credit reporting period for any period for which continuous reporting was not maintained.[11] The second crediting period shall begin on the day following the end date of the initial crediting period.

Deleted: If a project developer wishes to apply for eligibility under a second crediting period, they must do so within the final six months of the initial crediting period.[10] Thus, the Reserve may issue CRTs for GHG reductions quantified and verified according to the U.S. Landfill Project Protocol for a maximum of two ten-year crediting periods from the project start date. Sections 3.4.1 and 3.4.2 describe the requirements to qualify for a second crediting period. Deadlines and requirements for reporting and verification, as laid out in this protocol and the Verification Program Manual, will continue to apply without interruption.¶

3.4 Additionality

The Reserve strives to register only projects that yield surplus GHG reductions that are additional to what would have occurred in the absence of a carbon offset market.

Projects must satisfy the following tests to be considered additional:

1. The performance standard test
    a. Practice-change threshold
    b. End-use technology threshold
2. The legal requirement test

Deleted: <#>Size Threshold (LFGE projects only)¶

3.4.1 The Performance Standard Test

Projects pass the performance standard test by meeting a performance threshold, i.e., a standard of performance applicable to all landfill projects, established on an ex-ante basis by this protocol.[12]

If a project upgrades to a newer version of the protocol for a subsequent verification, it must meet the performance standard test requirements of that version of the protocol, applied as of the original project start date. If a project is submitted for a second crediting period, it is subject to the performance standard test in the most current version of the protocol at that time, applied as of the original project start date.

For this protocol, the Reserve uses both a practice-change technology threshold which focuses on the baseline scenario and changes made in the project scenario, as well as an end-use technology threshold, which focuses on the specific landfill methane destruction technology employed by the project. A project passes the performance standard test if it satisfies both of the following criteria (A and B).

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Deleted: (or "practice-based" threshold),

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(A) **Practice-Change Threshold**. The project must involve one of the following activities:

1. Installation of a landfill gas collection system and a new qualifying destruction device at an eligible landfill where landfill gas has never been collected and destroyed prior to the project start date.

2. Installation of a new qualifying destruction device at an eligible landfill where landfill gas is currently collected and vented, but has never been destroyed in any manner prior to the project start date.

3. Installation of a new qualifying destruction device at an eligible landfill where landfill gas was collected and destroyed at any time prior to the project start date using:

[11] See zero-credit reporting period guidance and requirements in the Reserve Program Manual, http://www.climateactionreserve.org/how/program/program-manual/.

[12] The Reserve defined the performance standard based upon an evaluation of landfill practices in the United States. A summary of the performance standard analysis is provided in Appendix A.

a. A non-qualifying destruction device (e.g., passive flare); or
b. A destruction device that is not otherwise eligible under the protocol (e.g., a destruction device installed prior to the earliest allowable project start date).

4. Installation of a new gas collection system on a physically-distinct[14] cell (or cells) where neither gas collection nor destruction has previously occurred, and connection of this new collection system to an existing landfill gas destruction system. The new collection system must have its own metering which satisfies the requirements of this protocol. In this scenario, more than one project may exist at a single landfill. The start date for this project shall be no more than 45 days following the first flow of landfill gas from the new collection system to the destruction system, regardless of the presence of adequate metering for crediting.

Destruction devices that were installed temporarily and utilized only for pilot or testing purposes specifically in anticipation of the GHG project shall not be considered in determining project eligibility or quantification. Devices may only be excluded under this provision if they were installed as a direct precursor to the project activity in order to gather information or determine project viability. Verifiable evidence of this intent must be presented. Changes in landfill ownership, or in the ownership of destruction devices, are not considered in determining prior landfill gas management practices. If landfill gas was previously collected and destroyed (in the given cells of the project) by a party other than the project developer, it still qualifies as "prior" collection and destruction.

Under scenarios (1), (2), and (3) above, expanding a well-field (either in conjunction with, or subsequent to, installing a new destruction device) may constitute a system expansion rather than a separate project. Expanding a well-field is eligible as a new, separate project only if it meets the conditions described in scenario (4). In these scenarios, expanding a well-field initiates a new crediting period.

The practice-change threshold is applied as of the project start date, and is evaluated at the project's initial verification.

(B) **End-Use Technology Threshold**. The second component of the performance standard test is a threshold based on the specific end-use technology employed to destroy the landfill methane.

Table 3.1. Eligible Landfill Methane Destruction Technologies[16]

Eligible Destruction Technologies	Ineligible Destruction Technologies
▪ Active flares (open or enclosed) ▪ On-site electricity generating systems ▪ Direct use pipelines (medium Btu)	▪ LFG upgrade for fuels (RNG, CNG or LNG) ▪ Injection into a natural gas common carrier pipeline or transmission and distribution network

The end-use technology threshold must be applied each time a landfill project is verified. The Reserve will periodically re-evaluate the appropriateness of the performance standard criteria by updating the analysis in Appendix A. As part of its periodic assessments of the performance threshold, the Reserve will use a stakeholder process to evaluate whether implementation of this protocol has resulted in negative environmental effects, such as increased emissions of

[14] The landfill cell must be engineered in such a way that landfill gas cannot migrate between that cell and other landfill cells.
[16] See Glossary of terms (Section 9) for definitions.

Deleted: <#>Installation of additional wells at an eligible closed landfill where landfill gas was collected and destroyed prior to the project start date using a qualifying flare (or flares) that is not otherwise eligible under the protocol (e.g. a flare installed prior to the earliest allowable project start date). The project is only eligible if a qualifying flare continues to be used to destroy collected methane.[13] Installation of additional flares, or flare upgrades, is permitted under this provision, provided that all destruction devices at the landfill site are flares. Only incremental gas collection and destruction (beyond baseline levels) is eligible for crediting.¶
<#>¶
<#>The practice threshold is applied as of the project start date, and is evaluated at the project's initial verification. If a project upgrades to a newer version of the protocol for a subsequent verification, it must meet the Practice Threshold of that version of the protocol, applied as of the original project start date. If a project is submitted for a second crediting period, it is subject to the Practice Threshold in the most current version of the protocol at that time, applied as of the original project start date.¶

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Deleted: Size Threshold (LFGE Projects Only). If the energy produced from destruction of any portion of the landfill gas is utilized on- or off-site (e.g. using an engine, turbine, microturbine, fuel cell or boiler), as of the first day of each reporting period[15], the waste in place (WIP) at the landfill must be less than 2.17 MMT for landfills located in "arid" counties and less than 0.72 MMT for landfills located in "non-arid" counties (see Figure A.1).¶
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The size

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¶
The Reserve recognizes the importance of waste diversion and recycling programs. Therefore,

criteria pollutants and/or methane. If it is determined that negative environmental effects have occurred, the Reserve will identify and implement revisions to the protocol to prevent such effects from occurring in the future, or may suspend implementation of the protocol if necessary.

3.4.2 The Legal Requirement Test

All projects are subject to a legal requirement test to ensure that the GHG reductions achieved by a project would not otherwise have occurred due to federal, state, or local regulations, or other legally binding mandates. Projects pass the legal requirement test when there are no laws, statutes, regulations, court orders, environmental mitigation agreements, permitting conditions, or other legally binding mandates requiring the destruction of landfill gas methane at the project site.[17] To satisfy the legal requirement test, project developers must submit a signed Attestation of Voluntary Implementation form[18] prior to the commencement of verification activities each time the project is verified. In addition, the project's Monitoring Plan (Section 6) must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the legal requirement test.

As of the project start date, landfills collecting and destroying landfill gas to comply with regulations or other legal mandates – or that are required by regulation or legal mandate to install a landfill gas control system in the future – are not eligible to register new projects with the Reserve. Landfills collecting and destroying landfill gas to comply with regulations or other legal mandates are not eligible to register GHG reductions associated with the early installation of gas control systems during landfill expansion into new cells.

If an eligible project begins operation at a landfill that later becomes subject to a regulation, ordinance, or permitting condition that calls for the installation of a landfill gas control system, GHG reductions may be reported to the Reserve up until the date that the installation of a landfill gas control system is legally required to be operational. If the landfill's methane emissions are included under an emissions cap (e.g., under a state or federal cap-and-trade program), emission reductions may likewise be reported to the Reserve until the date that the emissions cap takes effect.

3.4.2.1 Federal Regulations

There are several EPA regulations for MSW landfills that have a bearing on the eligibility of methane collection and destruction projects as voluntary GHG reduction projects. These regulations include:

- New Source Performance Standards (NSPS) for MSW Landfills, codified in 40 CFR 60 subpart WWW – Targets landfills that commenced construction or made modifications after May 1991
- Emission Guidelines (EG) for MSW Landfills, codified in 40 CFR 60 subpart Cc. – Targets existing landfills that commenced construction before May 30, 1991, but accepted waste after November 8, 1987
- The National Emission Standards for Hazardous Air Pollutants (NESHAP), codified in 40 CFR 63 subpart AAAA – Regulates new and existing landfills

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If a project developer wishes to apply for a second crediting period, the project must meet the eligibility requirements of the most current version of this protocol, including any updates to the Performance Standard Test.¶

[17] A project may pass the legal requirement test if a landfill gas control system is installed to treat landfill gas for NMOC in order to comply with a regulation, ordinance, or permitting condition, but destruction of the landfill gas is not the only compliance mechanism available to the landfill operator, and the total mass flow of NMOC for the landfill gas control system is less than the applicable NMOC threshold (see Section 3.4.2.1).

[18] Form available at http://www.climateactionreserve.org/how/program/documents/.

These regulations require control of non-methane organic compounds (NMOC) from landfills according to certain size and emission thresholds. In most cases, activities to reduce NMOC will also lead to a reduction in CH_4 emissions, as gas collection and destruction is a common NMOC management technique employed at regulated landfills. If the project start date occurs prior to the date of an NMOC test which crosses the regulatory threshold, the project may continue to receive credits for landfill gas destruction up until the date that the system is required to be operational by the regulation. If the project start date occurs after the date of an NMOC test which crosses the regulatory threshold, the landfill is not eligible to register as a project.

Landfills smaller than 2.5 million megagrams or 2.5 million cubic meters of waste, and those landfills not defined as MSW landfills such as landfills that contain only construction and demolition material or industrial waste, are not usually subject to NSPS, EG or NESHAP.

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Landfills with a design capacity of at least 2.5 million megagrams and 2.5 million cubic meters of municipal solid waste are subject to the NSPS or EG rules. Landfills above the design capacity size cutoff must calculate their annual NMOC emissions using equations or procedures in the NSPS or EG rules. The landfill must install a gas collection and control system within 30 months after the first annual NMOC emissions rate report in which the emissions rate equals or exceeds 50 Mg/yr. A landfill is subject to the NESHAP if the design capacity is at least 2.5 million megagrams and 2.5 million cubic meters of municipal solid waste, and it has estimated uncontrolled emissions equal to or greater than 50 Mg/yr NMOC as calculated according to Section 60.754(a) of the NSPS or U.S. EPA-approved federal, state or tribal plan.¶

3.4.2.2 State and Local Regulations, Ordinances, and Permitting Requirements

All states are required by the Clean Air Act (CAA) and Subtitle D of the Resource Conservation and Control Act (RCRA Subtitle D) to promulgate rules for landfills. Some landfills that exceed applicable emission thresholds will require site-specific permits requiring controls under the New Source Review (NSR) or Prevention of Significant Deterioration (PSD) permitting program authorized by the CAA and implemented by states. These state-level rules generally follow federal guidelines. However, the state rules can be more stringent, or require the installation of a gas collection and destruction system, or the destruction of volatile organic compounds (VOC), NMOC, or CH_4 earlier, or at smaller facilities, than the federal regulations would require.

For example, on June 17, 2010, California Air Resources Board (CARB) approved a discrete early action measure to reduce methane emissions from landfills. The control measure applies to landfills with greater than 450,000 Mg WIP. The regulation reduces methane emissions from landfills by requiring gas collection and control systems where these systems were not previously required, and establishes statewide performance standards to maximize methane capture efficiencies.[19]

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In recent years the inclusion of air quality, water quality and even GHG emission control measures in permitting requirements (CEQA, NEPA, etc.) has become more prevalent. State and local governments may regulate MSW landfills by putting in place nuisance laws or requiring solid waste facilities smaller than the facilities regulated by the CAA or RCRA Subtitle D to control landfill gas. Other regulations or ordinances may require minimal gas collection to prevent lateral migration of the landfill gas to neighboring properties. Collection and destruction activities required under NSPS, EG, NESHAP, CAA and other state and local regulations, ordinances or permitting requirements are not eligible as GHG reduction projects.[20]

The Reserve acknowledges that non-CAA programs such as RCRA Subtitle D, water quality regulations and other state and local regulations, ordinances or permitting requirements do not always dictate the installation of a landfill gas collection system as the only compliance mechanism to manage NMOC emissions or VOC water contamination, but that the installation

[19] California Air Resources Board, Landfill Methane Control Measure webpage: http://www.arb.ca.gov/cc/landfills/landfills.htm.

Deleted: http://www.arb.ca.gov/cc/landfills/landfills.htm.

[20] The Reserve acknowledges that the third-party verifier will need to exercise some discretion when reviewing permits that require the installation of a landfill gas control system or any portion thereof. Permits tend to include strong language, such as “must” or “shall” install a landfill gas control system, even in the case that a landfill chooses to voluntarily install a landfill gas control system but is required to obtain a permit to do so.

of a landfill gas collection system is commonly the most effective and least demanding compliance mechanism available. Therefore, the installation of a landfill gas collection and destruction system for compliance with non-CAA regulations will not qualify as a GHG reduction project under this protocol unless these projects also meet the eligibility requirements discussed below.

Some water quality, explosive gas mitigation, and local nuisance regulations and ordinances allow for passive landfill gas control systems, which collect and vent landfill gas to the atmosphere, but are not required to treat or destroy the vented gases. Project activities that add a destruction device to a landfill that is only required to implement a passive landfill gas control system pass the legal requirement test.

3.5 Regulatory Compliance

As a final eligibility requirement, project developers must attest that the project is in material compliance with all applicable laws (e.g., air, water quality, safety, etc.) prior to verification activities commencing each time a project is verified. Project developers are required to disclose in writing to the verifier any and all instances of non-compliance of the project with any law. If a verifier finds that a project is in a state of recurrent non-compliance or non-compliance that is the result of negligence or intent, then CRTs will not be issued for GHG reductions that occurred during the period of non-compliance. Non-compliance solely due to administrative or reporting issues, or due to “acts of nature,” will not affect CRT crediting.

Where projects are co-located at a single landfill, and in particular where projects share common equipment or infrastructure, the onus will be on the project developer(s) to demonstrate that a regulatory violation at the site is not relevant to all projects.

Deleted: <#>NMOC Threshold¶
<#>Certain water quality, explosive gas mitigation, and local nuisance regulations or ordinances require landfill gas collection systems. Once the landfill gas is collected and vented, the landfill may then become subject to air quality regulations requiring the control of NMOC emissions. In some instances, the air quality regulations may allow for flexibility in the treatment of landfill gas for NMOC using either destruction devices or other systems such as carbon adsorption (for the latter, the methane would be vented to atmosphere). Even in the regulatory situation where carbon adsorption is a compliance option, oftentimes a landfill gas destruction device will be the preferred compliance mechanism. Where it is determined that the destruction system is the preferred option, the landfill gas control system in question will not pass the Legal Requirement Test.¶
<#>¶
<#>The Reserve has developed an NMOC emissions threshold to determine the eligibility of projects at landfills where treatment of landfill gas for NMOC is required in order to comply with a regulation, ordinance, or permitting condition, but destruction of the landfill gas is not the only compliance mechanism available to the landfill operator.[21] The applicable threshold depends on whether or not closed flares are required by law at the landfill (e.g. by air district or local regulations). Specifically:¶
<#>¶
<#>For sites at which closed flares are not required by law, a project is eligible if the total mass flow of NMOC for the landfill gas control system is less than 1,775 pounds NMOC per month.¶
<#>¶
<#>For sites at which closed flares are required by law, a project is eligible if the total mass flow of NMOC for the landfill gas control system is less than 2,575 pounds NMOC per month.¶
<#>¶
<#>By default, projects must use the lower of the two thresholds. In order to use the higher threshold, the project developer must demonstrate to the satisfaction of a Reserve-approved verification body that an open flare could not be permitted at the landfill in question. ¶
<#>¶
<#>If the total mass flow of NMOC for the landfill gas control system is greater than the applicable NMOC threshold, then the landfill gas control system is not eligible as a GHG reduction project under this protocol. ¶

4 The GHG Assessment Boundary

The GHG Assessment Boundary delineates the GHG sources, sinks, and reservoirs (SSRs) that shall be assessed by project developers in order to determine the total net change in GHG emissions caused by a landfill project.

This protocol does not account for carbon dioxide emission reductions associated with displacing grid-delivered electricity or fossil fuel use.

CO_2 emissions associated with the generation and destruction of landfill gas are considered biogenic emissions[22] (as opposed to anthropogenic) and are not be included in the GHG Assessment Boundary. This is consistent with the Intergovernmental Panel on Climate Change's (IPCC) guidelines for captured landfill gas.[23]

Figure 4.1 below provides a general illustration of the GHG Assessment Boundary, indicating which SSRs are included or excluded from the boundary. All SSRs within the dashed line are accounted for under this protocol.

Table 4.1 provides greater detail on each SSR and provides justification for the inclusion or exclusion of SSRs and gases from the GHG Assessment Boundary.

[22] The rationale is that carbon dioxide emitted during combustion represents the carbon dioxide that would have been emitted during natural decomposition of the solid waste. Emissions from the landfill gas control system do not yield a net increase in atmospheric carbon dioxide because they are theoretically equivalent to the carbon dioxide absorbed during plant growth.

[23] *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*; p.5.10, ftnt.

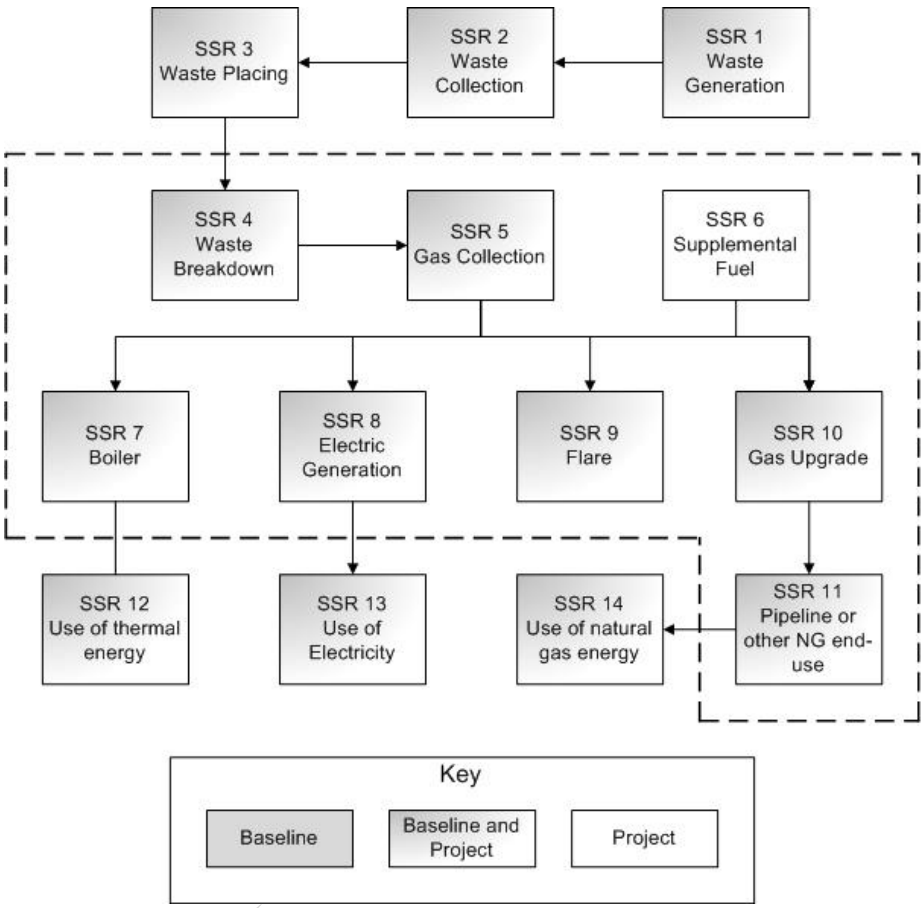

Figure 4.1. General Illustration of the GHG Assessment Boundary

Table 4.1. Summary of Identified Sources, Sinks, and Reservoirs

SSR	Source	Gas	Relevant to Baseline (B) or Project (P)	Included/ Excluded	Justification/Explanation
1	Emissions from Waste Generation	N/A	B,P	Excluded	GHG emissions from this source are assumed to be equal in the baseline and project scenarios
2	Emissions from Waste Collection	CO_2	B,P	Excluded	GHG emissions from this source are assumed to be equal in the baseline and project scenarios
		CH_4		Excluded	GHG emissions from this source are assumed to be equal in the baseline and project scenarios
		N_2O		Excluded	GHG emissions from this source are assumed to be equal in the baseline and project scenarios s
3	Emissions from Waste Placing Activities	CO_2	B,P	Excluded	GHG emissions from this source are assumed to be equal in the baseline and project scenarios
		CH_4		Excluded	GHG emissions from this source are assumed to be equal in the baseline and project scenarios
		N_2O		Excluded	This emission source is assumed to be equal in the baseline and project scenarios
4	Emissions from Waste Breakdown in Landfill	CO_2	B,P	Excluded	Biogenic CO_2 emissions are excluded
		CH_4		Included	Primary source of GHG emissions in baseline. Calculated based on destruction in baseline and project destruction devices.
5	Emissions from Gas Collection System	CO_2	P	Included	Landfill projects result in CO_2 emissions associated with the energy used for collection and processing of landfill gas
		CH_4		Excluded	This emission source is assumed to be very small
		N_2O		Excluded	This emission source is assumed to be very small
	Emissions from Baseline Gas Collection System	CO_2	B	Excluded	This emission source is assumed to be very small
		CH_4		Excluded	This emission source is assumed to be very small
		N_2O		Excluded	This emission source is assumed to be very small
6	Emissions from Supplemental Fuel	CO_2	P	Included	Landfill projects may require use of supplemental fossil fuel, resulting in significant new GHG emissions
		CH_4		Included	Calculated based on destruction efficiency of destruction device
		N_2O		Excluded	This emission source is assumed to be very small
	Emissions from Baseline Supplemental Fuel Use	CO_2	B	Excluded	This emission source is assumed to be very small
		CH_4		Excluded	This emission source is assumed to be very small
		N_2O		Excluded	This emission source is assumed to be very small
7		CO_2	P	Excluded	Biogenic CO_2 emissions are excluded

SSR	Source	Gas	Relevant to Baseline (B) or Project (P)	Included/ Excluded	Justification/Explanation
	Emissions from Project LFG Boiler Destruction	CH_4		Included	Calculated in reference to destruction efficiency
		N_2O		Excluded	This emission source is assumed to be very small
	Emissions from Baseline LFG Boiler Destruction	CO_2	B	Excluded	Biogenic CO_2 emissions are excluded
		CH_4		Included	Calculated in reference to destruction efficiency
		N_2O		Excluded	This emission source is assumed to be very small
8	Emissions from Project LFG Electricity Generation	CO_2	P	Excluded	Biogenic CO_2 emissions are excluded
		CH_4		Included	Calculated in reference to destruction efficiency
		N_2O		Excluded	This emission source is assumed to be very small
	Emissions from Baseline LFG Electricity Generation	CO_2	B	Excluded	Biogenic CO_2 emissions are excluded
		CH_4		Included	Calculated in reference to destruction efficiency
		N_2O		Excluded	This emission source is assumed to be very small
9	Emissions from Project LFG Flare Destruction	CO_2	P	Excluded	Biogenic CO_2 emissions are excluded
		CH_4		Included	Calculated in reference to destruction efficiency
		N_2O		Excluded	This emission source is assumed to be very small
	Emissions from Baseline LFG Flare Destruction	CO_2	B	Excluded	Biogenic CO_2 emissions are excluded
		CH_4		Included	Calculated in reference to destruction efficiency
		N_2O		Excluded	This emission source is assumed to be very small
10	Emissions from Upgrade of LFG	CO_2	B,P	Included	Landfill projects may result in GHG emissions from additional energy used to upgrade landfill gas
		CH_4		Excluded	This emission source is assumed to be very small
		N_2O		Excluded	This emission source is assumed to be very small
11	Emissions from Project LFG Pipeline or other NG end-use	CO_2	P	Excluded	Biogenic emissions are excluded
		CH_4		Included	Calculated in reference to destruction efficiency
		N_2O		Excluded	Assumed to be very small
	Emissions from Baseline LFG Pipeline or other NG end-use	CO_2	B	Excluded	Biogenic emissions are excluded
		CH_4		Included	Calculated in reference to destruction efficiency
		N_2O		Excluded	This emission source is assumed to be very small
12	Use of Project Generated Thermal Energy	CO_2	P	Excluded	This protocol does not cover displacement of GHG emissions from use of LFG-generated thermal energy
	Use of Baseline Generated Thermal Energy	CO_2	B	Excluded	This protocol does not cover displacement of GHG emissions from use of LFG-generated thermal energy

SSR	Source	Gas	Relevant to Baseline (B) or Project (P)	Included/ Excluded	Justification/Explanation
13	Use of Project Generated Electricity	CO_2	P	Excluded	This protocol does not cover displacement of GHG emissions from use of LFG-generated electricity.
	Use of Baseline Generated Electricity	CO_2	B	Excluded	This protocol does not cover displacement of GHG emissions from use of LFG-generated electricity.
14	Use of Natural Gas Energy	CO_2	P	Excluded	This protocol does not cover displacement of GHG emissions from use of LFG delivered through pipeline or other end uses
	Use of Baseline Natural Gas Energy	CO_2	B	Excluded	This protocol does not cover displacement of GHG emissions from use of LFG delivered through pipeline or other end uses

5 Quantifying GHG Emission Reductions

GHG emission reductions from a landfill project are quantified by comparing actual project emissions to baseline emissions at the landfill. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary (see Section 4) that would have occurred in the absence of the landfill project. Project emissions are actual GHG emissions that occur at sources within the GHG Assessment Boundary. Project emissions must be subtracted from the baseline emissions to quantify the project's total net GHG emission reductions (Equation 5.1).

GHG emission reductions must be quantified and reported on at least an annual basis. Such reports must be verified on a schedule in accordance with the requirements of Section 7.3. Project developers may choose to quantify and verify GHG emission reductions on a more frequent basis if they desire. The length of time over which GHG emission reductions are quantified and reported is called the "reporting period".

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The calculations provided in this protocol are derived from internationally accepted methodologies.[24] Project developers shall use the calculation methods provided in this protocol to determine baseline and project GHG emissions in order to quantify GHG emission reductions.

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Models that estimate biological and physical processes, such as the biological decomposition of solid waste in landfills and the migration of the landfill gas to the atmosphere are becoming increasingly refined and available. Process models typically rely on a series of input data that research has shown to be important drivers of the biological and geochemical process. In terms of GHG emission models, process models identify the mathematical relationships between inputs, basic conditions, and GHG emissions. The procedure for modeling landfills can be quite complex and subject to many different interpretations of how to address site-specific landfill gas generation factors and how to apply models effectively to landfills. At this time, no widely accepted method exists for determining the total amount of uncontrolled landfill gas emissions to the atmosphere from landfills. As new technologies and/or widely accepted modeling methods become available for the estimation of fugitive methane emissions from landfills, the Reserve will consider updating the protocol to incorporate these new approaches into the methane emission reduction quantification methodologies.

[24] The Reserve's GHG reduction calculation method is derived from the Kyoto Protocol's Clean Development Mechanism (ACM0001 V.6 and AM0053 V.1), the EPA's Climate Leaders Program (Draft Landfill Offset Protocol, October 2006), the GE AES Greenhouse Gas Services Landfill Gas Methodology V.1, and the RGGI Model Rule (January 5, 2007).

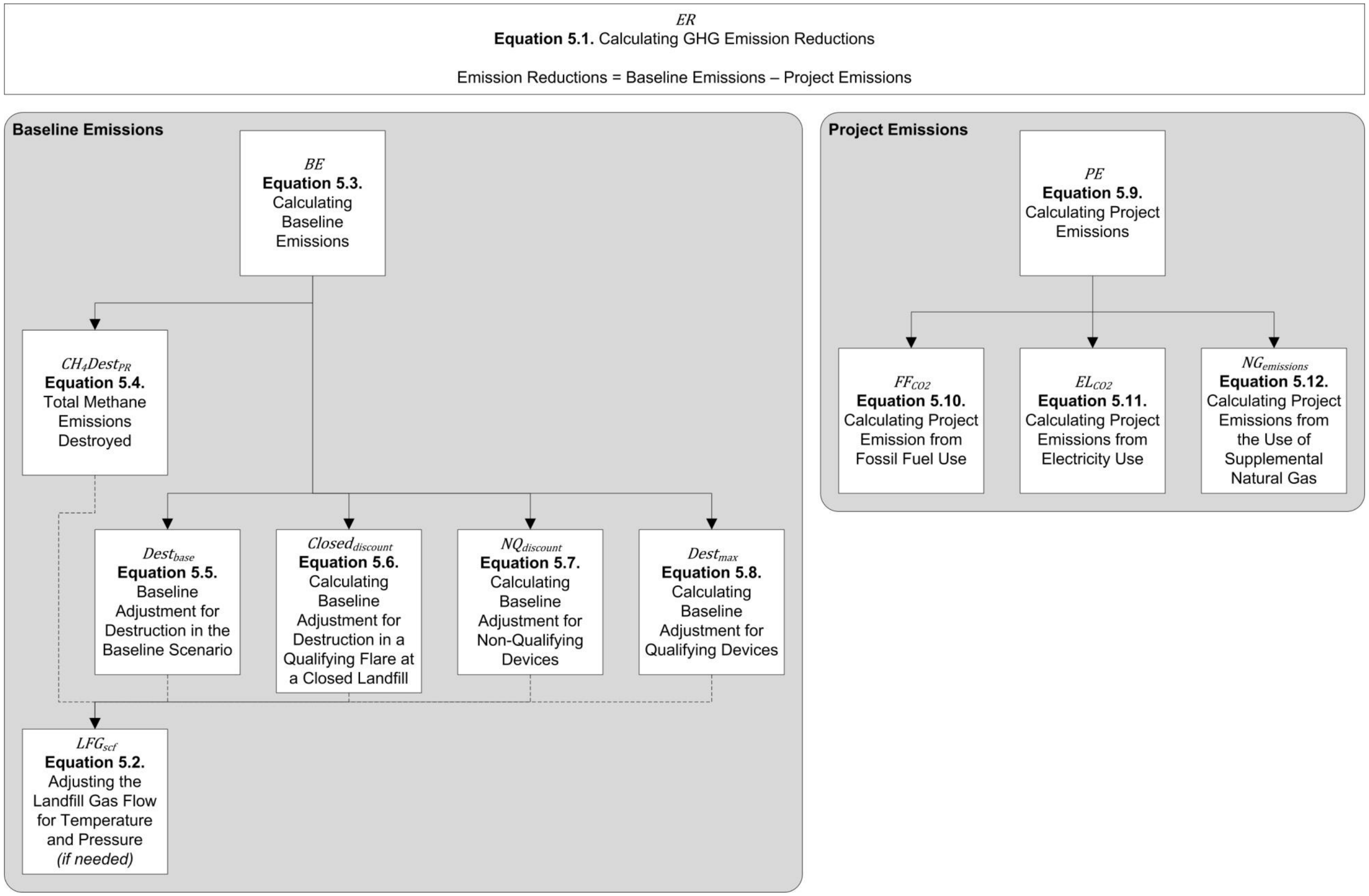

Figure 5.1. Organizational Chart for Equations in Section 5

Equation 5.1. Calculating GHG Emission Reductions

$$ER = BE - PE$$

Where,			Units
ER	=	GHG emission reductions of the project activity during the reporting period	tCO_2e
BE	=	Baseline emissions during the reporting period	tCO_2e
PE	=	Project emissions during the reporting period	tCO_2e

If any of the landfill gas flow metering equipment does not internally correct for the temperature and pressure of the landfill gas, separate pressure and temperature measurements must be used to correct the flow measurement. Corrected values must be used in all of the equations of this section. Apply Equation 5.2 only if the landfill gas flow metering equipment does not internally correct for temperature and pressure.

Equation 5.2. Adjusting the Landfill Gas Flow for Temperature and Pressure

$$LFG_{i,t} = LFG_{unadjusted} \times \frac{520}{T} \times \frac{P}{1}$$

Where,			Units
$LFG_{i,t}$	=	Adjusted volume of landfill gas fed to the destruction device *i*, in time interval *t*	scf
$LFG_{unadjusted}$	=	Unadjusted volume of landfill gas collected for the given time interval	acf
T	=	Measured temperature of the landfill gas for the given time period (°R = °F + 459.67)	°R
P	=	Measured pressure of the landfill gas in for the given time interval	atm

5.1 Quantifying Baseline Emissions

Traditional baseline emission calculations are not required for this protocol for the quantification of methane reductions. The baseline scenario assumes that all uncontrolled methane emissions are released to the atmosphere except for the portion of methane that would be oxidized by bacteria in the soil of uncovered landfills absent the project,[25] or destroyed by a baseline destruction device. Therefore, with the exception of the deductions outlined below, baseline emissions are equal to the sum of all methane destroyed by eligible destruction devices.

As noted in Section 3.4.1, projects may fall into five categories based on the baseline state of the landfill and level of landfill gas management. Each of these categories requires a slightly different methodology for calculating relevant baseline emissions.

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1. Landfills where no previous collection or destruction took place prior to the project start date must deduct the following from baseline emissions:
    a. The amount of methane that would have been oxidized by soil bacteria in the absence of the project.

2. Landfills where previous collection and/or destruction took place in a non-qualifying destruction device must deduct the following from baseline emissions:
    a. The amount of methane destroyed by the non-qualifying destruction device.

[25] A small portion of the methane generated in landfills (around 10%) is naturally oxidized to carbon dioxide by methanotrophic bacteria in the cover soils of well managed landfills. The 10% factor is based on Intergovernmental Panel on Climate Change (IPCC) guidelines (2006).

Deleted: Landfill cover systems incorporating a synthetic liner throughout the entire area of the final cover system should use a default methane oxidation rate of zero. A 10% methane oxidation factor shall be used for all other landfills.

   b. The amount of methane that would have been oxidized by soil bacteria in the absence of the project.

3. Landfills where previous collection and destruction took place in a qualifying destruction device must deduct the following from baseline emissions:
   a. The amount methane that could have been destroyed if the baseline destruction device was operating at full capacity.
   b. The amount of methane that would have been oxidized by soil bacteria in the absence of the project.

4. Closed landfills where previous collection and destruction took place in a qualifying flare must deduct the following from baseline emissions:
   a. The amount of methane collected by baseline landfill gas wells and destroyed in the qualifying flare.
   b. The amount of methane that would have been oxidized by soil bacteria in the absence of the project.

5. Projects where an existing GCCS is connected to a new landfill cell which was previously not affected by the GCCS must deduct the following from baseline emissions:
   a. If previous collection and destruction of methane from this cell (other than in the project GCCS), then the appropriate amount of methane shall be deducted according to the guidance in items 2-4, above, depending on which is relevant.
   b. The amount of methane that would have been oxidized by soil bacteria in the absence of the project.

These conditions ensure that the reductions resulting from the GHG project can be accounted for separately from collection and destruction that would have occurred from the baseline equipment. Only the landfill gas destroyed beyond what would have been destroyed by the baseline collection and destruction system is considered eligible for crediting.

Baseline emissions shall be calculated using Equation 5.3. Both the OX discount factor and the DF discount factor shall only be applied to periods of time during the reporting period for which each factor is applicable. The OX discount factor shall only be applied for the number of days during the reporting period when the landfill did not incorporate a synthetic liner throughout the entire area of the final cover system. The DF discount factor shall only be applied for the number of days during the reporting period when methane concentration values were taken at a frequency that is less than continuous (every 15 minutes). Thus, Equation 5.3 may be calculated separately for different portions of the reporting period, with the results summed to provide a total BE value for the entire reporting period.

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Equation 5.3. Calculating Baseline Emissions

$$BE = CH_4Dest_{PR} \times GWP \times (1 - OX) \times (1 - DF) - Dest_{base} \times (1 - OX)$$

Where,			Units
BE	=	Baseline emissions during the reporting period	tCO_2e
CH_4Dest_{PR}	=	Total methane destroyed by the project landfill gas collection and destruction system during the reporting period (see Equation 5.4)	tCH_4
GWP	=	Global warming potential factor of methane to carbon dioxide equivalent, equal to 25 at the time of publication[26]	tCO_2e/tCH_4
OX	=	Factor for the oxidation of methane by soil bacteria. Equal to 0.10 for all landfills except those that incorporate a synthetic liner throughout the entire area of the final cover system, where OX = 0	
DF	=	Discount factor to account for uncertainties associated with the monitoring equipment. (See Section 6.1.) Equal to zero if using continuous methane monitoring	
$Dest_{base}$	=	Adjustment to account for baseline LFG destruction device (see Equation 5.5). Equal to zero if no baseline LFG destruction system is in place prior to project implementation	tCO_2e

The term CH_4Dest_{PR} represents the amount of methane destroyed by the project. This term is calculated according to Equation 5.4.

[26] At time of publication, landfill projects are instructed to use GWP values from the IPCC 4th Assessment Report. This value may be updated in the future via guidance from the Reserve.

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Deleted: $Dest_{base}$

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Equation 5.4. Total Methane Emissions Destroyed

$$CH_4Dest_{PR} = \sum_{i}(CH_4Dest_i) \times (0.0423 \times 0.000454)$$

Where,			Units
CH_4Dest_{PR}	=	Total methane destroyed by the project landfill gas collection and destruction system during the reporting period	tCH_4
$CH_4\ Dest_i$	=	The net quantity of methane destroyed by destruction device *i* during the reporting period	scf CH_4
0.0423	=	Density of methane	lb CH_4/scf CH_4
0.000454	=	Conversion factor	tCH_4/lb CH_4

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And,

$$CH_4Dest_i = Q_i \times DE_i$$

Where,			Units
$CH_4\ Dest_i$	=	The net quantity of methane destroyed by device *i* during the reporting period	scf
Q_i	=	Total quantity of landfill methane sent to destruction device *i* during the reporting period	scf
DE_i	=	Methane destruction efficiency for device *i*. See Appendix B for guidance	

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And,

$$Q_i = \sum_{t}(LFG_{i,t} \times PR_{CH_4,t})$$

Where,			Units
Q_i	=	Total quantity of landfill methane sent to destruction device *i* during the reporting period	scf
$LFG_{i,t}$	=	Adjusted volume of landfill gas fed to the destruction device *i*, in time interval *t*	scf
t	=	Time interval for which LFG flow and concentration measurements are aggregated. See Table 6.1 for guidance	
$PR_{CH4,t}$	=	The average methane fraction of the landfill gas in time interval *t*	scf CH_4/ scf LFG

For projects where methane was destroyed in the baseline, Equation 5.5 must be applied. This equation accounts for the methane emissions calculated in Equation 5.4 which would have been destroyed in the absence of the project activity.

Any project at a landfill where methane was collected and destroyed at any time prior to the project start date – even if the prior collection and/or destruction system was removed or has been dormant for an extended period of time – must apply the baseline deduction. The time period over which the value of $Dest_{base}$ is to be aggregated, using Equation 5.5, may be chosen by the project developer, but cannot be less than weekly, and must be consistent throughout the reporting period.

Equation 5.5. Baseline Adjustment for Destruction in the Baseline Scenario

$$Dest_{base} = (Closed_{discount} + NQ_{discount} + Dest_{max}) \times 0.0423 \times 0.000454 \times GWP$$

Where,			Units
$Dest_{base}$	=	Adjustment to account for the baseline methane destruction associated with a baseline destruction device. Equal to zero if there is no baseline installation	tCO_2e
$Closed_{discount}$	=	Adjustment to account for the methane that would have been combusted in the baseline flare from baseline wells at a closed landfill. Equal to zero if the project is not a flare project at a closed landfill	scf CH_4
$NQ_{discount}$	=	Adjustment to account for the methane that would have been combusted in the baseline, non-qualifying combustion device. Equal to zero if there is no non-qualifying combustion device	scf CH_4
$Dest_{max}$	=	Deduction of the un-utilized capacity of the baseline destruction device. This deduction is to be applied only when a new destruction device is used during project activity. See Box 5.1 below for an example of the application of the $Dest_{max}$ adjustment	scf CH_4
0.0423	=	Density of methane	lb CH_4/ scf CH_4
0.000454	=	Conversion factor	tCH_4/ lb CH_4
GWP	=	Global warming potential factor of methane to carbon dioxide equivalent, equal to 25 at the time of publication[29]	tCO_2e/tCH_4

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Equation 5.6. Calculating Baseline Adjustment for Destruction in a Qualifying Flare at a Closed Landfill

$$Closed_{discount} = LFG_{B1} \times B_{CH_4,closed}$$

Where,			Units
$Closed_{discount}$	=	Adjustment to account for the methane which would have been combusted in the baseline flare from baseline wells at a closed landfill. Equal to zero if the project is not a flare project at a closed landfill	scf CH_4
LFG_{B1}	=	Landfill gas from the baseline landfill gas wells that would have been destroyed by the qualifying destruction system during the reporting period. See Appendix C for guidance on calculating LFG_{B1}	scf
$B_{CH4,closed}$	=	Methane fraction of landfill gas destroyed by the collection system during the reporting period. See Appendix C for guidance on calculating $B_{CH4,closed}$	scf CH_4/ scf LFG

$NQ_{discount}$, may be determined using either of the following options.

1. $NQ_{discount}$ shall be equal to the measured quantity of methane recovered through an active gas collection system installed into the corresponding cell or waste mass of the landfill in which the baseline devices operated. The landfill gas flow from these active wells shall be determined using Equation 5.4 above for a minimum of one month.[30]

[29] At time of publication, landfill projects are instructed to use GWP values from the IPCC 4th Assessment Report. This value may be updated in the future via guidance from the Reserve.

[30] For the purpose of using Equation 5.4 to determine $NQ_{discount}$, the quantity of landfill gas would be only that which is being metered from the corresponding cell or waste mass in which the baseline devices had operated, and not necessarily all of the landfill gas being destroyed by the destruction system.

2. $NQ_{discount}$ shall be monitored and calculated per Equation 5.7 and Appendix D.

Equation 5.7. Calculating Baseline Adjustment for Non-Qualifying Devices

$$NQ_{discount} = LFG_{B2} \times B_{CH_4,NQ}$$

Where,

			Units
$NQ_{discount}$	=	Adjustment to account for the methane that would have been combusted in the baseline, non-qualifying combustion device. Equal to zero if there is no non-qualifying combustion device	scf CH_4
LFG_{B2}	=	Landfill gas that would have been destroyed by the original, non-qualifying destruction system during the reporting period. See Appendix C for guidance on calculating LFG_{B2}	scf
$B_{CH4,NQ}$	=	Methane fraction of landfill gas destroyed by non-qualifying devices in the baseline. Equal to average methane concentration over the reporting period if maximum capacity is used for LFG_{B2}. See Appendix C for further guidance on calculating $B_{CH4,NQ}$	scf CH_4/ scf LFG

Equation 5.8. Calculating Baseline Adjustment for Qualifying Devices

$$Dest_{max} = \sum_t [(LFG_{Bmax,t} - LFG_{B3,t}) \times PR_{CH_4,t}]$$

Where,

			Units
$Dest_{max}$	=	Deduction of the un-utilized capacity of the baseline destruction device. This deduction is to be applied only when a new destruction device is used during project activity. See Box 5.1 below for an example of the application of the $Dest_{max}$ adjustment	scf CH_4
$LFG_{Bmax,t}$	=	The maximum landfill gas flow capacity of the baseline methane destruction device in time interval *t*	scf
$LFG_{B3,t}$	=	The actual landfill gas flow of the baseline methane destruction device in time interval *t*	scf
$PR_{CH4,t}$	=	The average methane fraction of the landfill gas in time interval *t* as measured	scf CH_4 /scf LFG
t	=	Time interval for which LFG flow and concentration measurements are aggregated. See Table 6.1 for guidance	

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Box 5.1. Applying the $Dest_{max}$ Adjustment

This adjustment was designed to help differentiate system upgrades from additional projects, while encouraging project developers to use their landfill gas beneficially. In short, this methodology assumes that any gas which *could* have been destroyed in the baseline qualifying device is not additional; diversion of that gas to a new destruction device represents an upgrade. Therefore, this term deducts from calculated project reductions that portion of gas which, in the absence of the new destruction device, still could have been destroyed.

Example:
A flare with a capacity of 1000 cfm was installed at a landfill in 1998. Therefore, because this flare was operational before 2001, the landfill gas control system is ineligible as a project under this protocol. However, in 2005, an electric generator with a 2000 cfm capacity was installed, and all landfill gas was diverted to this device. The addition of the electric generator meets the eligibility requirements of this protocol, and therefore qualifies as a new project. Because the baseline flare is a qualifying destruction device under this protocol and is not eligible as a project due to other eligibility criteria (i.e., operational date), it must be accounted for using $Dest_{max}$.

In 2005, 900 cfm was sent to generator, and 0 cfm was sent to the flare. In the year 2006, due to landfill expansion and installation of additional wells, the generator destroyed 1400 cfm while the flare was non-operational. In 2007, further well expansion allowed the generator to operate at full capacity and the flare was used to destroy an additional 300 cfm of landfill gas.

Calculations:

Year	Generator Destruction (cfm)	Flare Capacity (cfm)	Flare Destruction (cfm)	Deduction (cfm)	Project Reductions (cfm)
2005	900	1000	0	1000	-100 (0)
2006	1400	1000	0	1000	400
2007	1800	1000	300	700	1100

Note: this example and the calculations are significantly simplified for illustrative purposes. The example values are calculated on a cubic feet per minute of landfill gas basis. Reporters are actually required to report the cumulative value of methane gas sent to the destruction device for each time interval *t*.

5.2 Quantifying Project Emissions

Project emissions must be quantified at a minimum on an annual, *ex-post* basis. As shown in Equation 5.9, project emissions equal:

- Total indirect carbon dioxide emissions resulting from consumption of electricity from the grid related to project activities
- Total carbon dioxide emissions from the onsite destruction of fossil fuel related to project activities
- Total carbon dioxide emissions from the combustion of supplemental natural gas
- Total methane emissions from the incomplete combustion of supplemental natural gas

Project emissions shall be calculated using Equation 5.9.

Equation 5.9. Calculating Project Emissions

$$PE = FF_{CO_2} + EL_{CO_2} + NG_{emissions}$$

Where,			Units
PE	=	Project emissions during the reporting period	tCO_2e
FF_{CO2}	=	Total carbon dioxide emissions from the destruction of fossil fuel during the reporting period	tCO_2
EL_{CO2}	=	Total carbon dioxide emissions from the consumption of electricity from the grid during the reporting period	tCO_2
$NG_{emissions}$	=	Total quantity of emissions from supplemental natural gas, including both uncombusted methane and carbon dioxide emissions during the reporting period	tCO_2e

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Equation 5.10. Calculating Project Emissions from Fossil Fuel Use

$$FF_{CO_2} = \frac{\sum_j (FF_{PR,j} \times EF_{FF,j})}{1000}$$

Where,			Units
FF_{CO2}	=	Total carbon dioxide emissions from the destruction of fossil fuel during the reporting period	tCO_2
$FF_{PR,j}$	=	Total fossil fuel consumed by the project landfill gas collection and destruction system during the reporting period, by fuel type *j*	volume fossil fuel
$EF_{FF,j}$	=	Fuel specific emission factor. See Appendix B	kg CO_2/volume fossil fuel
1000	=	Conversion factor	kg CO_2/tCO_2

Equation 5.11. Calculating Project Emissions from Electricity Use

$$EL_{CO_2} = \frac{(EL_{PR} \times EF_{EL})}{2204.62}$$

Where,			Units
EL_{CO2}	=	Total carbon dioxide emissions from the consumption of electricity from the grid during the reporting period	tCO_2
EL_{PR}	=	Total electricity consumed by the project landfill gas collection and destruction system during the reporting period	MWh
EF_{EL}	=	CO_2 emission factor for electricity used[31]	lb CO_2/ MWh
2204.62	=	Conversion factor	lb CO_2/ tCO_2

[31] Refer to the most version of the U.S. EPA eGRID most closely corresponding to the time period during which the electricity was used. Projects shall use the annual total output emission rates for the subregion where the project is located, not the annual non-baseload output emission rates. The eGRID tables are available from the U.S. EPA website: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

Equation 5.12. Calculating Project Emissions from the Use of Supplemental Natural Gas

$$NG_{emissions} = \sum_i \left[NG_i \times NG_{CH_4} \times 0.0423 \times 0.000454 \times \left[\left((1 - DE_i) \times GWP\right) + \left(DE_i \times \frac{12}{16} \times \frac{44}{12}\right)\right]\right]$$

Where,			Units
$NG_{emissions}$	=	Total emissions from supplemental natural gas during the reporting period, including both uncombusted methane and carbon dioxide emissions	tCO_2e
NG_i	=	Total quantity of supplemental natural gas delivered to the destruction device *i* during the reporting period	scf
DE_i	=	Methane destruction efficiency of destruction device *i*. See Appendix B	
NG_{CH4}	=	Average methane fraction of the supplemental natural gas as provided for by fuel vendor	scf CH_4/scf NG
0.0423	=	Density of methane	lb CH_4/scf CH_4
0.000454	=	Conversion factor	tCH_4/lb CH_4
GWP	=	Global warming potential factor of methane to carbon dioxide equivalent, equal to 25 at the time of publication[32]	tCO_2e/tCH_4
12/16	=	Carbon ratio of methane	C/CH_4
44/12	=	Carbon ratio of carbon dioxide	CO_2/C

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[32] At time of publication, landfill projects are instructed to use GWP values from the IPCC 4th Assessment Report. This value may be updated in the future via guidance from the Reserve.

6 Project Monitoring

The Reserve requires a Monitoring Plan to be established for all monitoring and reporting activities associated with the project. The Monitoring Plan will serve as the basis for verifiers to confirm that the stipulations of this section and Section 7 have been and will continue to be met, and that consistent, rigorous monitoring and record-keeping is ongoing at the project site. The Monitoring Plan must cover all aspects of monitoring and reporting contained in this protocol and must specify how data for all relevant parameters in Table 6.1 (below) will be collected and recorded.

At a minimum the Monitoring Plan shall stipulate the frequency of data acquisition; a record keeping plan (see Section 7.2 for minimum record keeping requirements); the frequency of instrument cleaning, inspection, field check and calibration activities; and the role of the individual performing each specific monitoring activity, as well as QA/QC provisions to ensure that data acquisition and meter calibration are carried out consistently and with precision. The Monitoring Plan shall also contain a detailed diagram of the landfill gas collection and destruction system, including the placement of all meters and equipment that affect SSRs within the GHG Assessment Boundary (see Figure 4.1).

Finally, the Monitoring Plan must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the legal requirement test (Section 3.4.2).

Project developers are responsible for monitoring the performance of the project and operating the landfill gas collection and destruction system in a manner consistent with the manufacturer's recommendations for each component of the system.

6.1 Monitoring Requirements

Methane emission reductions from landfill gas capture and control systems must be monitored with measurement equipment that directly meters:

- The flow of landfill gas delivered to each destruction device, measured continuously and recorded every 15 minutes or totalized and recorded at least daily, adjusted for temperature and pressure

- The fraction of methane in the landfill gas delivered to the destruction device, measured continuously and recorded every 15 minutes and averaged at least daily (measurements taken at a frequency that is less than continuous and more than weekly may be used with the application of a 10% discount in Equation 5.3). Projects may not be eligible for crediting if methane concentration is not measured and recorded at least weekly.

If discontinuous CH_4 concentration monitoring is to be employed, then the project developer shall develop a prescriptive methodology for how such monitoring is to be carried out. The method should be reasonable in the circumstances of the project and shall be consistently applied throughout the reporting period. Any such methodology, and adherence to the methodology (or otherwise), should be clearly set out in the project monitoring report.

Methane fraction of the landfill gas is to be measured on a wet/dry basis, depending on the basis of measurement for flow, temperature, and pressure (must be measured on same basis as flow, temperature, and pressure). The methane analyzer and flow meter should be installed

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in the same relative placement to any moisture-removing components of the landfill gas system (there should not be a moisture-removing component separating the measurement of flow and methane fraction). The meters themselves should also operate on the same basis (i.e., if one meter internally dries the sample prior to measurement, the same should occur at other meters). An acceptable variation to this arrangement would be in the case where flow is measured on a dry basis, while the methane concentration is measured on a wet basis. The opposite arrangement is not permissible. No separate monitoring of temperature and pressure is necessary when using flow meters that automatically correct for temperature and pressure, expressing LFG volumes in normalized cubic meters.

A single flow meter may be used for multiple destruction devices under certain conditions. If all destruction devices are of identical efficiency and verified to be operational, no additional steps are necessary for project registration. Otherwise, the destruction efficiency of the least efficient destruction device shall be used as the destruction efficiency for all destruction devices monitored by this meter.

If there are any periods when not all destruction devices measured under a single flow meter are operational, methane destruction during these periods will be eligible provided that the verifier can confirm all of the following conditions are met:

1. The destruction efficiency of the least efficient destruction device in operation shall be used as the destruction efficiency for all destruction devices monitored by this meter; and

2. All devices are either equipped with valves on the input gas line that close automatically if the device becomes non-operational (requiring no manual intervention), or designed in such a manner that it is physically impossible for gas to pass through while the device is non-operational; and

3. For any period where one or more destruction device within this arrangement is not operational, it must be documented that the remaining operational devices have the capacity to destroy the maximum gas flow recorded during the period. For devices other than flares, it must be shown that the output corresponds to the flow of gas.

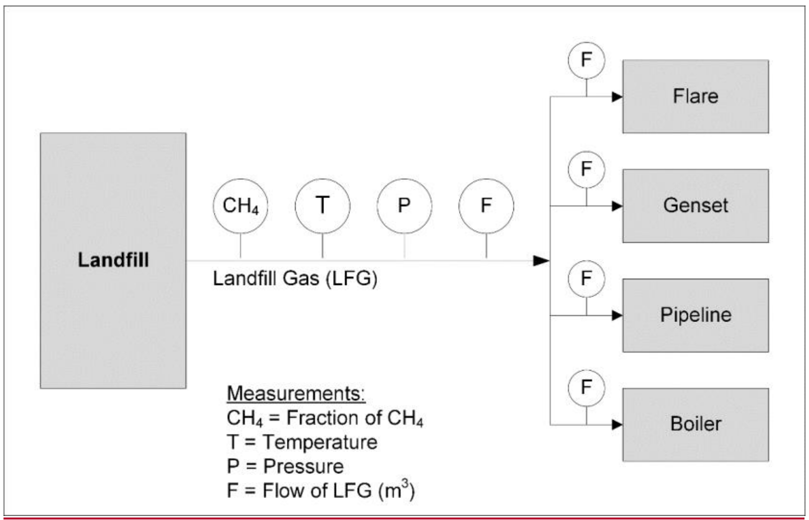
These means for allowing a single device to monitor multiple destruction devices shall not be construed to relax the requirement for hourly operational data for all destruction devices. Rather, this arrangement permits a specific metering arrangement during periods when one or more devices are *known* to not be operating. In order to know the operational status of a device, it must be monitored. All destruction devices must have their operational status monitored and recorded at least hourly. In other words, the project dataset will include an indication of operational status corresponding to each hour of landfill gas data. If these data are missing or never recorded for a particular device, that device will be assumed to be not operating and no emission reductions may be claimed for landfill gas destroyed by that device during the period when data are missing.

All flow data collected must be corrected for temperature and pressure at 60^{o} F and 1 atm. If any of the landfill gas flow metering equipment does not internally correct for the temperature and pressure of the landfill gas, separate pressure and temperature measurements must be used to correct the flow measurement. The temperature and pressure of the landfill gas must be measured continuously. Corrected values must be used in all of the equations of this section.

Apply Equation 5.2 only if the landfill gas flow metering equipment does not internally correct for temperature and pressure.

The continuous methane analyzer should be the preferred option for monitoring methane concentrations, as the methane content of landfill gas captured can vary by more than 20% during a single day due to gas capture network conditions (dilution with air at wellheads, leakage on pipes, etc.).[34] When using the alternative approach of discontinuous methane concentration measurement using a calibrated portable gas analyzer, project developers must account for the uncertainty associated with these measurements by applying a 10% discount factor to the total quantity of methane collected and destroyed in Equation 5.3.

Figure 6.1 represents the suggested arrangement of the landfill gas flow meters and methane concentration metering equipment.



Note: The number of flow meters must be sufficient to track the total flow as well as the flow to each combustion device. The above scenario includes one more flow meter than would be necessary to achieve this objective.
Source: Consolidated baseline methodology for landfill gas project activities, Clean Development Mechanism, Version 07, Sectoral Scope 13 (2007).

Figure 6.1. Suggested Arrangement of LFG Metering Equipment

The operational activity of the landfill gas collection system and the destruction devices shall be monitored and documented at least hourly to ensure actual landfill gas destruction. GHG reductions will not be accounted for during periods which the destruction device was not operational. For flares, operation is defined as thermocouple readings above 500° F. For all other destruction devices, the means of demonstration shall be determined by the project developer and subject to verifier review. If relying on the difference between ambient temperatures and temperatures recorded by a thermocouple to demonstrate operational activity (instead of using a fixed temperature threshold), then a temperature difference of at least 200° F shall be used. If any destruction device is equipped with a safety shut off valve, that prevents

[34] Consolidated baseline methodology for landfill gas project activities, Clean Development Mechanism, Version 07, Sectoral Scope 13 (2007).

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Deleted: Eligible projects may use monthly methane concentration measurements using a calibrated portable gas analyzer until January 1, 2009, after which a continuous methane analyzer or weekly measurement using a calibrated portable gas analyzer is required. In the case where monthly methane concentration measurements are used, project developers must account for the uncertainty associated with these measurements by applying a 20% discount factor to the total quantity of methane collected and destroyed.¶
¶

Deleted: Methane fraction of the landfill gas to be measured on a wet/dry basis (must be measured on same basis as flow, temperature, and pressure). The methane analyzer and flow meter should be installed in the same relative placement to any moisture-removing components of the landfill gas system (there should not be a moisture-removing component separating the measurement of flow and methane fraction). An acceptable variation to this arrangement would be in the case where the flow meter is placed after a moisture-removing component (dry basis), while the methane analyzer is placed before this component (wet basis). The opposite arrangement is not permissible. No separate monitoring of temperature and pressure is necessary when using flow meters that automatically correct for temperature and pressure, expressing LFG volumes in normalized cubic meters.

biogas flow to the destruction device when not operational, then demonstrating the presence and operability of the shut off valve will be sufficient to demonstrate operational activity of that device.

In “direct use” scenarios where landfill gas is delivered offsite to a third-party end user (not to a commercial natural gas transmission and distribution system or to a facility under management control of the project operator), reasonable efforts must be made to obtain data demonstrating the operational status of the destruction device(s). If it is not possible to obtain such data, the verifier must use their professional judgment to confirm that there has been no significant release of project landfill gas and that the project developer is using the destruction efficiency value appropriate for the end use. Evidence that may assist a verifier in making a determination to that effect may include, but is not limited to, one or more of the following:

- A signed attestation from the third-party operator of the destruction device that no catastrophic failure of destruction or significant release of landfill gas occurred during the reporting period, and that the safety features and/or design of the destruction equipment are such that the destruction device does not allow landfill gas to pass through it when non-operational and/or that the project developer is able to switch off the flow of landfill gas offsite in the event of emergencies (and has rigorous procedures in place to ensure such shutoff occurs immediately);
- The verifier confirming the same via a first-person interview with the third-party operator;
- Examination of the safety features and/or design of the destruction equipment, such that the destruction device does not allow landfill gas to pass through it when non-operational and/or that the project developer is able to switch off the flow of landfill gas offsite in the event of emergencies (and has rigorous procedures in place to ensure such shutoff occurs immediately);
- Records that can corroborate the type and level of operation of the destruction device during the reporting period, such as engine output data, etc.

If the verifier is reasonably assured that no significant release of landfill gas has occurred offsite during the reporting period, the project can use the destruction efficiency appropriate to that offsite destruction device, despite the lack of hourly data from a monitoring device confirming operational status.

6.1.1 Indirect Monitoring Alternative

As an alternative to the direct measurement of LFG, projects may instead choose to demonstrate volumes of CH_4 destroyed using output data for their destruction device. Where the output of destruction devices (such as gensets) is measured via the use of a commercial transfer meter (i.e., a meter whose output is used as the basis for the quantification under an energy delivery contract), which is subject to regular, professional maintenance, the project may use such data as the basis for determining the volume of CH_4 destroyed. The meter output shall be subjected to an appropriate conversion methodology to calculate the volume of CH_4 destroyed during the reporting period. One example of a methodology that may be suitable is brake-specific fuel consumption calculations. Projects may also be able to use results of performance testing mandated under 40 CFR Part 60 Subpart IIII, Subpart JJJJ, and Subpart KKKK, to develop an appropriate conversion methodology. If using the indirect monitoring alternative, the commercial meter must be maintained by appropriately-trained professionals, in accordance with manufacturer requirements. In scenarios where projects are able to control the maintenance of such meters, the QA/QC requirements in Section 6.2 apply. In scenarios where projects are not able to control the maintenance of such meters, reasonable efforts must be made to obtain documentation demonstrating manufacturer maintenance requirements have been met during the reporting period.

The monitoring methodology to be employed must be clearly set out in the project monitoring report, it must be applied consistently throughout the reporting period, and it must be demonstrated to the satisfaction of the projects verifier that the use of such data and methodology is reasonable in the circumstances, and results in a conservative estimation of the volume of CH_4 destroyed.

6.2 Instrument QA/QC

Monitoring instruments shall be inspected and calibrated according to the following schedule.

All gas flow meters[36] and continuous methane analyzers must be:

- Cleaned and inspected on a regular basis, as specified in the project's Monitoring Plan, with activities and results documented by site personnel. Cleaning and inspection procedures and frequency must, at a minimum, follow the manufacturer's recommendations;
- Field checked for calibration accuracy by a third-party technician with the percent drift documented, using either a portable instrument (such as a pitot tube) or manufacturer specified guidance, at the end of – but no more than two months prior to or after – the end date of the reporting period;[37]
- Calibrated by the manufacturer or a certified third-party calibration service per manufacturer's guidance or every 5 years, whichever is more frequent.

Conformance with the factory calibration requirement is only required during periods of time where data gathered by the meter are used for emission reduction quantification. Periods where the meter did not meet this requirement will not cause the project to fail this requirement, provided the meter was not being used for project emission reduction quantification during such periods, and provided the meter was brought back into conformance before being employed to gather project data.

If a stationary meter that was in use for 60 days or more is removed and not reinstalled during a reporting period, that meter shall either be field-checked for calibration accuracy prior to removal or calibrated (with percent drift documented) by the manufacturer or a certified calibration service (with as-found results recorded) prior to quantification of emission reductions for that reporting period.

If the required calibration or calibration check is not performed and properly documented, no GHG credits may be generated for that reporting period. Flow meter calibrations shall be documented to show that the meter was calibrated to a range of flow rates corresponding to the flow rates expected at the landfill. Methane analyzer calibrations shall be documented to show that the calibration was carried out to the range of conditions (temperature and pressure) corresponding to the range of conditions as measured at the landfill.

[36] Field checks and calibrations of flow meters shall ensure that the meter accurately reads volumetric flow, and has not drifted outside of the prescribed +/-5% accuracy threshold.
[37] Instead of performing field checks, the project developer may instead have equipment calibrated by the manufacturer or a certified calibration service per manufacturer's guidance, at the end of but no more than two months prior to or after the end date of the reporting period to meet this requirement.

The as-found condition (percent drift) of a field check must always be recorded. If the meter is found to be measuring outside of the +/- 5% threshold for accuracy, the data must be adjusted for the period beginning with the last successful field check or calibration event up until the meter is confirmed to be in calibration (unless the last event occurred during the prior reporting period, in which case adjustment is made back to the beginning of the current reporting period). If, at the time of the failed field check, the meter is cleaned and checked again, with the as-left condition found to be within the accuracy threshold, a full calibration is not required for that piece of equipment. This shall be considered a failed field check, followed by a successful field check. The data adjustment shall be based on the percent drift recorded at the time of the failed field check. However, if the as-left condition remains outside of the +/- 5% accuracy threshold (whether or not additional cleaning and accuracy testing occurs), calibration is required by the manufacturer or a certified service provider for that piece of equipment.

Deleted: If the field check on a piece of equipment reveals accuracy outside of a +/- 5% threshold, calibration by the manufacturer or a certified service provider is required for that piece of equipment.¶

For the interval between the last successful field check and any calibration event confirming accuracy outside of the +/- 5% threshold, all data from that meter or analyzer must be scaled according to the following procedure. These adjustments must be made for the entire period from the last successful field check until such time as the meter is properly calibrated.

1. For calibrations that indicate under-reporting (lower flow rates, or lower methane concentration), the metered values must be used without correction.

2. For calibrations that indicate over-reporting (higher flow rates, or higher methane concentration), the metered values must be adjusted based on the greatest calibration drift recorded at the time of calibration.

For example, if a project conducts field checks quarterly during a year-long reporting period, then only three months of data will be subject at any one time to the penalties above. However, if the project developer feels confident that the meter does not require field checks or calibration on a greater than annual frequency, then failed events will accordingly require the penalty to be applied to the entire year's data. Frequent calibration may minimize the total accrued drift (by zeroing out any error identified), and result in smaller overall deductions. Additionally, strong equipment inspection practices that include checking all probes and internal components will minimize the risk of meter and analyzer inaccuracies and the corresponding deductions. If it is not possible to determine the accrued drift and/or an appropriate method for scaling the data (e.g., drift is recorded in mw, which cannot be directly translated into a drift percentage), the project developer should seek guidance from the instrument manufacturer to confirm when the 5% drift threshold has been reached and how to appropriately scale the relevant data.

Additional field checks carried out during the reporting period at the project developer's discretion may be performed by an individual that is not a third-party technician. In this case, the competency of the individual and the accuracy of the field check procedure must be assessed and approved by the verification body. Furthermore, if the field check reveals accuracy outside of the +/- 5% threshold, calibration is required and the data must be scaled as detailed above. In order to provide flexibility in verification, data monitored up to two months after a field check may be verified. As such, the end date of the reporting period must be no more than two months after the latest successful field check.

If a portable instrument either:

1. acquires project data (e.g., a handheld methane analyzer is used to take weekly methane concentration measurements), or

2. is used to field check the calibration accuracy of equipment that acquires project data and the portable instrument produces a data output that is or could be used in emission reduction calculations (i.e., flow or concentration); then,

the portable instrument shall be maintained and calibrated per the manufacturer's specifications, and calibrated at least annually by the manufacturer, by a laboratory approved by the manufacturer, or at an ISO 17025 accredited laboratory. Other pieces of equipment used for QA/QC of monitoring instruments shall be maintained according to the manufacturer's specifications, including calibration where specified. Portable methane analyzers must also be field calibrated to a known sample gas prior to each use.

6.3 Missing Data

In situations where the flow rate or methane concentration monitoring equipment is missing data, the project developer shall apply the data substitution methodology provided in Appendix D. If for any reason the destruction device monitoring equipment is inoperable (for example, the thermocouple on the flare), then no emission reductions can be registered for the period of inoperability.

6.4 Monitoring Parameters

Prescribed monitoring parameters necessary to calculate baseline and project emissions are provided in Table 6.1.

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If available, the official source tested methane destruction efficiency shall be used in in place of the default methane destruction efficiency. Otherwise, project developers have the option to use either the default methane destruction efficiencies provided, or the site specific methane destruction efficiencies as provided by a state or local agency accredited source test service provider, for any of the destruction devices used in the project, performed on an annual basis. Device-specific source testing shall include at least three test runs, with the accepted final value being one standard deviation below the mean of the measured efficiencies.¶

Deleted: thermal coupler

Table 6.1. Monitoring Data to be Collected and Used to Estimate Emission Reductions

Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
		Regulatory compliance	Project developer attestation to compliance with regulatory requirements relating to landfill gas project	Each reporting period		Must be monitored and determined for each reporting period. The project developer shall document all federal, state, and local regulations, ordinances, and permit requirements (and compliance status for each) that apply to the GHG reduction project. The project developer shall provide a signed attestation to their compliance status for the above mentioned federal, state, and local regulations, ordinances, and permit requirements
		Legal requirement test	Project developer attestation of voluntary implementation	Each reporting period		Must be monitored and determined for each reporting period. The project developer shall document
		Operation of destruction device		Hourly	o	Required for each destruction device. For flares, operation is defined as thermocouple readings above 500° F. The presence and operability of a safety shut off valve will be sufficient to demonstrate operational activity of the given device.
Equation 5.1	ER	GHG emission reductions during the reporting period	tCO_2e	Per reporting period	c	

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Deleted: be documented as of the beginning of the reporting period to assess whether the landfill continues to satisfy the performance standard test (Section 3.4.1). For landfills

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Deleted: all federal, state, and local regulations, ordinances, and permit requirements (and compliance status for each) that apply to the GHG reduction project. The project developer shall provide a signed attestation to their compliance status for the above mentioned federal, state, and local regulations, ordinances, and permit requirements

Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
Equation 5.1 Equation 5.3	BE	Baseline emissions during the reporting period	tCO_2e	Per reporting period	c	
Equation 5.1 Equation 5.9	PE	Project emissions during the reporting period	tCO_2e	Per reporting period	c	
Equation 5.2 Equation 5.4	$LFG_{i,t}$	Adjusted volume of landfill gas fed to the destruction device *i*, in time interval *t*	scf	Continuous	m/c	Measured continuously by a flow meter and recorded at least once every 15 minutes. Data to be aggregated by time interval t (this parameter is calculated in cases where the metered flow must be corrected for temperature and pressure)
Equation 5.2	$LFG_{unadjusted}$	Unadjusted volume of landfill gas collected for the given time interval	acf	Continuous	m	Used only in cases where the flow meter does not automatically correct to 60° F and 1 atm
Equation 5.3 Equation 5.4	CH_4Dest_{PR}	Total methane destroyed by the project landfill gas collection and destruction system during the reporting period	tCH_4		c	
Equation 5.3	DF	Discount factor to account for uncertainties associated with the monitoring equipment	0-1.0	Continuous	r	Equal to zero if using continuous methane monitor (see Section 6.1)

Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
Equation 5.3	OX	Factor for the oxidation of methane by soil bacteria	0, 0.1		r	Equal to 0.10 for all landfills except those that incorporate a synthetic liner throughout the entire area of the final cover system where OX = 0
Equation 5.3	GWP	100-year global warming potential for CH_4	tCO_2e/tCH_4	Per reporting period	r	As of publication, the value is 25.[38] This may be updated in the future via guidance from the Reserve
Equation 5.3 Equation 5.5	$Dest_{base}$	Adjustment to account for the baseline methane destruction associated with a baseline destruction device	tCO_2e		c	Equal to zero if no baseline LFG destruction system is in place prior to project implementation
Equation 5.4	CH_4Dest_i	The net quantity of methane destroyed by destruction device *i* during the reporting period	scf CH_4		c	
Equation 5.4	Q_i	Total quantity of landfill methane sent to destruction device *i* during the reporting period	scf CH_4	Daily/Weekly	c	Calculated daily if methane is continuously metered or weekly if methane is measured weekly
Equation 5.4 Equation 5.12	DE_i	Methane destruction efficiency for device *i*	%	Once	r/m	See Appendix B for guidance and default values

[38] Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (2007).

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Deleted: Project developers have the option to use a state or local agency accredited source test service provider to test the actual methane destruction efficiency of each of the destruction devices used in the project case. If using source test data for destruction efficiencies in Equation 5.2, all source test documentation shall be provided to the verifier. See for default values

Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
Equation 5.4	*t*	Time interval for which LFG flow and concentration measurements are aggregated	week, day, or smaller interval	Continuous/ Daily/Other	r	The interval employed is contingent upon the interval of data acquisition.
Equation 5.4 Equation 5.8	$PR_{CH4,t}$	The average methane fraction of the landfill gas in time interval *t*	scf CH_4 / scf LFG	Continuous/ Other	m	Measured by continuous gas analyzer or a calibrated portable gas analyzer. Data to be averaged by time interval *t*.
Equation 5.5 Equation 5.6	$Closed_{discount}$	Adjustment to account for the methane which would have been combusted in the baseline flare from baseline wells at a closed landfill	scf CH_4	Yearly	c	Calculated per year, but may be scaled for project reporting periods less than one year
Equation 5.5 Equation 5.7	$NQ_{discount}$	Adjustment to account for the methane which would have been combusted in the baseline, non-qualifying combustion device	scf CH_4	Yearly	c	Calculated per year, but may be scaled for project reporting periods less than one year
Equation 5.5 Equation 5.8	$Dest_{max}$	Deduction of the un-utilized capacity of the baseline destruction device	scf CH_4	Weekly, Monthly, or Per reporting period (no more than weekly)	c	This deduction is to be applied only when a new destruction device is used during project activity

Deleted: Projects employing continuous methane concentration monitoring may use the interval of their data acquisition system. Otherwise, this parameter is equal to one day for continuously monitored methane concentration and one week for weekly monitored methane concentration.

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Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
Equation 5.6	LFG_{B1}	Landfill gas from the baseline landfill gas wells that would have been destroyed by the qualifying destruction system during the reporting period	scf LFG	Yearly	c	Calculated using Appendix D. Calculated per year, but may be scaled for project reporting periods less than one year
Equation 5.6	$B_{CH4,closed}$	Methane fraction of landfill gas destroyed by baseline flares at a closed landfill	scf CH_4 / scf LFG	Continuously/ Other	m	Measured by continuous gas analyzer or a calibrated portable gas analyzer.
Equation 5.7	LFG_{B2}	Landfill gas that would have been destroyed by the original, non-qualifying destruction system during the reporting period	scf LFG / yr	Yearly	c	Calculated per Section 5, or according to guidance provided in Appendix D. Calculated per year, but may be scaled for project reporting periods less than one year
Equation 5.7	$B_{CH4,NQ}$	Methane fraction of landfill gas destroyed by non-qualifying devices in the baseline	scf CH_4 / scf LFG	Continuously/ Other	m	Measured by continuous gas analyzer or a calibrated portable gas analyzer
Equation 5.8	$LFG_{Bmax,t}$	The maximum landfill gas flow capacity of the baseline methane destruction device in time interval *t*	scf	At beginning of first reporting period	c	Calculated based on manufacturer's and/or engineer specifications for the destruction device and blower system. The maximum capacity of the limiting component, either the destruction device or blower, shall be used

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Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
Equation 5.8	$LFG_{B3,t}$	The actual landfill gas flow of the baseline methane destruction device in time interval *t*	scf	Continuous	m	Measured continuously by a flow meter and recorded at least once every 15 minutes
Equation 5.9 Equation 5.10	FF_{CO2}	Total carbon dioxide emissions from the destruction of fossil fuel during the reporting period	tCO_2	Per reporting period	c	
Equation 5.9 Equation 5.11	EL_{CO2}	Total carbon dioxide emissions from the consumption of electricity from the grid during the reporting period	tCO_2		c	
Equation 5.9 Equation 5.12	$NG_{emissions}$	Total quantity of emissions from supplemental natural gas, including both uncombusted methane and carbon dioxide emissions during the reporting period	tCO_2	Per reporting period	c	Includes both uncombusted methane and carbon dioxide emissions

Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
Equation 5.10	$FF_{PR,j}$	Total fossil fuel consumed by the project landfill gas collection and destruction system during the reporting period, by fuel type *j*	volume fossil fuel	Monthly	o	Calculated from monthly record of fossil fuel purchased and consumed
Equation 5.10	$EF_{FF,j}$	Fuel specific emission factor	kg CO_2 / volume fossil fuel	Per reporting period	r	See Appendix C
Equation 5.11	EL_{PR}	Total electricity consumed by the project landfill gas collection and destruction system during the reporting period	MWh		m/o	Obtained from either onsite metering or utility purchase records. Required to determine CO_2 emissions from use of electricity to operate the project activity
Equation 5.11	EF_{EL}	Carbon emission factor for electricity used	lbCO_2 / MWh	Per reporting period	r	See the most up to date version available of the U.S. EPA eGRID[39]
Equation 5.12	NG_i	Total quantity of supplemental natural gas delivered to the destruction device *i* during the reporting period	scf	Continuous	m	Metered prior to delivery to destruction device

Deleted: . http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

[39] Available at: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
Equation 5.12	NG_{CH4}	Average methane fraction of the supplemental natural gas as provided for by fuel vendor	scf CH_4 / scf NG		r	Refer to purchase records
	T	Temperature of the landfill gas	°C	Continuous	m	No separate monitoring of temperature is necessary when using flow meters that automatically adjust flow volumes for temperature and pressure, expressing LFG volumes in normalized cubic feet
	P	Pressure of the landfill gas	atm	Continuous	m	No separate monitoring of pressure is necessary when using flow meters that automatically measure adjust flow volumes for temperature and pressure, expressing LFG volumes in normalized cubic feet

7 Reporting Parameters

This section provides guidance on reporting rules and procedures. A priority of the Reserve is to facilitate consistent and transparent information disclosure among project developers. Project developers must submit verified emission reduction reports to the Reserve annually at a minimum.

7.1 Project Documentation

Project developers must provide the following documentation to the Reserve in order to register a landfill gas destruction project:

- Project Submittal form
- Signed Attestation of Title form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Regulatory Compliance form
- Detailed system diagram from Monitoring Plan
- Verification Report
- Verification Opinion

Project developers must provide the following documentation each reporting period in order for the Reserve to issue CRTs for quantified GHG reductions:

- Verification Report
- Verification Opinion
- Signed Attestation of Title form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Regulatory Compliance form

At a minimum, the above project documentation will be available to the public via the Reserve's online reporting tool of the same name, the Climate Action Reserve. Further disclosure and other documentation may be made available on a voluntary basis. Project submittal forms and project registration information can be found at:
http://www.climateactionreserve.org/how/program/documents/.

7.2 Record Keeping

For purposes of independent verification and historical documentation, project developers are required to keep all information outlined in this protocol for a period of 10 years after the information is generated or 7 years after the last verification. This information will not be publicly available, but may be requested by the verifier or the Reserve.

System information the project developer should retain includes:

- All data inputs for the calculation of GHG reductions
- Copies of all solid waste, air, water, and land use permits; Notices of Violations (NOVs); and any administrative or legal consent orders dating back at least 3 years prior to the project start date, and for each subsequent year of project operation
- Project developer attestation of compliance with regulatory requirements relating to the landfill gas project
- Collection and control device information (installation dates, equipment list, etc.)

- LFG flow meter information (model number, serial number, manufacturer's calibration procedures)
- Methane monitor information (model number, serial number, calibration procedures)
- Destruction device monitor information (model number, serial number, calibration procedures)
- LFG flow data (for each flow meter)
- LFG flow meter calibration data (for each flow meter)
- Methane monitoring data
- Methane monitor calibration data
- Destruction device monitoring data (for each destruction device)
- Destruction device monitor calibration data (for each destruction device)
- CO_2e monthly and annual tonnage calculations
- Copies of the results of the NSPS/EG Tier 1 and/or Tier 2 NMOC emission rate estimates and the projected date when system start-up will be required by NSPS
- Initial and annual verification records and results
- All maintenance records relevant to the LFG control system, monitoring equipment, and destruction devices
- Operational records of the landfill relating to the amount of waste placed onsite (scalehouse records, etc.), or most recent documented WIP report accepted by a regulatory agency

Calibrated portable gas analyzer information that the project developer should retain includes:

- Date, time, and location of methane measurement
- Methane content of LFG (% by volume) for each measurement
- Methane measurement instrument type and serial number
- Date, time, and results of instrument calibration
- Corrective measures taken if instrument does not meet performance specifications

7.3 Reporting Period and Verification Cycle

7.3.1 Reporting Periods

The reporting period is the length of time over which GHG emission reductions from project activities are quantified. Project developers must report GHG reductions resulting from project activities during each reporting period. A reporting period may not exceed 12 months in length, except for the initial reporting period, which may cover up to 24 months. The Reserve accepts verified emission reduction reports on a sub-annual basis, should the project developer choose to have a sub-annual reporting period and verification schedule (e.g., monthly, quarterly, or semi-annually). Reporting periods must be contiguous; there must be no gaps in reporting during the crediting period of a project once the first reporting period has commenced.

7.3.2 Verification Periods

The verification period is the length of time over which GHG emission reductions from project activities are verified. The initial verification period for a landfill project is limited to one reporting period (i.e., up to 24 months). Subsequent verification periods may cover up to two reporting periods. CRTs will not be issued for reporting periods that have not been verified. For any reporting period that ends prior to the end of the verification period (i.e., year 1 of a 2 year verification period), an interim monitoring report must be submitted to the Reserve no later than 90 days following the end of the relevant reporting period. The interim monitoring report shall contain a summary of emission reductions, description of QA/QC activities, and description of

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Reporting periods must be contiguous; there may be no time gaps in reporting during the crediting period of a project once the initial reporting period has commenced.¶
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any potential nonconformances, data errors, metering issues, or material changes to the project.[40]

To meet the verification deadline, the project developer must have the required verification documentation (see Section 7.1) submitted within 12 months of the end of the verification period. The end date of any verification period must correspond to the end date of a reporting period.

7.3.3 Verification Site Visit Schedule

A site visit must occur during the initial verification, and at least once every two reporting periods thereafter. A reporting period may be verified without a new site visit if both of the following are true:

1. A new site visit occurred in conjunction with the verification of the previous reporting period; and,
2. The current verification is being conducted by the same verification body that conducted the site visit for the previous verification.

The above requirement applies regardless of whether the verification period contains one or two reporting periods.

[40] A template monitoring report is available at: http://www.climateactionreserve.org/how/program/documents/.

8 Verification Guidance

This section provides verification bodies with guidance on verifying GHG emission reductions from landfill gas projects developed to the standards of this protocol. This verification guidance supplements the Reserve's Verification Program Manual and describes verification activities in the context of landfill gas destruction projects.

Verification bodies trained to verify landfill gas projects must conduct verifications to the standards of the following documents:

- Climate Action Reserve Program Manual
- Climate Action Reserve Verification Program Manual
- Climate Action Reserve Landfill Project Protocol

The Reserve's Program Manual, Verification Program Manual, and project protocols are designed to be compatible with each other and are available on the Reserve's website at http://www.climateactionreserve.org.

In cases where the Program Manual and/or Verification Program Manual differ from the guidance in this protocol, this protocol takes precedent.

Only ISO-accredited verification bodies trained by the Reserve for this project type are eligible to verify landfill project reports. Verification bodies approved under other project protocol types are not permitted to verify landfill projects. Information about verification body accreditation and Reserve project verification training can be found in the Verification Program Manual.

8.1 Standard of Verification

The Reserve's standard of verification for landfill projects is the Landfill Project Protocol (this document), the Reserve Program Manual, and the Verification Program Manual. To verify a landfill project developer's project report, verification bodies apply the guidance in the Verification Program Manual and this section of the protocol to the standards described in Section 2 through 7 of this protocol. Sections 2 through 7 provide eligibility rules, methods to calculate emission reductions, performance monitoring instructions and requirements, and procedures for reporting project information to the Reserve.

8.2 Monitoring Plan

The Monitoring Plan serves as the basis for verification bodies to confirm that the monitoring and reporting requirements in Section 6 and Section 7 have been met, and that consistent, rigorous monitoring and record-keeping is ongoing at the project site. Verification bodies shall confirm that the Monitoring Plan covers all aspects of monitoring and reporting contained in this protocol and specifies how data for all relevant parameters in Table 6.1 are collected and recorded.

8.3 Verifying Project Eligibility

Verification bodies must affirm a landfill project's eligibility according to the rules described in this protocol. The table below outlines the eligibility criteria for a landfill project. This table does not represent all criteria for determining eligibility comprehensively; verification bodies must also look to Section 3 and the verification items list in Table 8.2.

Table 8.1. Summary of Eligibility Criteria

Eligibility Rule	Eligibility Criteria	Frequency of Rule Application
Start Date	Projects must be submitted for listing within 6 months of the project start date	Once during first verification
Location	United States and its territories	Once during first verification
Performance Standard: Practice Threshold	Installation of a qualifying destruction device where not required by law (see Section 3.4.1 for other requirements)	Once during first verification
Performance Standard: Technology Threshold	Projects must employ an eligible landfill gas destruction technology, as identified in Table 3.1.	Every verification
Legal Requirement Test	Signed Attestation of Voluntary Implementation form and monitoring procedures that lay out procedures for ascertaining and demonstrating that the project passes the legal requirement test	Every verification
Regulatory Compliance	Signed Attestation of Regulatory Compliance form and disclosure of all non-compliance events to verifier; project must be in material compliance with all applicable laws	Every verification
Exclusions	▪ Bioreactors ▪ Landfills which re-circulate a liquid other than leachate in a controlled manner ▪ Indirect emissions from the displacement of grid electricity or natural gas	Every verification

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8.4 Core Verification Activities

The Landfill Project Protocol provides explicit requirements and guidance for quantifying GHG reductions associated with the destruction of landfill methane. The Verification Program Manual describes the core verification activities that shall be performed by verification bodies for all project verifications. They are summarized below in the context of a landfill project, but verification bodies shall also follow the general guidance in the Verification Program Manual.

Verification is a risk assessment and data sampling effort designed to ensure that the risk of reporting error is assessed and addressed through appropriate sampling, testing, and review. The three core verification activities are:

1. Identifying emissions sources, sinks and reservoirs
2. Reviewing GHG management systems and estimation methodologies
3. Verifying emission reduction estimates

Identifying emission sources, sinks, and reservoirs

The verification body reviews for completeness the sources, sinks, and reservoirs identified for a project, such as system energy use, fuel consumption, combustion and destruction from various qualifying and non-qualifying destruction devices, and soil oxidation.

Reviewing GHG management systems and estimation methodologies
The verification body reviews and assesses the appropriateness of the methodologies and management systems that the landfill project uses to gather data on methane collected and destroyed and to calculate baseline and project emissions.

Verifying emission reduction estimates
The verification body further investigates areas that have the greatest potential for material misstatements and then confirms whether or not material misstatements have occurred. This involves site visits to the project to ensure the systems on the ground correspond to and are consistent with data provided to the verification body. In addition, the verification body recalculates a representative sample of the performance or emissions data for comparison with data reported by the project developer in order to double-check the calculations of GHG emission reductions.

8.5 Landfill Project Verification Items

The following tables provide lists of items that a verification body needs to address while verifying a landfill project. The tables include references to the section in the protocol where requirements are further described. The table also identifies items for which a verification body is expected to apply professional judgment during the verification process. Verification bodies are expected to use their professional judgment to confirm that protocol requirements have been met in instances where the protocol does not provide (sufficiently) prescriptive guidance. For more information on the Reserve's verification process and professional judgment, please see the Verification Program Manual.

Note: These tables shall not be viewed as a comprehensive list or plan for verification activities, but rather guidance on areas specific to landfill projects that must be addressed during verification.

8.5.1 Project Eligibility and CRT Issuance

Table 8.2 lists the criteria for reasonable assurance with respect to eligibility and CRT issuance for landfill projects. These requirements determine if a project is eligible to register with the Reserve and/or have CRTs issued for the reporting period. If any one requirement is not met, either the project may be determined ineligible or the GHG reductions from the reporting period (or sub-set of the reporting period) may be ineligible for issuance of CRTs, as specified in Sections 2, 3, and 6.

Table 8.2. Eligibility Verification Items

Protocol Section	Eligibility Qualification Item	Apply Professional Judgment?
2.2	Verify that the project meets the definition of a landfill project and is properly defined per Section 2.2	No
2.3	Verify ownership of the reductions by reviewing Attestation of Title	No
2.3	For direct use agreements between the project developer and the end user of the landfill gas (i.e., an industrial client purchasing the landfill gas from the project developer), verify that a legally binding mechanism is built into the agreement language to assure that the GHG offset credits will not be double counted	No
3.2	Verify eligibility of project start date	No
3.2	Verify accuracy of project start date based on operational records	Yes
3.3	Verify that project is within its 10-year crediting period	No

Protocol Section	Eligibility Qualification Item	Apply Professional Judgment?
3.4.1	Verify that the project meets the appropriate performance standard test for the project type per Section 3.4.1	No
3.4.2	Confirm execution of the Attestation of Voluntary Implementation form to demonstrate eligibility under the legal requirement test	No
3.4.2	Verify that the project activities comply with applicable laws by reviewing any instances of non-compliance provided by the project developer and performing a risk-based assessment to confirm the statements made by the project developer in the Attestation of Regulatory Compliance form	Yes
4	Confirm all baseline non-qualifying devices have been properly accounted for within project's GHG Assessment Boundary	No
4	Confirm all baseline qualifying devices have been properly accounted for within project's GHG Assessment Boundary	No
6	Verify that monitoring meets the requirements of the protocol. If it does not, verify that a variance has been approved for monitoring variations	No
6	Verify that the project monitoring plan contains procedures for ascertaining and demonstrating that the project passes the legal requirement test at all times	Yes
6	Verify that the landfill gas control system operated in a manner consistent with the design specifications	Yes
6	Verify that there is an individual responsible for managing and reporting GHG emissions, and that individual properly trained and qualified to perform this function	Yes
6.2	Verify that all gas flow meters and methane analyzers adhered to the inspection, cleaning, and calibration schedule specified in the protocol. If they do not, verify that a variance has been approved for monitoring variations or that adjustments have been made to data per the protocol requirements	No
6.2	If any piece of equipment failed a calibration check, verify that data from that equipment was scaled according to the failed calibration procedure for the appropriate time period	No
6.3	If used, verify that data substitution methodology was properly applied	No
7.1	Verify that appropriate documents are created to support and/or substantiate activities related to GHG emission reporting activities, and that such documentation is retained appropriately	Yes
	If any variances were granted, verify that variance requirements were met and properly applied	Yes

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8.5.2 Quantification of GHG Emission Reductions

Table 8.3 lists the items that verification bodies shall include in their risk assessment and re-calculation of the project's GHG emission reductions. These quantification items inform any determination as to whether there are material and/or immaterial misstatements in the project's GHG emission reduction calculations. If there are material misstatements, the calculations must be revised before CRTs are issued.

Table 8.3. Quantification Verification Items

Protocol Section	Quantification Item	Apply Professional Judgment?
4	Verify that SSRs included in the GHG Assessment Boundary correspond to those required by the protocol and those represented in the project	No
5	Verify that the project developer correctly accounted for baseline methane destruction in the baseline scenario	No
5	Verify that the project developer correctly monitored, quantified and aggregated the amount of methane collected from the landfill and destroyed by the project landfill gas control system?	No
5	Verify that the project developer correctly quantified and aggregated electricity use	Yes
5	Verify that the project developer correctly quantified and aggregated fossil fuel use	Yes
5	Verify that the project developer applied the correct emission factors for fossil fuel combustion and grid-delivered electricity	No
5	Verify that the project developer applied the correct methane destruction efficiencies	No
Appendix B	If the project developer used source test data in place of the default destruction efficiencies (Appendix B), verify accuracy and appropriateness of data and calculations	Yes

8.5.3 Risk Assessment

Verification bodies will review the following items in Table 8.4 to guide and prioritize their assessment of data used in determining eligibility and quantifying GHG emission reductions.

Table 8.4. Risk Assessment Verification Items

Protocol Section	Item that Informs Risk Assessment	Apply Professional Judgment?
6	Verify that the project monitoring plan is sufficiently rigorous to support the requirements of the protocol and proper operation of the project	Yes
6	Verify that appropriate monitoring equipment is in place to meet the requirements of the protocol	No
6	Verify that equipment calibrations have been carried out to satisfy the requirements of the protocol	No
6	Verify that the individual or team responsible for managing and reporting project activities are qualified to perform this function	Yes
6	Verify that appropriate training was provided to personnel assigned to greenhouse gas reporting duties	Yes
6	Verify that all contractors are qualified for managing and reporting greenhouse gas emissions if relied upon by the project developer. Verify that there is internal oversight to assure the quality of the contractor's work	Yes
6.2	Verify that the methane destruction equipment was operated and maintained according to manufacturer specifications	Yes
7.2	Verify that all required records have been retained by the project developer	No

8.6 Completing Verification

The Verification Program Manual provides detailed information and instructions for verification bodies to finalize the verification process. It describes completing a Verification Report, preparing a Verification Opinion, submitting the necessary documents to the Reserve, and notifying the Reserve of the project's verified status.

9 Glossary of Terms

Accredited verification body	A verification firm approved by the Climate Action Reserve to provide verification services for project developers.
Additionality	Landfill management practices that are above and beyond business-as-usual operation, exceed the baseline characterization, and are not mandated by regulation.
Anaerobic	Pertaining to or caused by the absence of oxygen.
Anthropogenic emissions	GHG emissions resultant from human activity that are considered to be an unnatural component of the Carbon Cycle (i.e., fossil fuel destruction, de-forestation, etc.).
Biogenic CO_2 emissions	CO_2 emissions resulting from the destruction and/or aerobic decomposition of organic matter. Biogenic emissions are considered to be a natural part of the Carbon Cycle, as opposed to anthropogenic emissions.
Bioreactor	Any landfill which: a. Meets the EPA definition of a bioreactor: "a MSW landfill or portion of a MSW landfill where any liquid other than leachate (leachate includes landfill gas condensate) is added in a controlled fashion into the waste mass (often in combination with recirculating leachate) to reach a minimum average moisture content of at least 40 percent by weight to accelerate or enhance the anaerobic (without oxygen) biodegradation of the waste."[41] b. Has been designated by local, state, or federal regulators as a bioreactor. c. Has received grants or funding to operate as a bioreactor.
Carbon dioxide (CO_2)	The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.
Closed landfill	A landfill that has ceased waste acceptance, and has submitted a closure report to EPA or the state indicating that it will no longer accept waste.
CO_2 equivalent (CO_2e)	The quantity of a given GHG multiplied by its total global warming potential. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.
Direct emissions	Greenhouse gas emissions from sources that are owned or controlled by the reporting entity.
Direct Use Project	A Landfill Gas to Energy Project where the landfill gas is used for its thermal capacity. Direct use projects offer a cost-effective alternative for fueling combustion or heating equipment at facilities located near a landfill. Qualifying destruction devices include boilers, leachate evaporators, kilns, sludge dryers, burners, furnaces.
Eligible landfill	An "eligible landfill" is a landfill that: 1. Is not subject to regulations or other legal requirements requiring the destruction of methane gas 2. Is not a bioreactor 3. Does not add any liquid other than leachate into the waste mass in a controlled manner

[41] 40 CFR 63.1990 and 40 CFR 258.28a.

Electricity Project	A Landfill Gas to Energy Project for the generation of electricity. Technologies include engines, turbines, microturbines and fuel cells.
Emission factor (EF)	A unique value for determining an amount of a greenhouse gas emitted for a given quantity of activity data (e.g., metric tons of carbon dioxide emitted per barrel of fossil fuel burned).
Emission guidelines (EG)	Guidelines for State regulatory plans that have been developed by the U.S. EPA. For landfills, emission guidelines are codified in 40 CFR 60 Subpart CC.
Flare	A destruction device that uses an open flame to burn combustible gases with combustion air provided by uncontrolled ambient air around the flame.
Fossil fuel	A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.
Greenhouse gas (GHG)	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), or perfluorocarbons (PFCs).
Global warming potential (GWP)	The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO_2.
Indirect emissions	Emissions that are a consequence of the actions of a reporting entity, but are produced by sources owned or controlled by another entity.
Landfill	A defined area of land or excavation that receives or has previously received waste that may include household waste, commercial solid waste, non-hazardous sludge and industrial solid waste.
Landfill gas (LFG)	Gas resulting from the decomposition of wastes placed in a landfill. Typically, landfill gas contains methane, carbon dioxide and other trace organic and inert gases.
Landfill gas project	Installation of infrastructure that in operating causes a decrease in GHG emissions through destruction of the methane component of landfill gas.
Landfill gas-to-energy (LFGE)	A LFGE project is one where the LFG destruction involves a destruction device that generates saleable energy (engine, turbine, microturbine, fuel cell, boiler, upgrade to pipeline, upgrade to CNG/LNG, etc.). This does not include small-scale, non-commercial applications, such as leachate drying.
Medium Btu project	See Direct Use project definition
Metric ton or "tonne" (t, Mg)	A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1 short tons.
Methane (CH_4)	A potent GHG with a GWP of 21, consisting of a single carbon atom and four hydrogen atoms.
MMBtu	One million British thermal units.
Mobile combustion	Emissions from the transportation of materials, products, waste, and employees resulting from the combustion of fuels in company owned or controlled mobile combustion sources (e.g., cars, trucks, tractors, dozers, etc.).
National Emission Standards for Hazardous Air Pollutants (NESHAP)	Federal emission control standards codified in 40 CFR 63. Subpart AAAA of Part 63 prescribes emission limitations for MSW landfills.
New Source Performance Standards	Federal emission control standards codified in 40 CFR 60. Subpart WWW of Part 60 prescribes emission limitations for MSW landfills.

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(NSPS)	
Non-methane organic compounds (NMOC)	Non-methane organic compounds as measured according to the provisions of 40 CFR 60.754.
Non-qualifying destruction device	A passive flare or other combustion system that results in the destruction of methane, but which cannot serve as the primary destruction device for a methane destruction project under this protocol.
Nitrous oxide (N_2O)	A GHG consisting of two nitrogen atoms and a single oxygen atom.
Project baseline	A business-as-usual GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.
Project developer	An entity that undertakes a project activity, as identified in the Landfill Project Protocol. A project developer may be an independent third party or the landfill operating entity.
Qualifying destruction device	A utility flare, enclosed flare, engine, boiler, pipeline, vehicle, or fuel cell which can serve as the primary destruction device for a methane destruction project under this protocol.
Renewable Energy Certificates (RECs)	As defined by the U.S. EPA Green Power Partnership, a REC represents the property rights to the environmental, social, and other non-power qualities of renewable electricity generation. For a landfill project this is represented by the existence of a REC contract or participation of the landfill in a REC tracking system. The RECs may be sold as bundled (green power) or unbundled from the associated energy that is generated.
Reporting period	Specific time period of project operation for which the project developer has calculated and reported emission reductions and is seeking verification and issuance of credits. The reporting period must be no longer than 12 months.
Resource Conservation and Recovery Act (RCRA)	Federal legislation under which solid and hazardous waste disposal facilities are regulated.
Stationary combustion source	A stationary source of emissions from the production of electricity, heat, or steam, resulting from combustion of fuels in boilers, furnaces, turbines, kilns, and other facility equipment.
Upgraded Landfill Gas Project	A Landfill Gas to Energy Project where the landfill gas is cleaned to a level similar to natural gas. Three common types of projects are RNG (Renewable Natural Gas), CNG (Compressed Natural Gas) or LNG (Liquefied Natural Gas).
Verification	The process used to ensure that a given participant's GHG emissions or emission reductions have met the minimum quality standard and complied with the Reserve's procedures and protocols for calculating and reporting GHG emissions and emission reductions.
Verification body	An ISO-accredited and Reserve-approved firm that is able to render a verification opinion and provide verification services for operators subject to reporting under this protocol.
Verification cycle	The Reserve requires verification of landfill projects annually, but does not require verifications to be completed on specific dates. Project developers select the reporting period to be verified. Thus, each project has a unique verification cycle that begins the first time a project is

	verified, occurs at least annually, and ends once the crediting period expires or the project is no longer eligible, whichever happens first.
Waste in place	The cumulative amount of solid waste, measured in metric tons, that has been permanently placed into the landfill.

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Appendix A Development of the Performance Standard Threshold

The initial performance standard for the Landfill Project Protocol Version 1.0 was adopted in 2007. This analysis used as its primary data source the database of nearly 2,400 landfills in the United States developed and maintained by the U.S. EPA's Landfill Methane Outreach Program (LMOP).[42] This database does not represent all U.S. landfills, but rather a subset of all landfills that have been identified as having current LFGE projects or where potential opportunities exist for such projects. This database is updated on an ongoing basis by LMOP staff. Landfill gas projects take time to move from conception to operation (often two years or more) so the database does not see rapid, significant changes. The original analysis conducted in 2007 concluded that any new installation of a landfill gas collection system and/or qualifying destruction device where gas had not previously been collected and destroyed (or was destroyed using a non-qualifying destruction device) could be considered additional.

In the years following the 2007 analysis, there was a significant increase in the market penetration of landfill gas to energy systems. Hence in 2011 the performance standard underwent a significant update, with the release of Version 4.0 of the Landfill Project Protocol. The focus on the original performance standard test and the 2011 update were landfills not required to collect and control gas emissions by NSPS/EG either because they are under the landfill design size that would make them subject to the regulation or because they were still below the NMOC emissions per year threshold to trigger gas destruction obligations. The purpose of the 2011 analysis was to identify whether new criteria were necessary to continue to ensure that only additional landfill gas destruction projects are eligible to register with the Reserve, and if so, what criteria should be.

A.1 2007 Performance Standard Analysis

Table A.1 and Table A.2 provide the summary conclusions of the Reserve's 2007 performance standard analysis, using the LMOP database available at that time. The original analysis excluded all landfills that were closed prior to 2001, since their methane production was assumed to have already dropped off significantly and they would therefore be poor candidates for landfill gas projects.

Table A.1. Summary of Information on U.S. Landfills (NSPS/EG and Non-NSPS/EG) (2007)

	Landfills	Percent of Landfills	Number w/ LFG Collection	Percent w/ LFG Collection
Landfills in Analysis				
NSPS/EG	697	37.35	697	100
Non-NSPS/EG	1169	62.65	261	22.33
Subtotal	1866	100	958	51.34
Landfills Excluded from Analysis	518			
Total U.S. Landfills	2384			

[42] LMOP is a voluntary partnership program that was created to reduce methane emissions from landfills by encouraging the use of landfill gas for energy. LMOP tracks whether or not specific landfills are required to reduce landfill gas emissions under the New Source Performance Standards and Emission Guidelines for Municipal Solid Waste Landfills (NSPS/EG), promulgated March 1996. Because LMOP is not a regulatory program, it cannot make an official EPA designation regarding any landfill's NSPS/EG status. Information relating to NSPS/EG was obtained by voluntary submittal and is subject to change over time. Therefore, LMOP cannot guarantee the validity of this information.

Deleted: However, it has been over four years since the Reserve first developed the Landfill Project Protocol using this database, and there have been many updates in the interim. These updates merit a new evaluation of data supporting the performance standard for this protocol.¶
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The purpose of a performance standard analysis is to identify criteria or conditions that effectively distinguish landfill gas collection and destruction projects that are likely to be additional from those that are likely to be non-additional.¶

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The focus of the original analysis, as well as this update, is on those landfills not currently subject to NSPS/EG, since these regulated landfills are generally required to collect and control landfill gas emissions.¶

Table A.2. Summary of Non-NSPS/EG Landfills under Assumption that Flare-Only Landfills Are Already Regulated (2007)

	Flares Included		Flares Excluded	
Non-NSPS/EG Landfills	**Number of Landfills**	**Percentage**	**Number of Landfills**	**Percentage**
Flare-Only	166	14.2	Excluded	Excluded
Electricity	67	5.7	67	6.7
Gas Projects	28	2.4	28	2.8
Subtotal	261	22.3	95	9.5
No LFG collection	908	77.7	908	90.5
Total	1169	100.0	1003	100.0
Estimated Market Penetration of LFG Collection Projects at Unregulated Landfills		**22.3%**		**9.5%**

A.2 2011 Performance Standard

A.2 Test: Size Threshold for LFGE Projects

In the 2011 performance standard analysis the Reserve sought to identify characteristics or conditions that could distinguish between additional and non-additional projects. The analysis was based on the premise that in the absence of any incentives provided by GHG offsets or RECs, the feasibility of installing an LFGE project at an unregulated landfill depended largely on the amount of methane produced at the landfill. Landfills that produce more methane are more likely to be better candidates for such projects. The Reserve identified two key factors in methane production potential, first the amount of waste in place (WIP) and second, annual precipitation at the landfill.

Having identified two key factors in methane production potential, the next step in the Reserve's analysis was to examine the market penetration of voluntary LFGE projects at unregulated landfills as a function of the size of the landfill (measured as WIP at the time the project was installed) and annual precipitation.

The Reserve identified a WIP threshold for each precipitation zone that effectively screened out a majority of non-additional LFGE projects. The objective of excluding non-additional projects, however, had to be balanced against concerns about unfairly excluding landfills from eligibility where no projects currently exist. The result was to target a WIP threshold for each zone such that the percentage of unregulated landfills with LFGE projects was 5% or less (i.e., the "natural" market penetration of LFGE projects at landfills below the threshold was no more than 5%). For landfills in the arid precipitation zone, this threshold was determined to be 2.17 million metric tons (MMg). For landfills in the non-arid precipitation zone, this threshold was determined to be 0.72 MMg (Table A.3).

The percentage of incorrectly excluded landfills at these thresholds differs markedly for the arid and non-arid zones. For the arid zone, only 10% of unregulated landfills without LFGE projects are incorrectly excluded. For the non-arid zone, however, nearly 60% of unregulated landfills without LFGE projects are incorrectly excluded. Although that was a high rate of incorrect exclusions, the Reserve believed it was important to strike a balance strongly in favor of ensuring that projects that *did* pass an additionality screen were likely to be additional. In the

Deleted: Although imposing a prohibition on selling RECs could in principle exclude a significant segment of non-additional projects from eligibility, it would still leave a sizable number as eligible. More than 13% of unregulated landfills host LFGE projects that receive no environmental incentive payments and would still be incorrectly classified as additional. Because of concerns that a REC exclusion may have limited effectiveness (and could have unintended consequences in some markets),

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Deleted: The LMOP database includes entries for the WIP (in tons), the year that the WIP figure was reported, and the year that a LFGE project (if any) was installed. To control for temporal disparity, projects were excluded from the analysis if the year that the WIP figure was reported diverged by more than three years from the year that the LFGE project was installed. In addition, any landfills selling GHG offset credits were excluded from the analysis. After applying these screens, a total of 411 landfills were included in the analysis.

Deleted: Next, each landfill in the analysis was assigned to a precipitation zone, either "arid" or "non-arid," depending on the annual precipitation in the landfill's county. County precipitation was identified using the United States Geological Survey (USGS) map layer of Hydrologic Regions, which was aggregated into regions of less than 25 inches and regions of 25 inches or greater annual precipitation.[49] See for the location of arid and non-arid precipitation zones by U.S. county.¶
¶
Finally, landfills in both the arid and non-arid categories were sorted according to size (WIP). Once sorted, it was possible to determine for any given size threshold:¶
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absence of alternative characteristics or conditions that could be used to screen for additional projects, the Reserve believed it was necessary to adopt a stringent WIP threshold.

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Table A.3. WIP Values for 5% Market Penetration of LFGE Projects[50]

	Arid Counties (<25" Annual Precipitation)	Non-Arid Counties (>25" Annual Precipitation)
WIP Threshold for 5% Market Penetration of LFGE Projects at Unregulated Landfills (metric tons)	2,165,000	715,000
Percentage of Landfills with No LFG Collection Excluded by this WIP Threshold	10%	58%

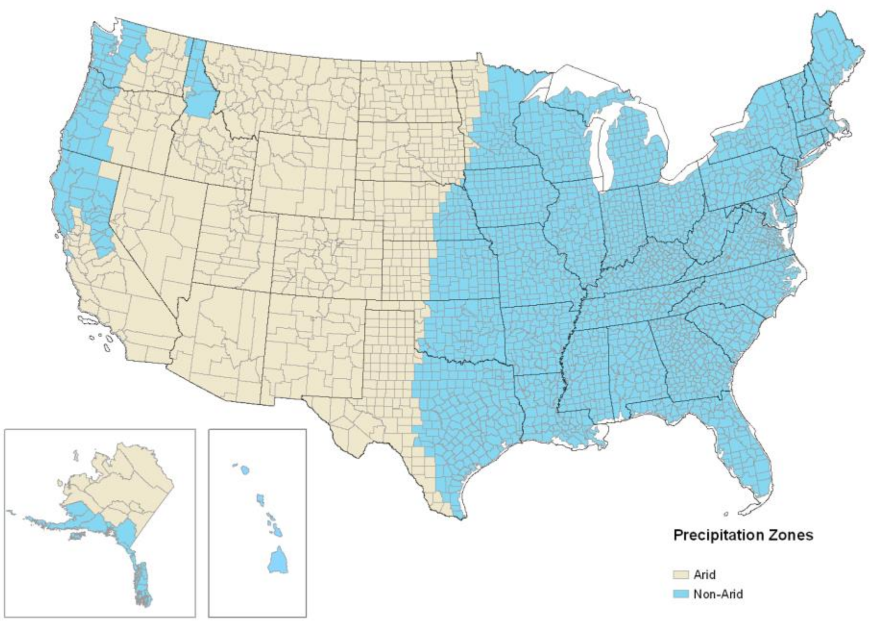

Figure A.1. Precipitation Zones of the United States, by County

Based on the USGS Hydrologic Zones of the United States (2003). Arid counties average less than 25 inches of precipitation annually, and non-arid counties average 25 inches or greater precipitation annually.

[50] As suggested in footnote 42, it is likely that some of the LFGE projects at landfills not subject to NSPS/EG and below the size thresholds presented here are in fact required by local regulations. Thus, the actual "natural" market penetration below these thresholds is likely to be below 5%, and may be significantly below 5%. The analysis conservatively assumes that none are legally required.

A.3 Protocol Version 5.0 Performance Standard Analysis

Since the 2011 performance standard analysis, there have been significant changes in the U.S. domestic energy landscape and thus landfill gas market conditions. A review of updated LMOP data reveals that the market penetration of landfill gas to energy (LFGE) projects has remained steady (with relatively few LFGE project closures), but that the uptake of new LFGE projects has fallen off significantly in recent years. LMOP data are used in Figure A.2 below, to depict the number of new LFGE projects installed per year from the period of 2000 through to 2018. These data indicate a significant decline in new LFGE project installations per year over the past few years; this is projected to continue beyond 2018.

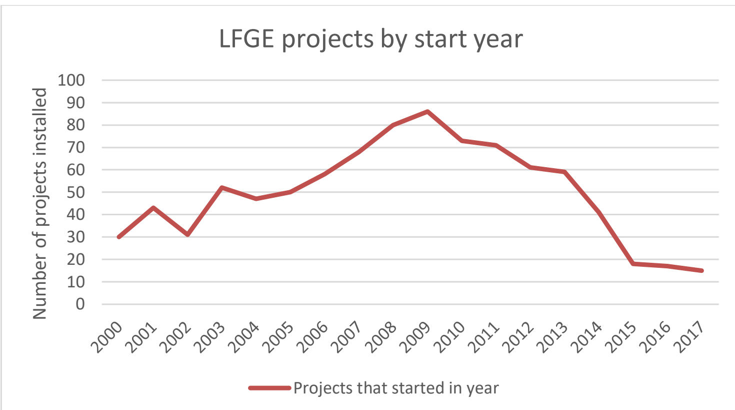

Figure A.2. New LFGE Installations
The number of new LFGE projects installed per year from the year 2000 to 2017.

Given this declining trend of new LFGE project uptake occurred whilst the U.S. was experiencing a boom in domestic energy production, in particular natural gas (NG), Reserve staff sought to explore the nexus between NG pricing and LFGE project uptake. Reserve staff examined Energy Information Administration data on U.S. energy costs, including coal, petroleum and natural gas. As landfill gas and natural gas can be effectively substitutes in the production of marginal electrical demand, Reserve staff sought to determine if the price of natural gas could be a useful means to predict LFGE project uptake.

Figure A.3 below, indicates that a correlation can be drawn between declining costs of inputs for marginal electricity generation and the decline in the development of new LFGE projects. This data suggests a strong correlation between declining costs of energy inputs competing with LFG, in particular NG, and the installation of new LFGE projects.

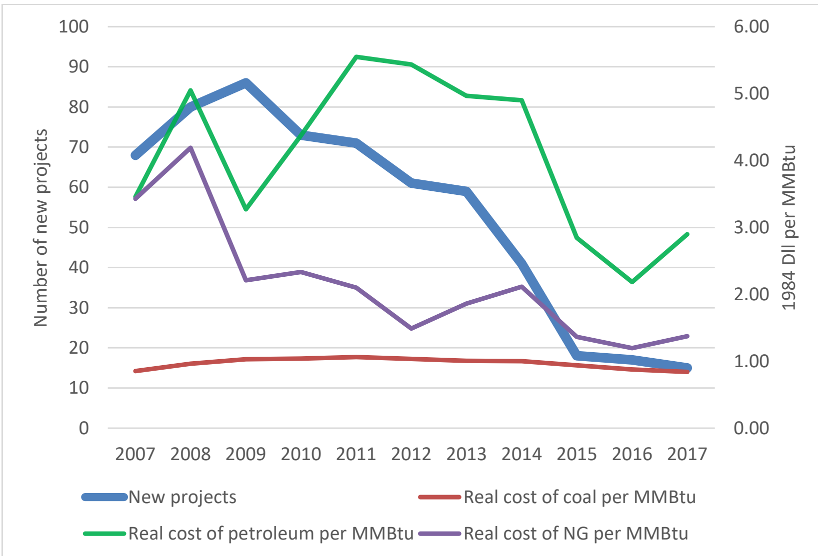

Figure A.3. New LFGE Installations and Marginal Power Input Costs
The number of new LFGE projects installed per year from the year 2007 to 2017 (both regulated and unregulated landfills), and marginal power generation fuel input costs (coal, petroleum, and NG).

Despite the strong observed correlation between NG pricing and new LFGE project development, Reserve staff and Work Group members were cautious not to assume causality. Expert guidance from the Work Group, literature and Reserve staff, suggested that NG pricing alone is insufficient to capture the complexities of LFGE market conditions. Instead Reserve staff sought to look more broadly at the financial feasibility of LFGE projects, and examine other potentially key contributory factors, including regulatory conditions, LFGE incentives, availability of infrastructure such as NG pipelines, availability of end-use buyers, tax rates, as well as the underlying size and gassiness of landfills.

To more accurately distinguish the projects that would be financially feasible given current market conditions, the Reserve focused on three market factors: 1) landfill gas energy end use categories; 2) market penetration per end use category and; 3) LFGE project's financial feasibility (including the impacts of incentives other than offsets). Following expert guidance the Reserve split LFGE projects into three categories for this assessment: high Btu projects (RNG, CNG or LNG projects injecting compressed gas into pipelines), medium Btu projects (projects where gas is piped directly to a nearby customer or used onsite for its thermal capacity) and, electricity generation projects.

The analysis of High Btu projects reveals that they are not common practice (less than 1% of LMOP landfills have a high Btu project in place[51]), however some 39 new high Btu projects are

[51] Penetration rate is defined as the number of landfills with at least one operational project divided by the total number of landfills in the LMOP database.

either currently in their planning stages or under construction (almost 60% of all LMOP planned or under construction projects for 2019 onwards[52]). Discussions with industry experts reveal some 50 existing high-Btu projects currently receive incentives under the federal Renewable Fuel Standard (RFS) program, and that RFS incentives are currently providing revenues equivalent to approx. $58/tCO$_2$e. This analysis suggests that if a landfill is able to support an RNG/CNG/LNG project, it will potentially be eligible for RFS RIN revenues, and will thus be feasible without offset revenues. Such projects are also very highly likely to trigger NSPS/EG size thresholds and be excluded pursuant to the legal requirement test. The analysis thus suggests such projects could reasonably be deemed non-additional.

Medium Btu projects, on the other hand, remain uncommon (landfills with at least one operational Medium Btu project represent less than 3% of all landfills in the LMOP database). Similarly, Medium Btu projects face stiff competition from natural gas as they are typically used for their gas thermal capacity. Natural gas prices are currently very competitive relative to medium Btu LFGE projects. In addition, the most limiting factor for the feasibility of a Medium Btu project is the availability of an end-use buyer of the landfill gas that is within close enough proximity to make the development of local transmission pipelines feasible (typically such facilities must be within a 10-mile radius for the project to be feasible).[53] Given that these projects remain uncommon, and continue to face significant barriers, these projects can reasonably be deemed additional.

With a total number of 459 operational projects by September 2018, electricity projects represented close to 75% percent of all operational LFGE projects in the LMOP database. In other words, 14% of all landfills in the LMOP database have at least one active electricity project making this technology type fairly common. While electricity projects currently represent the vast majority of LFGE projects, LMOP data reveals that the majority of new planned and in-construction LFGE projects are now set to utilize RNG/CNG. Furthermore, expert guidance indicated that despite electricity LFGE projects being common practice, new electricity LFGE projects currently face significant barriers to entry, as reflected by the low numbers of projected and planned electricity LFGE projects[54].

To expand on the understanding of the downward trend for electricity projects, the Reserve sought to identify under which conditions projects would be additional. To do this, the Reserve evaluated the electricity generation capacity at which projects were likely to reach financial feasibility in the absence of GHG offset revenue. It was assumed that a project reaches the point of financial feasibility when it achieves a positive Net Present Value (NPV). The financial feasibility of 32 landfill scenarios was assessed using the LMOP Landfill Gas to Energy Cost Model (LFGcost-Web). The LFGcost-Web is an Excel-based tool that allows users to estimate the financial feasibility of a wide range of LFGE projects, based on specific landfill and project characteristics[55]. Once the Reserve input the set of assumptions for a given scenario in the model, the project design flow rate was gradually increased to evaluate the NPV that the model returned. If the NPV became positive, then landfills under the mix of assumptions for that specific scenario were considered non-additional at or above the given flow rate.

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52 Landfill Methane Outreach Program. "Webinar: Renewable Natural Gas from LFG and Sustainability at L'Oreal (PDF)". United States Environmental Protection Agency. December 12, 2018. Available at https://www.epa.gov/lmop/webinar-renewable-natural-gas-landfill-gas-and-sustainability-loreal

53 Landfill Methane Outreach Program. "LFG Energy Project Development Handbook." United States Environmental Protection Agency. 2017. Available at: https://www.epa.gov/lmop/landfill-gas-energy-project-development-handbook

54 LMOP, 2018

55 A copy of the LFGcost-Web tool and background information can be accessed here: https://www.epa.gov/lmop/lfgcost-web-landfill-gas-energy-cost-model.

The Reserve retained a number of LFGcost model default assumptions and edited several, follow expert consultation. The LFGcost input factors that most affected modelled results were the projects' regulatory status under NSPS, landfill ownership types (private or public) and, revenue streams. Below is a summary of assumptions underlying how these specific factors were modelled:

1. Regulatory status: Smaller unregulated projects were assumed to not have an LGCC in place prior to installing an electricity project; thus the costs of installing the piping, collection and flaring systems are included in the modelling of such scenarios. Regulated (larger projects) on the other hand, were assumed to have a LGCC system in place prior to assessing the feasibility of an electricity project, and therefore the costs of installing an LGCC system was not included in the modelling of such scenarios.

2. Landfill ownership status: Assumptions regarding whether a landfill was owned by a public entity or a private entity was critical, in that it determined the tax rates imposed on the project. Projects funded and developed by local governments had a 0% tax rate, while private projects were given a 25% tax rate. The private tax rate was equal to the sum of the 21% federal tax rate plus an average 4% state tax assumption suggested by the Workgroup. Private and public projects were also subject to different discount rates.

3. Revenue streams: Project revenue streams modelled in the various scenarios was a mix of energy tax credits, Renewable Electricity Credits and, most critically, an electricity sales price. These assumptions were differentiated based on the availability of incentives and revenues across different regions in the United States. The assumption with respect to the electricity sales price warrants specific discussion, as it had the single largest effect on project NPV. The LFGcost tool used a default electricity sales price of $0.06/kWh. Expert guidance indicated that this price was not representative of wholesale prices paid to LFGE project operators, and was thus too high. In our analysis we therefore replaced this value with a price representing the national average historical wholesale 'high' price for 2018.[56] We then identified any pricing regions for which the average historical 2018 price was higher than this national average, and for such regions, we used the regional average, as this ensures the resulting NPV is more representative and conservative. In two regions we used an electricity sales price which was above the national average historical 2018 wholesale price. In Vermont we used an electricity price of $0.09/kWh[57], representing the feed in tariff available under their Standard Offer program. The average price in New England was set at 0.058 $/kWh, reflecting the average 2018 wholesale electricity price there (specifically at the Nepool MH DA LMP Peak).[58]

Of all the scenarios modelled, only four returned a positive NPV, indicating such scenarios should be considered non-additional. In each such scenario, landfills were public (no tax rate and low discount rate), the cost of the landfill gas collection and flaring system was not included in the project cost (regulated landfills), REC incentives were available, and electricity sale prices were higher than the national average wholesale price.

[56] Energy Information Administration and Intercontinental Exchange (ICE). Wholesale Electricity and Natural Gas Market Data. Accessed in Jan 30, 2019. Available at https://www.eia.gov/electricity/wholesale/
[57] VEPP Inc. Standard Offer Program Request for Proposals. 2019 RFP Coming January 2019. Available at: http://www.vermontstandardoffer.com/2019-rfp-informational/
58 EIA and ICE, 2019.

The assumption regarding the costs of installing a collection and flaring system was most critical to all scenarios. The added cost of installing an LGCCS as part of an electricity project resulted high enough to make any unregulated project infeasible even with the availability of incentives. Given that no unregulated project scenarios returned a positive NPV the Reserve believes that the legal requirement test is enough to address the additionality of electricity projects. In the case of the four scenarios that turned positive NPV values, the landfill itself was large enough to trigger the legal requirement test to make it ineligible. For this reason, we have not included these four scenarios in the performance standard test itself, as such projects will effectively be excluded from eligibility via the legal requirement test. Table A.6 below summarizes the results of this current performance standard analysis.

Table A.4 Summary of Performance Standard Thresholds

Eligible LFGE Projects Under LPP V5.0	Ineligible LFGE Projects Under LPP V5.0
▪ All projects which do not employ a beneficial use (e.g., flare-only projects) ▪ Electricity projects ▪ Direct use projects (Medium Btu)	▪ Upgraded landfill gas projects (RNG, CNG or LNG) ▪ Injection into a natural gas common carrier pipeline or transmission and distribution network

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Purpose¶
For the specific case in which a landfill gas control system is required to treat landfill gas for NMOC in order to comply with a regulation, ordinance, or permitting condition, but destruction of the landfill gas is not the only compliance mechanism available to the landfill operator, the Reserve has developed an NMOC emissions threshold whereby the eligibility of a project can be determined. If a landfill gas control system is required to treat landfill gas for NMOC and the total mass flow of NMOC for the landfill gas control system is less than the threshold (measured in pounds NMOC per month), then the landfill gas control system is eligible as a GHG reduction project under this protocol. If a landfill gas control system is required to treat landfill gas for NMOC and the total mass flow of NMOC for the landfill gas control system is greater than the threshold, then the landfill gas control system is *not* eligible as a GHG reduction project under this protocol. The Reserve has established two separate NMOC thresholds for 1) landfills in air management districts or regions that permit the use of open flares, and 2) landfills in air management districts or regions that permit *only* enclosed flares.¶
¶
The NMOC mass flow at a given landfill is one of many factors including the quantity, age and composition of the waste, and the environmental conditions at the landfill.¶
Data¶
The primary data source for the threshold analysis is a series of empirical capital cost and monthly operating cost data supplied to the Reserve from fourteen landfills with experience using carbon adsorption to treat varying levels of NMOC. In addition, the Reserve obtained quotes for the purchase, installation, and operation of both open (candlestick or utility-type) flares and enclosed flares from a number of prominent vendors and engineering firms.[59]¶
Summary¶
The analysis below reveals that an estimated NMOC[60] mass flow threshold of 1,775 lbs NMOC/month is appropriate for the performance standard in areas where open flares may be used, and a threshold of 2,575 is appropriate for the performance standard in areas where only enclosed flares may be installed. This analysis was performed based on the empirical data and estimates obtained for flare and carbon adsorption systems with capacities of 40 to 1,000 cubic feet per minute (CFM) of landfill gas and an operational life of ten years. While the upfront costs for a flare system are relatively high (approximately $200,000 for an open flare and $290,000 for an ...

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Total NPV cost for the carbon adsorption system was calculated as follows:¶
Total NPV cost for the carbon adsorption system was calculated as follows:¶

$$Cost_{Carbon,i} = Capital_{Carbon} + \sum_{t=1year}^{10} \frac{(Carbon_{mon}}{(1+0.0}$$ ...

Appendix B Emission Factor Tables

Table B.1. CO_2 Emission Factors for Fossil Fuel Use[61]

Fuel Type	Default High Heat Value	Default CO_2 Emission Factor	
Coal and coke	mmBtu/ short ton	kg CO_2/ mmBtu	kg CO_2/ short ton
Anthracite	25.09	103.69	2601.582
Bituminous	24.93	93.28	2325.470
Subbituminous	17.25	97.17	1676.183
Lignite	14.21	97.72	1388.601
Coal Coke	24.8	113.67	2819.016
Mixed (Commercial sector)	21.39	94.27	2016.435
Mixed (Industrial coking)	26.28	93.9	2467.692
Mixed (Industrial sector)	22.35	94.67	2115.875
Mixed (Electric Power sector)	19.73	95.52	1884.610
Natural gas	mmBtu/ scf	kg CO_2/ mmBtu	kg CO_2/ scf
(Weighted U.S. Average)	0.001026	53.06	0.054
Petroleum products	mmBtu/ gallon	kg CO_2/ mmBtu	kg CO_2/ gallon
Distillate Fuel Oil No. 1	0.139	73.25	10.182
Distillate Fuel Oil No. 2	0.138	73.96	10.206
Distillate Fuel Oil No. 4	0.146	75.04	10.956
Residual Fuel Oil No. 5	0.14	72.93	10.210
Residual Fuel Oil No. 6	0.15	75.1	11.265
Used Oil	0.138	74	10.212
Kerosene	0.135	75.2	10.152
Liquefied petroleum gases (LPG)1	0.092	61.71	5.677
Propane1	0.091	62.87	5.721
Propylene2	0.091	67.77	6.167
Ethane1	0.068	59.6	4.053
Ethanol	0.084	68.44	5.749
Ethylene2	0.058	65.96	3.826
Isobutane1	0.099	64.94	6.429

[61] 40 CFR Part 98 Subpart C Table C-1: Default CO_2 Emission Factors and High Heat Values for Various Types of Fuel

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Fuel Type	Default High Heat Value	Default CO_2 Emission Factor	
Isobutylene1	0.103	68.86	7.093
Butane1	0.103	64.77	6.671
Butylene1	0.105	68.72	7.216
Naphtha (<401 deg F)	0.125	68.02	8.503
Natural Gasoline	0.11	66.88	7.357
Other Oil (>401 deg F)	0.139	76.22	10.595
Pentanes Plus	0.11	70.02	7.702
Petrochemical Feedstocks	0.125	71.02	8.878
Petroleum Coke	0.143	102.41	14.645
Special Naphtha	0.125	72.34	9.043
Unfinished Oils	0.139	74.54	10.361
Heavy Gas Oils	0.148	74.92	11.088
Lubricants	0.144	74.27	10.695
Motor Gasoline	0.125	70.22	8.778
Aviation Gasoline	0.12	69.25	8.310
Kerosene-Type Jet Fuel	0.135	72.22	9.750
Asphalt and Road Oil	0.158	75.36	11.907
Crude Oil	0.138	74.54	10.287
Other fuels—solid	mmBtu/ short ton	kg CO_2/ mmBtu	kg CO_2/ short ton
Municipal Solid Waste	9.953	90.7	902.737
Tires	28	85.97	2407.160
Plastics	38	75	2850.000
Petroleum Coke	30	102.41	3072.300
Other fuels—gaseous	mmBtu/ scf	kg CO_2/ mmBtu	kg CO_2/ scf
Blast Furnace Gas	0.000092	274.32	0.025
Coke Oven Gas	0.000599	46.85	0.028
Propane Gas	0.002516	61.46	0.155
Fuel Gas4	0.001388	59	0.082
Biomass fuels—solid	mmBtu/ short ton	kg CO_2/ mmBtu	kg CO_2/ short ton
Wood and Wood Residuals (dry basis)5	17.48	93.8	1639.624
Agricultural Byproducts	8.25	118.17	974.903
Peat	8	111.84	894.720
Solid Byproducts	10.39	105.51	1096.249
Biomass fuels—gaseous	mmBtu/ scf	kg CO_2/ mmBtu	kg CO_2/ scf
Landfill Gas	0.000485	52.07	0.025
Other Biomass Gases	0.000655	52.07	0.034

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Fuel Type	Default High Heat Value	Default CO_2 Emission Factor	
Biomass Fuels—Liquid	mmBtu/ gallon	kg CO_2/ mmBtu	kg CO_2/ gallon
Ethanol	0.084	68.44	5.749
Biodiesel (100%)	0.128	73.84	9.452
Rendered Animal Fat	0.125	71.06	8.883
Vegetable Oil	0.12	81.55	9.786

[1] The HHV for components of LPG determined at 60 °F and saturation pressure with the exception of ethylene.
[2] Ethylene HHV determined at 41 °F (5 °C) and saturation pressure.
[3] Use of this default HHV is allowed only for: (a) Units that combust MSW, do not generate steam, and are allowed to use Tier 1; (b) units that derive no more than 10 percent of their annual heat input from MSW and/or tires; and (c) small batch incinerators that combust no more than 1,000 tons of MSW per year.
[4] Reporters subject to subpart X of this part that are complying with §98.243(d) or subpart Y of this part may only use the default HHV and the default CO2 emission factor for fuel gas combustion under the conditions prescribed in §98.243(d)(2)(i) and (d)(2)(ii) and §98.252(a)(1) and (a)(2), respectively. Otherwise, reporters subject to subpart X or subpart Y shall use either Tier 3 (Equation C-5) or Tier 4.

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Default CO_2 emission factors (per unit energy) are calculated as: Carbon Content × Fraction Oxidized × 44/12. ¶
Default CO_2 emission factors (per unit mass or volume) are calculated as: Heat Content x Carbon Content × Fraction Oxidized × 44/12× Conversion Factor (if applicable). Heat content factors are based on higher heating values (HHV).¶

B.1 Destruction Efficiencies for Combustion Devices

If available, the official source tested methane destruction efficiency shall be used in Equation 5.4 in place of the default methane destruction efficiency. Device-specific source testing shall be conducted annually, by a state or local agency accredited service provider, and include at least three test runs, with the accepted final value being one standard deviation below the mean of the measured efficiencies. If neither the state nor locality relevant to the project site offer accreditation for source testing service providers, projects may use an accredited service provider from another U.S. state or domestic locality. Alternatively, projects may choose a non-accredited service provider, under the following conditions: 1) the service provider must provide verifiable evidence of prior testing which was accepted for compliance by a domestic regulatory agency, and 2) the prior testing procedures must be substantially similar to the procedures used for determining methane destruction efficiency for the project destruction device(s).

If site-specific source test results conforming with the above paragraph are not available, project developers shall use the default methane destruction efficiencies provided below.

Table B.2. Default Destruction Efficiencies for Combustion Devices

Destruction Device	Destruction Efficiency (DE)
Open Flare	0.96
Enclosed Flare	0.995
Lean-burn Internal Combustion Engine	0.936
Rich-burn Internal Combustion Engine	0.995
Boiler	0.98
Microturbine or large gas turbine	0.995
Upgrade and use of gas as CNG/LNG fuel	0.95
Upgrade and injection into natural gas transmission and distribution pipeline	0.98*
Offsite use of gas under direct-use agreement	Per corresponding destruction device factor (not pipeline)

Source: The default destruction efficiencies for enclosed flares and electricity generation devices are based on a preliminary set of actual source test data provided by the Bay Area Air Quality Management District. The default destruction efficiency values are the lesser of the twenty fifth percentile of the data provided or 0.995. These default destruction efficiencies may be updated as more source test data is made available to the Reserve.

***** The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories gives a standard value for the fraction of carbon oxidized for gas destroyed of 99.5% (Reference Manual, Table 1.6, page 1.29). It also gives a value for emissions from processing, transmission and distribution of gas which would be a very conservative estimate for losses in the pipeline and for leakage at the end user (Reference Manual, Table 1.58, page 1.121). These emissions are given as 118,000kgCH_4/PJ on the basis of gas consumption, which is 0.6%. Leakage in the residential and commercial sectors is stated to be 0 to 87,000kgCH_4/PJ, which equates to 0.4%, and in industrial plants and power station the losses are 0 to 175,000kg/CH_4/PJ, which is 0.8%. These leakage estimates are compounded and multiplied. The methane destruction efficiency for landfill gas injected into the natural gas transmission and distribution system can now be calculated as the product of these three efficiency factors, giving a total efficiency of (99.5% * 99.4% * 99.6%) 98.5% for residential and commercial sector users, and (99.5% * 99.4% * 99.2%) 98.1% for industrial plants and power stations. [62]

[62] GE AES Greenhouse Gas Services, Landfill Gas Methodology, Version 1.0 (July 2007).

Deleted: Otherwise, project developers have the option to use either the default methane destruction efficiencies provided, or the site specific methane destruction efficiencies as provided

Deleted: source test

Deleted: for any of the destruction devices used in the project, performed on an annual basis. Device-specific source testing shall

Appendix C Baseline Monitoring and Calculation of LFG_{B1}, LFG_{B2}, and B_{CH4}

This appendix shall be used to calculate LFG_{B2} and $B_{CH4,NQ}$ for use in Equation 5.7. Much of the discussion here is concerned with accommodating the added complexity of monitoring passive flares and other non-qualifying devices. However, the methodology described is also applicable for measuring and documenting LFG_{B1} and $B_{CH4,closed}$ for calculating $Closed_{discount}$ in Equation 5.6.

C.1 Baseline Monitoring

Passive flares and other non-qualifying destruction devices are often installed at landfills for purposes other than methane destruction, and therefore are not amenable to simple monitoring. For example, flares installed for odor control may be used intermittently and without any instrumentation tracking gas flow and methane concentration. This makes assessing baseline methane destruction from passive flares extremely difficult to quantify. Quantification is further exacerbated by the fact that passive flares are not necessarily designed to accommodate metering equipment; for example, in many cases passive flares do not have sufficient straight pipe length to control for turbulence. These limitations, combined with the low flow rates generally seen at passive flares greatly limit the number and type of metering equipment that can be used. Monitoring destruction of landfill gas from baseline landfill gas wells at closed landfill flares will face fewer obstacles.

The Reserve recognizes that the constraints on monitoring landfill gas from passive flares are unique to each landfill. We have attempted to make this methodology as flexible as possible to make it widely applicable. Any deviations from this methodology will require a formal request for variance.

C.2 Monitoring

Non-qualifying destruction devices (e.g., passive flares) and qualifying flares at closed landfills must be monitored for a period of at least three months. This period must occur prior to the project start date to ensure that the measured gas flow is not decreased by the addition of project wells or pressure changes that result from the project activity. Methane destruction from the chosen period must be extrapolated to one year based on the 90% upper confidence limit of the methane destruction identified in this period. Therefore, monitoring for more than three months, or with greater than weekly frequency, may lessen statistical uncertainty and reduce the required $NQ_{discount}$ or $Closed_{discount}$.

Gas flow must be measured weekly at a minimum, and must be normalized to maximum flow capacity (scfm, 60° and 1 atm). If gas flow falls below the measurable range for the chosen metering device, the minimum flow value of the chosen metering device must be applied to that time interval. Methane concentration must also be measured at least weekly.

One measurement should be entered on each day for which readings were taken. If continuous measurements were taken, these should be averaged. If a single measurement was taken, then this value should be used. Therefore, if a daily monitoring plan is chosen for the three-month period, a total of 90 data points will be available (one per day). However, if weekly measurements are taken, then only 13 data points will be available for the analysis (one per week). Alternatively, irregular measurement intervals (for example, if someone is onsite three consecutive days) or bi-weekly measurements can be used as well, allowing for anywhere between 13 and 90 data points for any 90-day period. However, no more than one data point per calendar day may be applied and all collected data must be used.

All metering equipment used in baseline monitoring is subject to the same maintenance, calibration, and QA/QC requirements outlined previously for project metering equipment. In the case where a project does not meet the baseline monitoring maintenance, calibration, and QA/QC requirements of this protocol version, it shall be acceptable for that project to have its baseline monitoring, maintenance, calibration, and QA/QC verified against the requirements of a previous version of this protocol, so long as it is the version that was in force at the beginning date of the project's baseline monitoring period.

C.3 Passive Flare Configuration

As the configuration of passive flares will be unique to each landfill, it is not possible to dictate a single monitoring methodology. Rather, the following options have been devised as acceptable configurations.

1. Each passive flare will be monitored individually for both flow and methane concentration according to the schedule outlined in Section C.2.
2. Wells from two or more passive flares may be connected to a single flare with a single set of meters for both flow and methane concentration. Additional engineering may be required to ensure that the altered pressure characteristics of the system do not decrease total gas flow. The flow characteristics of this system will require substantiation from engineering documents and calculations and will be assessed by the verification body.
3. Wells from two or more passive flares may be connected with the active collection system and monitored separately from the new project wells while under vacuum from the blower.

C.4 Calculation

Please use Equation C.1 to calculate the $Closed_{discount}$ and Equation C.2 to calculate the $NQ_{discount}$.

Equation C.1. Calculation of Baseline Discount for Flares at a Closed Landfill

$$Closed_{discount} = 525,600 \times CH_{4_{min}}$$

$$LFG_{B1} = 525,600 \times 90\%UCL(LFG_{scfm})$$

Where,			Units
LFG_{B1}	=	Landfill gas from the baseline landfill gas wells that would have been destroyed by the qualifying destruction system during the reporting period	scf LFG
$90\%UCL(LFG_{scfm})$	=	90% upper confidence limit of the average flow rate in the metered period (must be >3 months)	scfm LFG
525,600	=	Minutes in one year	min/yr

$$B_{CH_4,closed} = 90\%UCL(B_{CH_4,closed,t})$$

Where,			Units
$B_{CH4,closed,t}$	=	Methane concentration for baseline calculations	scf CH_4/ scf LFG
$90\%UCL(B_{CH4,closed,t})$	=	90% upper confidence limit of the average methane concentration in the metered period (must be >3 months)	scf CH_4/ scf LFG

$$90\%UCL = mean + t_{value} \times \left(\frac{SD}{\sqrt{n}}\right)$$

Where,			Units
mean	=	Sample mean (of $B_{CH4,closed,t}$ or LFG_{scfm})	scf or %
t_{value}	=	90% t-value coefficient for data set with degrees of freedom *df* (use Excel feature: =TINV(0.1,df)	
SD	=	Standard deviation of the sample (of $B_{CH4,closed,t}$ or LFG_{scfm})	scf or %
n	=	Sample size	
df	=	Degrees of freedom (= n-1)	

Equation C.2. Calculation of Baseline Discount for a Non-Qualifying Device

$$NQ_{discount} = 525,600 \times CH_{4_{min}}$$

$$LFG_{B2} = 525,600 \times 90\%UCL(LFG_{scfm})$$

Where,			Units
LFG_{B2}	=	Landfill gas that would have been destroyed by the original, non-qualifying destruction system during the reporting period	scf LFG
$90\%UCL(LFG_{scfm})$	=	90% upper confidence limit of the average flow rate in the metered period (must be >3 months)	scfm LFG
525,600	=	Minutes in one year	min/yr

$$B_{CH_4,NQ} = 90\%UCL(B_{CH_4,NQ,t})$$

Where,			Units
$B_{CH4,NQ,t}$	=	Methane concentration for baseline calculations	scf CH_4/ scf LFG
$90\%UCL(B_{CH4,NQ,t})$	=	90% upper confidence limit of the average methane concentration in the metered period (must be >3 months)	scf CH_4/ scf LFG

$$90\%UCL = mean + t_{value} \times \left(\frac{SD}{\sqrt{n}}\right)$$

Where,			Units
mean	=	Sample mean (of $B_{CH4,NQ,t}$ or LFG_{scfm})	scf or %
t_{value}	=	90% t-value coefficient for data set with degrees of freedom *df* (use Excel feature: =TINV(0.1,df)	
SD	=	Standard deviation of the sample (of $B_{CH4,NQ,t}$ or LFG_{scfm})	scf or %
n	=	Sample size	
df	=	Degrees of freedom (= n-1)	

C.5 Example

The following example (Table C.1) demonstrates the necessary calculation for determining $Closed_{discount}$ or $NQ_{discount}$. The calculations outlined above in Section C.4 are represented by the first three columns of data. The final conversions to tCO_2e/yr are done using Equation 5.5.

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Note that although the measurements had average values yielding a deduction of 5,961 tCO_2e/yr, due to the limited data and variability of the measurements, the appropriate deduction is 7,830 tCO_2e/yr. If, instead of weekly data there was daily data over this three month period that yielded the exact same mean and standard deviation, the additional data alone would have lowered the deduction to only 6,807 tCO_2/yr. Alternately, if the data had been more consistent and showed a standard deviation for the flow data of only 6 with the same mean, then the deduction with 14 samples would have been only 6,689 tCO_2/yr. Therefore, the added uncertainty deduction of this method is directly related to the level of variability in the data and the number of samples.

Table C.1. Example Dataset and Calculation of $Closed_{discount}$ or $NQ_{discount}$

	Calculated According to Equations C.1 and C.2				Calculated According to Equation 5.5	
	CH_4 (%)	Flow (scfm)	Flow CH_4 (scfm)	CH_4/year (scf/yr)	CH_4/year (t/yr)	tCO_2e/year
6/1/2008	56.7	48	27	14,304,703	274	5,760
6/8/2008	55.3	75	41	21,799,260	418	8,778
6/15/2008	58.1	21	12	6,412,846	123	2,582
6/22/2008	54.0	90	49	25,544,160	490	10,286
6/29/2008	55.6	47	26	13,734,979	263	5,531
7/6/2008	56.3	23	13	6,805,994	131	2,741
7/13/2008	57.2	70	40	21,045,024	404	8,475
7/20/2008	58.0	15	9	4,572,720	88	1,841
7/27/2008	52.3	89	47	24,465,103	469	9,852
8/3/2008	55.7	42	23	12,295,886	236	4,951
8/10/2008	54.8	51	28	14,689,469	282	5,915
8/17/2008	62.1	19	12	6,201,554	119	2,497
8/24/2008	59.3	66	39	20,570,933	394	8,284
8/31/2008	57.6	70	40	21,192,192	406	8,534
Mean	**56.6**	**51.86**	**28**	**14,803,281**	**284**	**5,961**
SD	0.02	25.70				
n	14	14				
df	13	13				
90% t-value	1.77	1.77				
UCL at 90%	**57.8**	**64.02**	**37**	**19,443,275**	**373**	**7,830**

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Appendix D Data Substitution Guidelines

This appendix provides guidance on calculating emission reductions when data integrity has been compromised due to missing data points. No data substitution is permissible for equipment such as thermocouples, which monitor the proper functioning of destruction devices. Rather, the methodologies presented below are to be used only for the methane concentration and flow metering parameters.

The Reserve expects that projects will have continuous, uninterrupted data for the entire verification period. However, the Reserve recognizes that unexpected events or occurrences may result in brief data gaps.

The following data substitution methodology may be used only for flow and methane concentration data gaps that are discrete, limited, non-chronic, and due to unforeseen circumstances. Data substitution can only be applied to methane concentration *or* flow readings, but not both simultaneously. If data is missing for both parameters, no reductions can be credited.

Further, substitution may only occur when two other monitored parameters corroborate proper functioning of the destruction device and system operation within normal ranges. These two parameters must be demonstrated as follows:

1. Proper functioning can be evidenced by thermocouple readings for flares, energy output engines, etc.
2. For methane concentration substitution, flow rates during the data gap must be consistent with normal operation.
3. For flow substitution, methane concentration rates during the data gap must be consistent with normal operations.

If corroborating parameters fail to demonstrate any of these requirements, no substitution may be employed. If the requirements above can be met, the following substitution methodology maybe applied:

Duration of Missing Data	Substitution Methodology
Less than six hours	Use the average of the four hours immediately before and following the outage
Six to 24 hours	Use the 90% lower or upper confidence limit of the 24 hours prior to and after the outage, whichever results in greater conservativeness
One to seven days	Use the 95% lower or upper confidence limit of the 72 hours prior to and after the outage, whichever results in greater conservativeness
Greater than one week	No data may be substituted, and no credits may be generated

The lower confidence limit should be used for both methane concentration and flow readings for landfill projects, as this will provide the greatest conservativeness.

For weekly measured methane concentration, the lower of the measurement before and the measurement after must be used. This substitution may only be used to substitute data for one consecutive missing weekly measurement.