Landfill Project Reporting Protocol

Collecting and Destroying Methane
from Landfills

Version 2.0

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Abbreviations and Acronyms

ACF	actual cubic feet
CAA	Clean Air Act
California Registry	California Climate Action Registry
CARB	California Air Resources Board
CARROT	The Climate Action Registry Reporting Online Tool
CEQA	California Environmental Quality Act
CH_4	methane
CIWMB	California Integrated Waste Management Board
CNG	condensed natural gas
CO_2	carbon dioxide
EG	Emission Guidelines
EPA	U.S. Environmental Protection Agency
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
LNG	liquefied natural gas
MG	mega gram (1,000,000 grams or one tonne, or "t")
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
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

SCF	standard cubic feet (60°F and 1 atm)
VOC	volatile organic compound

1 Introduction

The California Climate Action Registry's (California Registry) Landfill Gas Project Reporting 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 California Registry is a private non-profit organization which runs a voluntary GHG registry called the Climate Action Reserve (Reserve). Its purpose is to promote and facilitate the measurement, monitoring and reduction of GHG emissions. Participants in the program account for and verify their GHG emissions according to the California Registry's protocols.

Project developers that install landfill gas capture and destruction technologies use this document to register GHG reductions with the California Registry. This protocol provides eligibility rules, methods to calculate reductions, performance-monitoring instructions, and procedures for reporting project information to the California Registry. Additionally, all project reports receive annual, independent verification by California Air Resources Board- (CARB) and California Registry-approved verifiers. Guidance for verifiers to verify reductions is provided in the corresponding Landfill Project Verification Protocol.

This project protocol facilitates the creation of GHG emission reductions, and ensures that they are calculated in a complete, consistent, transparent, accurate, and conservative manner that incorporates relevant sources.[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 California Registry. To register GHG reductions125 with the California Registry, 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

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 25 percent of total CH_4 emissions.[2] However, the solid waste industry has made significant efforts to reduce their GHG emissions over the past 20 years.[3]

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.

2.1 Project Definition

For the purpose of this protocol, the GHG reduction project is the installation of a landfill gas control system for capturing and destroying methane gas that commences operation on or after January 1, 2001. Captured landfill gas could be destroyed on-site, transported for off-site use (e.g. through gas distribution or transmission pipeline), or used to power vehicles. Regardless of how project developers take advantage of the captured landfill gas, for the project to be eligible to register GHG reductions under this protocol, the ultimate fate of the methane must be destruction.[4]

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 off-site 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.

In addition to reducing methane, the installation and operation of a landfill gas collection and destruction system could impact anthropogenic carbon dioxide and methane emissions

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[2] U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005, EPA-430-R-07-002 (April 2007).
[3] The updated Draft California Greenhouse Gas Inventory, developed by the Air Resources Board (August 2007), shows significant improvement in fugitive methane emission control at landfills within the state of California.
[4] 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.

associated with the consumption of electricity and fossil fuels. Depending on the project's particular circumstances, this effect could either increase or decrease operational GHG emissions. Section 4, The GHG Assessment Boundary, delineates the scope of the accounting framework.

2.2 The Project Developer

Project developers can be landfill owners/operators and owners of the landfill gas rights. However, they can also include other entities such as third-party aggregators. Ownership of the GHG reductions must be established by clear and explicit title.

2.3 Additional GHG Reduction Activities in the Solid Waste Sector

The California Registry recognizes that project developers could implement a variety of GHG reduction activities associated with the collection, transportation, sorting, recycling and disposal of solid waste; installing technology to capture and destroy methane from landfills is but one of many GHG emission reduction projects that could occur within the solid waste sector.

However, GHG reduction activities not associated with the installation of a landfill gas collection and destruction system do not meet this protocol's definition of the GHG reduction project. Furthermore, production of power for the electricity grid, which results in the displacement of fossil-fueled power plant GHG emissions, is a complementary and separate GHG project activity to destroying methane gas from landfills and is not included within this protocol's accounting framework.

Landfill operations that meet the EPA definition of a bioreactor are not eligible to use this protocol, as it is unclear what effects the bioreactor may have on the net total and temporal distribution of fugitive methane emissions relative to project baseline conditions. As defined by the EPA, a bioreactor is any MSW landfill or portion of a MSW landfill with a minimum average moisture content of at least 40 percent by weight that is re-circulating leachate, or a MSW landfill or portion of a MSW landfill that is adding any liquid other than leachate (leachate includes landfill gas condensate) in a controlled fashion to accelerate or enhance the anaerobic biodegradation of the waste.[5]

The California Registry anticipates that separate project protocols will be developed in the future to facilitate further solid waste sector emission reduction opportunities to balance and complement the Landfill Project Protocol. These may include composting, anaerobic digestion, recycling and waste-to-energy.

[5] 40 CFR 63.1990 and 40 CFR 258.28a.

3 Eligibility Rules

Project developers using this protocol must satisfy the following eligibility rules to register reductions with the California Registry. These criteria apply only to projects that meet the definition of a GHG reduction project as defined in Section 2.

Eligibility Rule I:	Location	→	*U.S.-based landfill*
Eligibility Rule II:	Project Operation Start Date	→	*January 1, 2001*
Eligibility Rule III:	Additionality	→ →	*Meet performance standard* *Exceed regulatory requirements*

3.1 Location

All projects located at landfill operations in the United States are eligible to register reductions with the California Registry. The scope of the analysis of landfill practices that formed the basis of the performance standard (Section 3.3.1) covered landfill operations in the United States. Therefore, the California Registry will estimate GHG reductions from all U.S.-based projects that follow the guidance in this protocol in the same manner.

The California Registry anticipates that this protocol could be applicable internationally. The calculation procedure is consistent with international practices and, considering its rigor, the performance standard could apply to regions outside of the U.S. However, at this time, reductions from international projects are not eligible to be registered with the California Registry.

3.2 Project Start Date

California Senate Bill 1771 (Sher) created the California Registry in September of 2000 to serve as a platform to record and register GHG reduction activities, among other things. This sent a signal to GHG-emitting entities, including landfill operators, that project activities could receive recognition for their carbon value. The establishment of the California Registry to support GHG reduction activities is the basis for the project start date criterion.

Eligible projects must have a start date on or after January 1, 2001. The project start date is defined as the date at which a qualifying destruction device becomes operational.

Projects that began operating before being listed with the California Registry, but after January 1, 2001, are considered pre-existing projects. Pre-existing projects will be eligible to become listed with the Reserve for a period of 12 months from the effective date of this protocol (Version 2.0). This is to ensure that the Reserve is providing “early actors” (those that implemented a GHG reduction project prior to a project protocol being available for their project activity) enough time to list their project.[6] After this 12 month grace period, pre-existing projects are required to submit for listing within 6 months of becoming operational. Those that fail to list within this 6 month period will be considered non-additional and excluded from eligibility. Projects that began operating before January 1, 2001, are not eligible to register reductions according to this protocol. For the California Registry's purpose, the commencement of operation means a constructed system that is capturing and destroying methane gas from the landfill operation.

3.3 Additionality

The California Registry strives to support only projects that yield surplus GHG reductions that are additional to what might otherwise have occurred. That is, the reductions are above and beyond business-as-usual, the baseline case. Project developers satisfy the "additionality" eligibility rule by passing two tests:

1. The Performance Standard Test
2. The Regulatory Test

3.3.1 The Performance Standard Test

Project developers pass the Performance Standard Test by meeting a program-wide performance threshold (i.e. a standard of performance applicable to all landfill projects, established on an ex-ante basis). The performance threshold represents "better than business-as-usual." If the project meets the threshold, then it exceeds what would happen under the business-as-usual scenario and generates surplus/additional GHG reductions.

For this protocol, the California Registry uses a technology-specific threshold, sometimes also referred to as a practice-based threshold, which serves as "best practice standard" for managing landfill gas fugitive emissions. A project developer passes the Performance Standard Test by installing a landfill gas collection and destruction system at a landfill that is not required to do so by regulations.

There are three possible scenarios under which the practice-based performance threshold is met:

1. If the landfill is not currently collecting and destroying any landfill gas, the project is considered additional.[7]

2. If the landfill was previously collecting and destroying landfill gas using a destruction device which would not qualify under this protocol (e.g. passive flares), the project is additional under the following condition:
    a. Only the landfill gas destroyed beyond that resulting from the pre-project collection and destruction system is considered additional (i.e. those reductions resulting from the implementation of the new GHG reduction

[6] A project is considered "listed" when the project developer has created an account with the Reserve, submitted the required Project Submission Form and related required documents, paid the project submission fee, and the Reserve has approved the project for listing.
[7] For landfills that are currently collecting and venting, but not combusting landfill gas, the installation of a landfill gas combustion device is an eligible project activity.

project). The pre-project methane must be netted out of emission reductions according to Equation 5.3.

3. If the landfill was previously collecting and destroying methane using a destruction device which would qualify under this protocol, the project is additional under the following conditions:
    a. The previous system does not, on its own, qualify as a project under this protocol. Expanding the well-field constitutes a system expansion rather than initiation of a new project.
    b. The new GHG project requires the addition of a separate destruction device.
    c. Only the landfill gas destroyed beyond the maximum capacity of the pre-project destruction device is considered additional (i.e. those reductions resulting from the implementation of the new GHG reduction project). The maximum capacity of the pre-project system must be netted out of emission reductions according to Equation 5.3.
    d. However, landfills currently collecting and destroying landfill gas to comply with NSPS & EG regulations are not eligible to register new projects with the California Registry.[8]

These conditions ensure that the reductions resulting from the new GHG project can be accounted for separately from current collection and destruction.

The California Registry 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.

All projects that pass this test are eligible to register reductions with the California Registry for the lifetime of the project crediting period, even if the Performance Standard Test changes during mid-period. As stated in Section 7, Reporting Parameters, the project crediting period is ten years or until failure of the regulatory additionality test. The crediting period commences at the project start date regardless of whether sufficient monitoring data is available to register credits.

The California Registry will periodically re-evaluate the appropriateness of the performance standard threshold by updating the market penetration analysis in Appendix A. The California Registry recognizes the importance of waste diversion and recycling programs. Therefore, as part of its periodic assessments of the performance threshold, the California Registry will use a stakeholder process to evaluate whether implementation of this protocol has resulted in negative environmental effects, such as increased emissions of criteria pollutants and/or methane. The assessment will pay particular attention to the status of other GHG reduction project protocols including composting, anaerobic digestion, recycling and waste-to-energy, which would act to balance and complement the Landfill Project Reporting Protocol. If it is determined that negative environmental effects have occurred, the California Registry 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.

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[8] Landfills currently collecting and destroying landfill gas to comply with NSPS & EG regulations are not eligible to register GHG reductions associated with the early installation of gas control systems during landfill expansion into new cells.

3.3.2 The Regulatory Test

All GHG reduction projects are subject to a regulatory test to ensure that the emission reductions achieved by a project would not have occurred in the baseline case due to federal, state or local regulations. The Monitoring Plan (Section 6) must incorporate into the monitoring procedures a mechanism for ensuring and demonstrating that the project at all times passes the Regulatory Test. The preferred method for demonstrating compliance with the Regulatory Test is a regulatory audit, performed on a periodic basis. At a minimum, an executive-level representative must formally attest to compliance with the Regulatory Test on an annual basis. The California Registry has developed an official Attestation of Regulatory Compliance form to be used for this purpose.

3.3.2.1 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.

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.

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.

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.

3.3.2.2 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 21, 2007, CARB approved a Landfill Methane Capture Strategy as a discrete early action measure. Accordingly, CARB staff, in collaboration with California Integrated Waste Management Board (CIWMB) staff, is currently developing a control measure to provide enhanced control of methane emissions from landfills. The control measure will reduce methane emissions from landfills by requiring gas collection and control systems where these systems are not currently required, and will establish statewide performance standards to maximize methane capture efficiencies.[9]

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.[10]

The California Registry 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 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 Regulatory Test.

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 can become subject to air quality regulations requiring the control of NMOC emissions. The air quality regulations may allow for flexibility in the treatment of landfill gas for NMOC using

[9] California Air Resources Board, Landfill Methane Control Measure web page: http://www.arb.ca.gov/cc/ccea/landfills/landfills.htm.

[10] The California Registry 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.

destruction devices or 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 clearly be the most preferred compliance mechanism. In this situation, the landfill gas control system in question will not pass the Regulatory Test.

Where a landfill 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 California Registry has developed an NMOC emissions threshold by which the eligibility of a project can be determined. If the total mass flow of NMOC for the landfill gas control system is less than 620 pounds NMOC per month, then the landfill gas control system is eligible as a GHG reduction project under this protocol. If the total mass flow of NMOC for the landfill gas control system is greater than 620 pounds NMOC per month, then the landfill gas control system is not eligible as a GHG reduction project under this protocol. A summary of the development of the NMOC emissions threshold is provided in Appendix B.

Additionally, for project developers to pass the Regulatory Test they must demonstrate that the project meets federal, state and local air and water quality regulations. In some cases the installation of landfill gas destruction devices may cause co-pollutant emissions such as NOx and Carbon Monoxide. Therefore, while controlling GHG emissions, an offset project has the potential to degrade local air quality. In the case that a landfill gas collection project triggers the need for criteria pollutant offsets, the project operator must demonstrate that appropriate emission offsetting measures have been followed.

Projects that are in non-compliance with air or water quality regulations are not eligible to register GHG reductions with the California Registry. If a project verifier finds that a GHG reduction project is in a state of recurrent non-compliance or non-compliance that is the result of negligence or intent, then GHG reduction credits from the period of non-compliance will be deemed void. Non-compliance solely due to administrative and reporting issues or “acts of god” will not affect GHG reduction registration and crediting. Once the project developer verifies regulatory compliance, GHG reductions associated with the portion of the crediting period for which the project developer was in compliance will be considered valid.

Project developers pass the Regulatory Test by demonstrating that:

- there are no federal, state or regional regulations or permitting requirements (as well as local agency ordinances/rulings) requiring the landfill to control NMOC emissions or requiring the installation of a landfill gas collection and destruction system at the project location
- if adding a destruction device to a passive landfill gas control system, the regulation, ordinance or permitting condition that requires the landfill gas control system does not require any treatment of the vented landfill gas
- 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 620 pounds NMOC per month
- the project meets all applicable federal, state, and local regulations or ordinances

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 of a landfill gas control system, emission reductions can be reported to the California Registry up until the date that the landfill gas control system is legally required to be operational. The regulatory additionality test must be applied annually, at the beginning of each emission reduction accounting cycle.

4 The GHG Assessment Boundary

The GHG assessment boundary delineates the GHG sources and gases included in the calculation of the net change in emissions associated with installing a landfill gas collection and destruction system.

The GHG assessment boundary for the project includes all emission sources from the operation of the landfill gas collection system to the ultimate destruction of the landfill gas.

CO_2 emissions associated with the generation and destruction of landfill gas are considered biogenic emissions[11] (as opposed to anthropogenic) and will not be included in the GHG reduction calculation. This is consistent with the Intergovernmental Panel on Climate Change's (IPCC) guidelines for captured landfill gas.[12]

This protocol does not account for CO_2 reductions associated with the displacement of fossil-based grid-delivered electricity or natural gas. This is classified as an indirect emission reduction activity because the change in GHGs occurs from sources owned and controlled by the power producer or the end user of the natural gas. Capturing and using methane to displace fossil-based electricity on the grid or natural gas in gas transmission and distribution systems could potentially be considered complementary and separate GHG reduction projects.

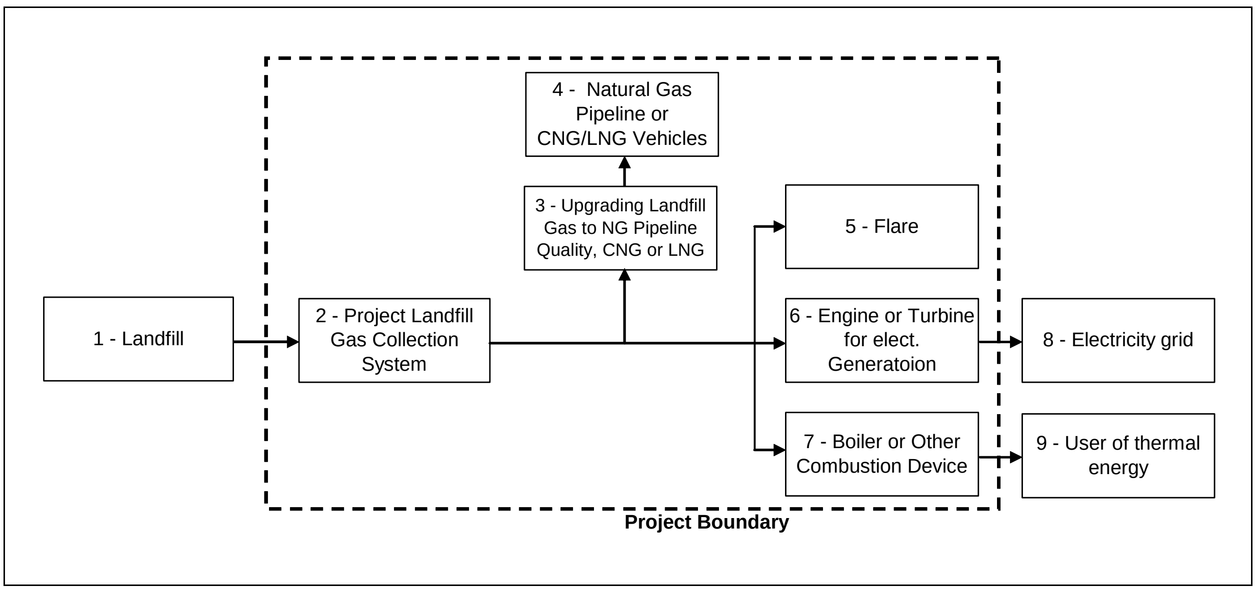

Figure 4.1. General illustration of the GHG assessment boundary.

[11] 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.

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

4.1 Leakage

Leakage is an increase in GHG emissions or decrease in sequestration caused by the project but not accounted for within the project boundary. The underlying concept is that a particular project can produce effects outside of the physical boundary that fully or partially negate the benefits of the project. Although there are other forms of leakage, for this performance standard, leakage is limited to activity shifting which is the displacement of activities and their associated GHG emissions outside of the project boundary.

Landfill methane collection and destruction projects are not expected to result in leakage of GHGs outside the GHG assessment boundary.

Table 4.1. Main GHG sources associated with the source categories. This table specifies the gases included in the calculation procedure.

GHG Source Category	GHG Source	Gas	Included in Project Boundary	Comment
1. Landfill	• Fugitive emissions from landfill surface	CO_2	No	*Biogenic emissions are excluded.**
		CH_4	No	*Emissions would have occurred absent the project. ***
2. Landfill Gas Collection System	• Well heads and collection headers	CH_4	No	*Emissions would have occurred absent the project.***
	• Emissions resulting from fossil fuel derived energy used by compressors, blowers, gathering and upgrade system	CO_2	Yes	*All CO_2 emissions (direct and indirect) due to fossil fuel destruction are included.*
		CH_4	No	*Excluded, as this emission source is assumed to be very small.*
		N_2O	No	*Excluded, as this emission source is assumed to be very small.****
	• Fugitive emissions from conduit to destruction device	CH_4	No	*Emissions would have occurred absent the project.***
3. Upgrading Landfill Gas to NG Pipeline Quality	• Emissions resulting from fossil fuel derived energy used to upgrade the quality of and transport the gas to the NG pipeline	CO_2	Yes	*All CO_2 emissions (direct and indirect) due to fossil fuel destruction are included.*
		CH_4	No	*Excluded, as this emission source is assumed to be very small.*
		N_2O	No	*Excluded, as this emission source is assumed to be very small. ****
4. Natural Gas Pipeline or CNG/LNG	• Emissions from compressors and other equipment associated with transporting the natural gas through the pipeline	CO_2	No	*Excluded, as this emission source is assumed to be very small.*
		CH_4	Yes	*Based on efficiency of end-user destruction, as well as processing, transmissions, and distribution losses. *****
		N_2O	No	*Excluded, as this emission source is assumed to be very small. ****
5. Flare	• Emissions resulting from the destruction of landfill gas in flare	CO_2	No	*Biogenic emissions are excluded.**
		CH_4	Yes	*Based on destruction efficiency of flare.*

GHG Source Category	GHG Source	Gas	Included in Project Boundary	Comment
5. Cont.		N_2O	No	*Excluded, as this emission source is assumed to be very small.****
	• Emissions resulting from the destruction of fossil fuel in flare	CO_2	Yes	*All CO_2 emissions due to fossil fuel destruction are included.*
		CH_4	Yes	*Un-destroyed CH_4 from natural gas use is based on destruction efficiency of flare.*
		N_2O	No	*Excluded, as this emission source is assumed to be very small****
6. Engine or Turbine for Electricity Generation	• Emissions resulting from the destruction of landfill gas in engine or turbine	CO_2	No	*Biogenic emissions are excluded.**
		CH_4	Yes	*Based on destruction efficiency of engine or turbine*
		N_2O	No	*Excluded, as this emission source is assumed to be very small.****
	• Emissions resulting from the destruction of fossil fuel in engine or turbine	CO_2	Yes	*All CO_2 emissions due to fossil fuel destruction are included.*
		CH_4	Yes	*Un-destroyed CH_4 from natural gas use is based on destruction efficiency of engine or turbine.*
		N_2O	No	*Excluded, as this emission source is assumed to be very small.****
7. Boiler or Other Destruction Device	• Emissions resulting from the destruction of landfill gas in boiler or other destruction device	CO_2	No	*Biogenic emissions are excluded.**
		CH_4	Yes	*Based on destruction efficiency of boiler device.*
		N_2O	No	*Excluded, as this emission source is assumed to be very small.****
	• Emissions resulting from the destruction of fossil fuel in boiler or other destruction device	CO_2	Yes	*All CO_2 emissions due to fossil fuel destruction are included.*
		CH_4	Yes	*Un-destroyed CH_4 from natural gas use is based on destruction efficiency of boiler.*
		N_2O	No	*Excluded, as this emission source is assumed to be very small.****
8. Electricity Grid	• Displacement of GHG emissions from fossil fuel destruction from electricity generated using landfill gas	CO_2	No	*This Protocol does not cover displacement of GHG emissions from Landfill Gas to Energy Projects.*
		CH_4	No	
		N_2O	No	
9. User of Thermal Energy	• Displacement of GHG emissions from fossil fuel destruction from thermal energy generated using landfill gas	CO_2	No	*This Protocol does not cover displacement of GHG emissions from Landfill Gas to Thermal Energy Projects.*

***** Carbon dioxide emissions from the destruction of landfill gas are considered biogenic emissions (as opposed to anthropogenic) and will not be included in the GHG reduction calculation.

****** Methane emissions that escape from the cap, or from leaking valves or seals do not need to be included within the project boundary because these methane emissions would have occurred absent the project

*** Nitrous Oxide emissions are excluded from this protocol as they are considered to be very small. Also, the level of uncertainty associated with the nitrous oxide emission factors that are currently available is substantial.

******** 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 118,000kgCH4/PJ on the basis of gas consumption, which is 0.6%. Leakage in the residential and commercial sectors is stated to be 0 to 87,000kgCH4/PJ, which equates to 0.4%, and in industrial plants and power station the losses are 0 to 175,000kg/CH4/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.[13]

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

5 GHG Reductions Calculation Method[14]

Project GHG reductions are verified and registered with the Reserve, at a minimum on an annual basis, but may be verified and registered more frequently if desired.

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 California Registry will consider updating the protocol to incorporate these new approaches into the methane emission reduction quantification methodologies.

5.1 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.[15]

As noted in section 3.3.1, projects may fall into three categories based on the pre-project state of the landfill and level of landfill gas management. Each of these categories requires a slightly different methodology for calculating relevant baseline emissions.

1. Landfills where no previous collection or destruction took place prior to project implementation 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 (see Equation 5.3).

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[14] The California Registry'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).

[15] Landfill cover systems incorporating synthetic liners as part of the final cover systems should use a default methane oxidation rate of zero. A 10% methane oxidation factor shall be used for all other landfills. 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).

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 pre-project destruction device was operating at full capacity (Equation 5.3).
   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 current collection and destruction. Only the landfill gas destroyed beyond that resulting from the pre-project collection and destruction system is considered additional (i.e. those reductions resulting from the implementation of a new GHG reduction project).

When a new GHG reduction project is sited at a landfill where a pre-project landfill gas collection and destruction system is in operation, it is important that the new landfill gas collection system is designed to minimize the overlap of the effective radius of influence of the original and the newly installed landfill gas collection wells. In order to account for any potential overlap of the two systems, specific pre-project installation monitoring of the landfill gas flow rate and methane concentration for the original landfill gas collection system is required.

As stated above, landfill operations that meet the EPA definition of a bioreactor are not eligible to use this protocol, as it is unclear what effects the bioreactor may have on the fugitive methane emissions relative to baseline conditions.

This protocol accounts for the difference in electricity consumption between the baseline scenario and the project by assuming no electricity consumption in the base case and deducting the annual indirect CO_2 emissions due to the project activity from the annual project emission reductions.

5.2 Project Emissions

Certain GHG emissions may occur or increase as a result of the project activity, and therefore must be deducted from the overall project reductions. These added emissions are typically a result of the increased use of fossil-derived energy used to power project blowers, monitoring equipment, support vehicles, or gas treatment. As such, the following categories of emissions must be accounted for under this protocol:

- total annual indirect carbon dioxide emissions resulting from consumption of electricity from the grid
- total annual carbon dioxide emissions from the on-site destruction of fossil fuel
- total annual carbon dioxide emissions from the combustion of supplemental natural gas
- total annual methane emissions from the incomplete combustion of supplemental natural gas

However, unlike the emissions from incomplete destruction of supplemental natural gas, those resulting from incomplete destruction of landfill gas or the fugitive release of landfill gas do not need to be accounted for. It is assumed that these would have been released to the atmosphere in the baseline scenario as well.

5.3 Project Emission Reductions

Project emission reductions are GHG emission reductions that occur within the GHG assessment boundary as a result of the installation of the landfill gas control system. Project emission reductions are calculated on an annual, ex-post basis.

As shown in the following equations, project GHG emission reductions equal:

- the total amount of uncontrolled methane collected from the landfill and destroyed by the project landfill gas control system, minus
- the portion of methane oxidized in the baseline scenario, minus
- carbon dioxide emissions from fossil fuel consumption, minus
- methane emissions from incomplete destruction of natural gas, if applicable, minus
- indirect carbon dioxide emissions from the use of electricity from the grid, minus
- the effective radius of influence adjustment, if applicable, minus
- the discount factor to account for uncertainties associated with the project monitoring equipment

Equation 5.1. Project GHG emission reductions.

$$ER_y = [(CH_4Dest_{PR}) * 21 * (1 - OX) * (1 - DF)] - FFCO_2 - ELCO_2 - PRE_{discount}$$

Where,

		Units
ER_y =	total annual project GHG emission reductions	tCO_2e/yr
$CH_4\ Dest_{PR}$ =	total annual methane emissions destroyed by the project landfill gas collection and destruction system – see Equation 5.2	tCH_4/yr
21 =	Global Warming Potential factor of methane to carbon dioxide equivalent[16]	
OX =	factor for the oxidation of methane by soil bacteria. Equal to 0.10 for all landfills except those that are covered with a synthetic liner as part of the final cover systems where OX = 0.	
$PRE_{discount}$ =	adjustment to account for pre-project LFG destruction device (see Equation 5.3). Equal to zero if no pre-project LFG destruction system is in place prior to project implementation.	tCO_2e/yr
DF =	discount factor to account for uncertainties associated with the project monitoring equipment. Either 0, 0.05, 0.10, 0.15, 0.20, or 0.25 (see Section 6, Project Monitoring). Equal to zero if using continuous methane monitor with no missing data and all calibration tests are within a 5% margin of error.	

$$FFCO2 = \frac{\sum_i (FF_{PR,i} * EF_{FF,i})}{1000}$$

Where,

		Units
$FFCO_2$ =	total annual carbon dioxide emissions from the destruction of fossil fuel	tCO_2/yr
$FF_{PR,i}$ =	total annual fossil fuel consumed by the project landfill gas collection and destruction system, by fuel type i	volume fossil fuel/yr
$EF_{FF,i}$ =	fuel specific emission factor, California Registry General Reporting Protocol Appendix C.3 and C.5[17]	kg CO_2/volume fossil fuel
1000 =	$kgCO_2/tCO_2$	

$$ELCO_2 = \frac{(EL_{PR} * EF_{EL})}{2204.62}$$

Where,

		Units
$ELCO_2$ =	total annual indirect carbon dioxide emissions from the consumption of electricity from the grid	tCO_2/yr
EL_{PR} =	total annual electricity consumed by the project landfill gas collection and destruction system	MWh
EFEL =	carbon emission factor for electricity used[18]	lb CO_2/MWh
2204.62 =	$lbCO_2/tCO_2$	

[16] IPCC Second Assessment Report: Climate Change 1996.
[17] California Climate Action Registry General Reporting Protocol V. 3.0, Appendix C, tables C.4 and C.6.

Equation 5-2. Total annual methane emissions destroyed

$$CH_4Dest_{PR} = \left(CH_4Dest_{flare} + CH_4Dest_{electricity} + CH_4Dest_{thermal} + CH_4Dest_{upgrade}\right) * \left(0.0423 * 0.000454\right)$$

Where,

		Units
CH_4 $Dest_{flare}$ =	the net quantity of methane destroyed by flaring	scf/yr
CH_4 $Dest_{electricity}$ =	the net quantity of methane destroyed by generation of electricity	scf/yr
CH_4 $Dest_{thermal}$ =	the net quantity of methane destroyed for the generation of thermal energy	scf/yr
CH_4 $Dest_{upgrade}$ =	the net quantity of methane destroyed by upgrading landfill gas to natural gas pipeline quality and injecting it into the pipeline for destruction by end users	scf/yr
0.0423 =	density of methane	$lbCH_4$ / ft^3 CH_4
0.000454 =	tCH_4 / $lbCH_4$	

$$CH_4Dest_i = \left(Q_i * DE_i\right) - FFCH_{4,i}$$

Where,

		Units
CH_4 $Dest_i$ =	the net quantity of methane destroyed by device i	scf/yr
Q_i =	total quantity of methane sent to destruction device i	scf/yr
$FFCH_{4,i}$ =	emissions from incomplete destruction of supplemental natural gas sent to destruction device i. Equal to zero if no supplemental natural gas used.	scf/yr
DE_i =	default methane destruction efficiency for device i[19,20] Enclosed flare = 0.995 Open flare = 0.960 Lean Burn IC engines for electricity = 0.936 Rich Burn IC engines for electricity = 0.995 Large Gas turbine for electricity = 0.995 Microturbine for electricity = 0.995 Thermal boiler = 0.98 Upgraded to natural gas transmission and distribution system = 0.98 Upgraded to CNG and LNG for vehicles = 0.95	

[18] Utility specific emission factors for California Registry member utilities are available in the Public Reports section of the CARROT database (see Reference Documents section of the Public Report for a link to the PUP reporting form) -http://www.climateregistry.org/CARROT/public/reports.aspx. If a utility specific emission factor is not available, use the EPA eGRID subregion emission factor available in the California Registry's General Reporting Protocol (GRP) V. 3.0, Appendix C, tables C.2 (also see GRP III.6.1).

[19] If available, the official source tested methane destruction efficiency shall be used 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 each of the combustion devices used in the project case.

[20] 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 California Registry.

Equation 5.2 (continued). Total annual methane emissions destroyed.

$$Q_i = \sum_t LFG_{i,t} * PR_{CH4,t}$$

Where,

			Units
$LFG_{i,t}$	=	total quantity of landfill gas fed to the destruction device i, in time interval t – see Equation 5-4 for additional guidance on adjusting the LFG flow for temperature and pressure	scf/t
t	=	time interval for which LFG flow and concentration measurements are aggregated. Equal to one day for continuously monitored methane concentration and one week for weekly monitored methane concentration.	
$PR_{CH4,t}$	=	the average methane fraction of the landfill gas in time interval t as measured	ft^3 CH_4 / ft^3 LFG

$$FFCH_{4,i} = FF_i * FFG_{CH4} * (1 - DE_i)$$

Where,

			Units
FF_i	=	total annual quantity of supplemental natural gas delivered to the destruction device i.	scf/yr
FFG_{CH4}	=	the average methane fraction of the supplemental natural gas as provided for by fuel vendor	ft^3 CH_4 / ft^3 FFG
DE_i	=	methane destruction efficiency (use destruction efficiency provided in Equation 5-2) of destruction device i.	

Equation 5.3. Pre-project adjustment for destruction in the baseline scenario.[21]

$$PRE_{discount} = (NQ_{discount} + Dest_{max}) * 0.0423 * 0.000454 * 21$$

Where,		Units
$PRE_{discount}$ =	Adjustment to account for the baseline methane destruction associated with a pre-project destruction device. Equal to zero if there is no pre-project installation.	tCO2e
0.0423 =	Density of methane	$lbCH_4$ / scf CH_4
0.000454 =	Conversion factor	tCH_4 / $lbCH_4$
21 =	Global Warming Potential factor of methane to carbon dioxide equivalent	

$$NQ_{discount} = LFG_{PP1} * PP_{CH4}$$

Where,		Units
$NQ_{discount}$ =	Adjustment to account for the methane which would have been combusted in the baseline, non-qualifying combustion device.	scf CH_4
LFG_{PP1} =	Pre-project annual amount of landfill gas destroyed by the original, non-qualifying destruction system– see Equation 5.4 for additional guidance on adjusting the LFG flow for temperature and pressure	scf/yr
PP_{CH4} =	Pre-project methane fraction in the landfill gas of the original collection system	ft^3 CH4 / ft^3 LFG

$$Dest_{max} = \sum_t [(LFG_{PP\max,t} - LFG_{PP2,t}) * PR_{CH4,t}]$$

Where,		Units
$Dest_{max}$ =	Deduction of the un-utilized capacity of the pre-project destruction device. This deduction is to be applied only when a new destruction device is used during project activity. See Box 1 below for an example of the application of the $Dest_{max}$ adjustment.	scf CH_4
$LFG_{PPmax,t}$ =	the maximum landfill gas flow capacity of the pre-project methane destruction device in time interval t	ft^3/t
$LFG_{PP2,t}$ =	the actual landfill gas flow of the pre-project methane destruction device in time interval t	ft^3/t
$PR_{CH4,t}$ =	the average methane fraction of the landfill gas in time interval t as measured	ft^3 CH_4 / ft^3 LFG
t =	time interval for which LFG flow and concentration measurements are aggregated. Equal to one day for continuously monitored methane concentration and one week for weekly monitored methane concentration.	

[21] This calculation is not necessary if the pre-project collection and destruction system is 100% separated by a non-permeable liner and shares no part of a landfill cell with the new landfill project.

Equation 5.4. Adjusting the landfill gas flow for temperature and pressure.

If 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.

Important: Apply the following equation only if the landfill gas flow metering equipment does not internally correct for temperature and pressure.

$$LFG_{scf} = LFG_{unadjusted} * \frac{520}{T} * \frac{P}{1}$$

Where,

		Units
LFG =	adjusted volume of landfill gas collected for the given time interval, measured at 60° F and 1 atm	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

Box 1. Applying the $Dest_{max}$ adjustment.

This adjustment was designed to help differentiate system upgrades from truly new and 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 pre-project 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 1500 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 pre-project 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.

6 Project Monitoring

The California Registry 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 Sections 6 and 7 have been and will continue to be met, and that consistent, rigorous monitoring and record-keeping occurs. The Monitoring Plan does not require ISO or any other certification, but must cover all aspects of monitoring and reporting contained in this protocol. Further, the Monitoring Plan must provide a mechanism by which to annually evaluate and attest to the status of the regulatory test. At a minimum the Monitoring Plan must include a written account of the frequency of data acquisition, the record keeping plan (see Section 7.2 for minimum record keeping requirements), the frequency of instrument calibration activities and the role of the individual performing each specific monitoring activity. The Monitoring Plan shall also include QA/QC provisions to ensure that data acquisition and meter calibration are carried out consistently and with precision.

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

- the continuous rate of landfill gas flow, temperature and pressure prior to delivery to destruction device
- the fraction of methane in the landfill gas measured with a continuous analyzer or, alternatively, with weekly or monthly measurements using a calibrated portable gas analyzer
- the continuous flow rate of landfill gas to each destruction device
- the continuous rate of landfill gas flow, temperature, pressure and methane concentration prior to injection into the natural gas transmission and distribution system or distributed as CNG or LNG for use in vehicles

Often, the direct measurement instrument also uses a data recorder to store and document the landfill gas flow and methane concentration data and can be tailored to provide the amount of methane (by volume) collected from the landfill on a periodic basis as specified by the operator.

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.). [22, 23] When using the alternative approach of weekly 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.

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[22] 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). No separate monitoring of temperature and pressure is necessary when using flow meters that automatically measure temperature and pressure, expressing LFG volumes in normalized cubic meters.
[23] Consolidated baseline methodology for landfill gas project activities, Clean Development Mechanism, Version 07, Sectoral Scope 13 (2007).

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

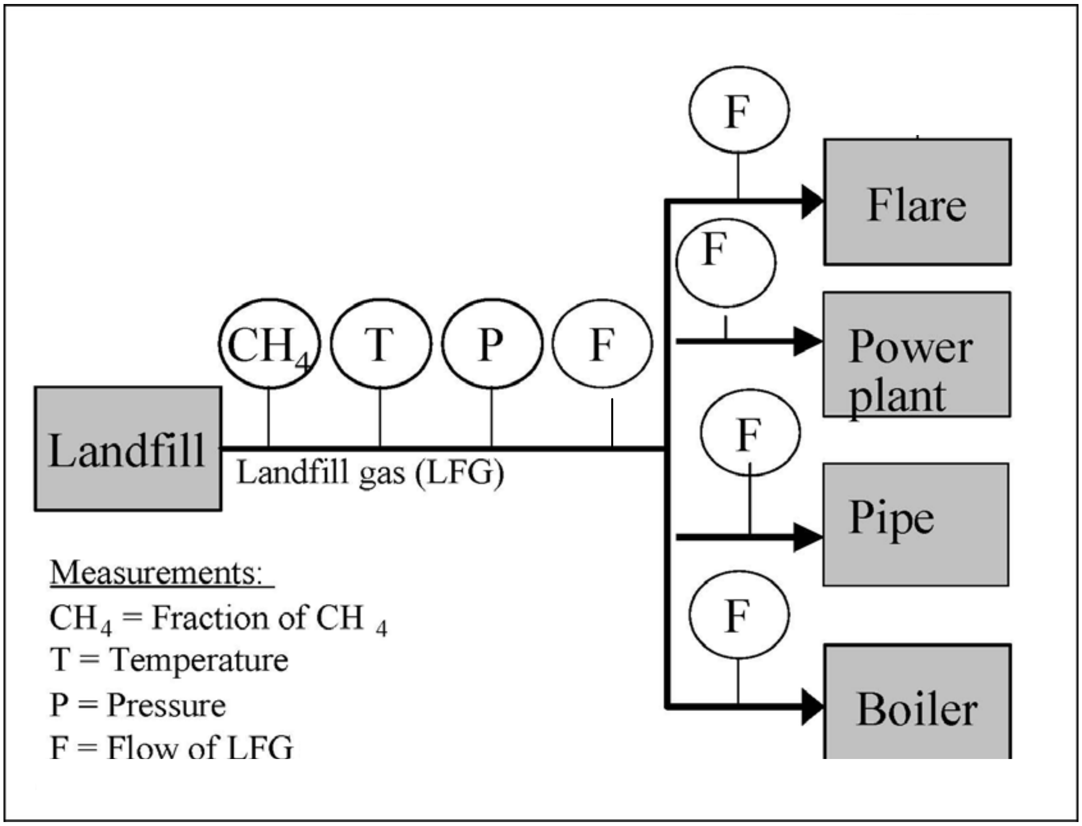

Figure 6.1. Suggested arrangement of LFG metering equipment.

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).

Qualifying 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.

The hourly operational activity of the landfill gas collection system and the destruction devices shall be monitored and documented to ensure actual landfill gas destruction. GHG reductions will not be accounted for during periods which the destruction device was not operational. The measurement equipment is sensitive for gas quality (humidity, particulate, etc.), so a strong QA/QC procedure for the calibration of this equipment should be built into the monitoring plan. At a minimum, monitoring instruments shall be inspected, cleaned and calibrated quarterly. If a portable calibration instrument is used, such as a pitot tube or a calibrated portable gas analyzer, the portable instrument shall be calibrated at least annually at an ISO 17025 accredited laboratory.

In situations where the flow rate or methane concentration monitoring equipment has failed a calibration test (tested to be outside of allowable 5% margin of error), or is missing data, the project developer should apply the data substitution methods provided for under the U.S. EPA Acid Rain Program in 40 CFR Part 75 Subpart D 75.33.[24] In the case where monitoring equipment has failed a calibration test, or is missing data, project developers must account for the uncertainty associated with the data substitution methods by applying a 5% discount factor to the total estimated quantity of methane collected and destroyed during the period affected by the faulty calibration or missing data. If for any reason the destruction device monitoring equipment (for example, the thermal coupler on the flare) is inoperable, then no emission reductions can be registered for the period of inoperability.

In the case where a new GHG reduction project is sited at a landfill where a pre-project landfill gas collection and destruction system is in operation, project developers are required to monitor pre-project installation and post-project installation landfill gas flow and methane concentration for the original landfill gas collection system, as required to calculate the effective radius-of-influence adjustment factor in Equation 5.3.

Either of the above mentioned methane concentration measurement methodologies can be used for this monitoring activity.

If available, the official source tested methane destruction efficiency shall be used in Equations 5.2 and 5.2a 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 case.

Prescribed monitoring parameters necessary to calculate baseline and project emissions are provided in Table 6.1 (adapted from ACM0001, V.6).

[24] Available at the Electronic Code of Federal Regulations website: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=%2Findex.tpl.

Table 6.1. Monitoring data to be collected and used to estimate emission reductions.

Parameter	Description	Data unit	calculated (c) measured (m) estimated (e)	Measurement frequency	Comment
$LFG_{PR\ total}$	Total amount of Project landfill gas collected	ft^3	m	Continuously	Measured continuously by a flow meter and recorded at least once every 15 minutes. Data to be aggregated by time interval t (see Equation 5.2).
LFG_{PP1}	Pre-project installation amount of landfill gas destroyed by the original non-qualifying system	ft^3	m/c	Yearly	Calculated based on the maximum flow capacity (scfm) of the destruction device, or according to guidance to be provided in the forthcoming addendum.
LFG_{PP2}	Post-project installation amount of landfill gas destroyed by the original collection system	ft^3	m/c	Continuously	Measured continuously by a flow meter and recorded at least once every 15 minutes. Measured for calculation of discount factor in Equation 5.3.
LFG_{PPmax}	Maximum landfill gas flow capacity of the pre-project qualifying methane destruction device	ft^3	c	At beginning of first reporting cycle	Calculated based on manufacturer's and/or engineers specifications for the destruction device and blower system. The maximum capacity of the limiting component, either the destruction device or blower, shall be used.
LFG_{flare}	Amount of landfill gas flared	ft^3	m	Continuously	Measured continuously by a flow meter and recorded at least once every 15 minutes. Data to be aggregated by time interval t (see Equation 5.2) for each flare.
$LFG_{electricity}$	Amount of landfill gas destroyed in power plant	ft^3	m	Continuously	Measured continuously by a flow meter and recorded at least once every 15 minutes. Data to be aggregated by time interval t (see Equation 5.2) for each power plant.
$LFG_{thermal}$	Amount of landfill gas destroyed in boiler	ft^3	m	Continuously	Measured continuously by a flow meter and recorded at least once every 15 minutes. Data to be aggregated by time interval t (see Equation 5.2) for each boiler.
$LFG_{upgrade}$	Amount of upgraded landfill gas delivered to NG Transmission and Distribution System or CNG/LNG vehicles	ft^3	m	Continuously	Measured continuously by a flow meter and recorded at least once every 15 minutes. Data to be aggregated by time interval t (see Equation 5.2) for each system.

Parameter	Description	Data unit	calculated (c) measured (m) estimated (e)	Measurement frequency	Comment
PR_{CH4}	Methane fraction in the landfill gas	ft^3 CH_4 / ft^3 LFG	m	Continuously or weekly	Measured by continuous gas analyzer or a calibrated portable gas analyzer. Data to be averaged by time interval t (see Equation 5.2) for the reporting cycle. Methane fraction of the landfill gas to be measured on wet/dry basis[25]. Measured to determine the density of methane D_{CH4}.
PP_{CH4}	Pre-project installation methane fraction in the landfill gas of the original collection system	ft^3 CH_4 / ft^3 LFG	m	Continuously, weekly, or monthly	Measured by continuous gas analyzer or a calibrated portable gas analyzer. Data to be averaged for one year preceding the date that the project became operational. Methane fraction of the landfill gas to be measured on wet/dry basis. Measured for calculation of discount factor in Equation 3.
T	Temperature of the landfill gas	°C	m	Continuously	Measured to adjust the flow of LFG. 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	m	Continuously	Measured to adjust the flow of LFG. 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.
t	Time interval	day or week		N/A	If methane concentration is measured continuously, t=1 day, if it is measured weekly, t=1 week.
EL_{PR}	Total amount of electricity required to meet project requirement	MWh	m	Monthly	Obtained from either onsite metering or utility purchase records. Required to determine CO_2 emissions from use of electricity to operate the project activity.
EF_{EL}	Carbon emission factor of electricity	Kg CO_2/MWh	c	Annually	Utility specific emission factors for California Registry member utilities are available in the Public Reports section of the CARROT database. Utility specific not available use the EPA eGRID subregion emission factor from the California Registry's General Reporting Protocol (GRP), Appendix C, tables C.1 (also see GRP Figure III.6.1)
FF_x	Total annual quantity of supplemental natural gas delivered to destruction device	ft^3/yr	m	Continuously	Metered prior to delivery to destruction device. Required to determine CH_4 emissions from incomplete destruction of supplemental natural gas at each destruction device.

[25] Landfill gas flow, methane concentration, temperature, and pressure may be measured on either a wet or dry basis. However, all parameters must be measured and calculated in the *same* basis.

Parameter	Description	Data unit	calculated (c) measured (m) estimated (e)	Measurement frequency	Comment
FF_{PR}	Total amount of fossil fuel required to meet project requirement	scf or gallons	c	Monthly	Calculated from monthly record of fossil fuel purchased and consumed. Required to determine CO_2 emissions from use of fossil fuels to operate the project activity.
Regulations	Project developer attestation to compliance with regulatory requirements relating to landfill gas project	n/a	n/a	At the begining of each reporting cycle.	The information is used for the application of the regulatory additionality test. 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.
Operation of the energy plant	Operation of the energy plant	Hours	m	Hourly	This is monitored to ensure methane destruction is claimed for methane used in electricity plant only when it is operational.
Operation of the boiler	Operation of the boiler	Hours	m	Hourly	This is monitored to ensure methane destruction is claimed for methane used in boiler only when it is operational.
Operation of the flare	Operation of the flare	Hours	m	Hourly	This is monitored to ensure methane destruction is claimed for methane used in flare only when it is operational.
DE	Optional: Source test data for destruction device methane destruction efficiency	% destruction efficiency	m	Annually	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.

7 Reporting Parameters

This section provides guidance on reporting rules and procedures. A priority of the California Registry is to facilitate consistent and transparent information disclosure among project developers. Net methane and carbon dioxide emission reductions within the GHG assessment boundary should be reported. Project developers must submit verified emission reduction reports to the California Registry annually.

7.1 Project Submittal Documentation

Project developers shall provide the following information to the California Registry before registering reductions associated with installing a landfill gas collection and destruction system.

- Completed project submittal form (Appendix C)
- Signed Attestation of Title document
- Complete project verification report (annually)
- Positive verification opinion document (annually)
- Signed Attestation of Regulatory Compliance (annually)

At a minimum, the above project documentation will be available to the public via the California Registry's online reporting tool, The Climate Action Reserve (Reserve). Further disclosure and other documentation may be made available on a voluntary basis through the Reserve.

Project developers shall submit annual project reports through the Reserve. Project submittal forms and project registration information can be found at:
http://www.climateregistry.org/offsets/project-registration.html

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.

System information the project developer should retain includes:

- All data inputs for the calculation of the project emission 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

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 Cycle

For the purposes of this protocol, project developers report GHG reductions associated with installing a landfill gas collection and destruction system that occurred the preceding year. Although projects must be verified annually at a minimum, the California Registry will accept verified emission reduction reports on a sub-annual basis, should the project developer choose to have a sub-annual verification schedule (i.e. monthly, quarterly, etc.).

7.4 Project Crediting Period

Project developers are eligible to register GHG reductions with the California Registry according to this protocol for a period of ten years or until regulatory compliance is required due to failure of the regulatory additionality test. 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, emission reductions can be reported to the California Registry up until the date that the landfill gas control system is legally required to be operational.

The project crediting period begins when the landfill gas collection and destruction system becomes operational regardless of whether sufficient monitoring data is available to register credits.

7.5 Non-California Climate Action Registry Reporting

The California Registry requests that project developers only register reductions from GHG reduction projects with one registry. However, under a voluntary system, enforcement authority is limited. Therefore, if a project developer participates in this program it is their responsibility to transparently disclose the registration of all emission reductions associated with the project activity that occur outside of the California Registry. Upon submittal of project listing documentation to the California Registry, project developers are required to provide a signed attestation to the California Registry stating that the GHG reductions being registered are not being registered elsewhere. If the California Registry determines that duplicative emission reduction registration has occurred, all duplicate reductions reported with the California Registry will be made void.

In the event that GHG reductions from the project were previously registered with or claimed by another registry or program, or sold to a third party prior to submitting the project to the California Registry, a Project Transfer Form must be completed and submitted to the California Registry along with other project listing documentation.

Glossary of Terms

Accredited verifier	A verification firm approved by the California Registry 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	A MSW landfill or portion of a MSW landfill with a minimum average moisture content of at least 40 percent by weight that is re-circulating leachate or a MSW landfill or portion of a MSW landfill that is adding any liquid other than leachate (leachate includes landfill gas condensate) in a controlled fashion to accelerate or enhance the anaerobic biodegradation of the waste.
Carbon dioxide (CO_2)	The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.
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.
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 tonnes 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.
Metric tonne (MT) or "tonne"	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 (NSPS)	Federal emission control standards codified in 40 CFR 60. Subpart WWW of Part 60 prescribes emission limitations for MSW landfills.
Non-Methane Organic Compounds (NMOC)	Non-methane organic compounds as measured according to the provisions of 40 CFR 60.754.
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.
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.
Verification	The process used to ensure that a given participant's greenhouse gas

	emissions or emission reductions have met the minimum quality standard and complied with the California Registry's procedures and protocols for calculating and reporting GHG emissions and emission reductions.
Verification body	A California Registry and State of California accredited firm that is able to render a verification opinion and provide verification services for operators subject to reporting under this protocol.

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Appendix A Development of the Performance Standard Threshold

The primary data source for the performance standard threshold is the database of nearly 2,400 landfills in the United States developed and maintained by the EPA's Landfill Methane Outreach Program (LMOP).[26] If landfill gas collection and combustion projects at regulated landfills do not pass the California Registry's Regulatory Test, they are not eligible as greenhouse gas offset projects. Therefore, detailed data on regulated landfills need not be included in this analysis.

Landfill summary information is provided in Tables A.1 and A.2 with a focus on those landfills not currently subject to the New Source Performance Standards and Emission Guidelines for existing sources (NSPS/EG) promulgated in March 1996.

For the purposes of this analysis, we excluded all landfills that were closed prior to 2001, as their methane production has already dropped off significantly. Of the remaining 1,866 landfills in the U.S., the analysis revealed that an estimated 697 are subject to NSPS/EG, and 1,169 are not subject to NSPS/EG (not required to combust landfill gas under federal regulations). Of the non-NSPS/EG landfills, 261 (22.33%) currently have gas collection and destruction projects, of which 166 (14.20%) are flare only, 67 (5.73%) are electricity projects, and 28 (2.40%) are gas projects.

Focusing on the non-NSPS/EG landfill operations, the California Registry has developed an estimated range for market penetration of voluntary landfill gas collection and control projects at unregulated landfills. As the LMOP database does not contain information on state and local regulations, ordinances or permitting requirements that may affect landfill operations, it is necessary to make assumptions regarding additional regulatory influence on landfill operations. To estimate an upper bound for market penetration, it is assumed that all 261 non-NSPS/EG landfills with gas collection and control (see Table A.2) are *not* required to collect and control gas. Under this assumption, 261 out of 1,169 landfills have implemented voluntary landfill gas projects, equating to a market penetration of 22.3%. To construct a lower bound, it is assumed that all 166 non-NSPS/EG landfills with flares (see Table A.2) are required by state and local regulations, ordinances or permitting requirements to have the flares installed. This assumption is based on the observation that there is generally no incentive for a landfill to install a flare absent requirements imposed by regulations, ordinances or permitting requirements. Therefore it is likely that many non-NSPS/EG landfills with flares are required by state or local regulations, ordinances or permitting requirements to combust landfill gas. By assuming all 166 non-NSPS/EG landfills with flares are required to combust landfill gas, a lower bound for market penetration can be estimated. Under this assumption, 95 out of 1,003 unregulated landfills have implemented voluntary landfill gas projects, resulting in a market penetration of 9.5%.

[26] 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). 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 can not guarantee the validity of this information.

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

	Landfills	Percent of Landfills	Number w/ Gas Collection and Control	Percent w/ Gas Collection and Control
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			

Table A.2. Summary of Non-NSPS/EG Landfills under assumption that Flare Only landfills are already regulated.

Non-NSPS/EG Landfills	Number of Landfills	Percent of Unregulated Landfills – Flares Included	Percent of Unregulated Landfills – Flares Excluded
Flare Only	166	14.2%	Excluded
Electricity	67	5.7%	6.7%
Gas Projects	28	2.4%	2.8%
Subtotal	261	22.3%	9.5%
No Gas Collection and Control	908	77.7%	90.5%
Total	1169	100.0%	100.0%
Estimated Market Penetration of Gas Collection and Control Projects into unregulated landfills		**22.3%**	**9.5%**

Appendix B Development of the NMOC Emissions Threshold

B.1 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 California Registry has developed an NMOC emissions threshold whereby the eligibility of a project can be determined. If 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 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.[27]

B.2 Data

The primary data source for the threshold analysis is a series of capital cost and monthly operating cost estimates supplied to the California Registry by major carbon adsorption service providers, flare installation and maintenance providers, and other quotes from the industry sector.[28] This data was obtained for flare and carbon adsorption systems of varying capacity and reflects a range of operating parameters.

B.3 Summary

The analysis below reveals that an estimated NMOC[29] mass flow threshold of 620 lbs NMOC/month is appropriate for the performance standard. This analysis was performed based on actual vendor cost quotes for flare and carbon adsorption systems with capacities of 40 to 500 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 (over $350,000), the costs for installing a carbon adsorption system are significantly lower ($106,000 to $165,000). Both systems require comparable operation and maintenance costs in the range of $6,000 to $8,000 per month, but the carbon adsorption system has an additional cost associated with the replacement and disposal of activated carbon. As NMOC levels increase, additional carbon is required, and therefore costs increase as well. The overall cost of a carbon adsorption system is therefore highly dependent on the flow of NMOC, as the carbon must be replaced once saturated. Thus, determining the NMOC threshold is a matter of identifying the NMOC level that requires carbon costs equal to or greater than the additional cost of the flare. The analysis shows that the installation of a flare system for NMOC control is more cost effective than carbon adsorption if the measured landfill gas flow rate (CFM) and NMOC concentration (ppmv) result in a total mass flow of 620 lbs of NMOC/month or greater. Above this level, costs of carbon adsorption

[27] In the rare case where the project developer can demonstrate that a project should be considered eligible even though the total mass flow of NMOC is greater than the threshold, the project developer can submit a written request for variance to the California Registry, including sufficient documentation to substantiate the case. In such cases, the California Registry would consult with interested stakeholders in the decision process.
[28] Due to proprietary confidentiality, the service providers will remain anonymous.
[29] NMOC concentration (ppmv) normalized to hexane.

systems, particularly the monthly carbon replacement costs, become cost prohibitive relative to flare systems even in light of the high capital costs of flares.

B.4 Methodology

In order to carry out this analysis, the California Registry required reliable information for the capital, installation, operation and maintenance costs of both carbon adsorption and enclosed flare systems. These data were obtained by soliciting quotes from the technical sales departments of well known carbon and flare vendors who supplied accurate cost estimates. Multiple quotes were obtained for each system type to accurately reflect the costs of systems scaled to varying landfill gas capacities. These quotes allowed us to calculate a net present value (NPV) cost of the installation, operation, maintenance, and regulatory costs of the flare and carbon systems over a ten-year operational life, using a 10% discount rate. A summary of these costs is provided in Table B.1.

These data and relationships allowed us to calculate the NMOC mass flow at which an enclosed landfill flare becomes more cost effective than a carbon adsorption system at a range of landfill gas control system capacities. Both control systems have standard monthly costs, and in all scenarios the flare costs exceeded the carbon system costs, prior to inclusion of carbon replacement costs. The difference between the total NPV cost of the flare and the total NPV cost of the carbon adsorption system represents the excess cost of the flare system prior to inclusion of carbon replacement costs. This value corresponds to the amount that a landfill operator would be able to spend on carbon over the course of the project and have that system remain cost-competitive to the flare system.

$$\text{Additional NPV Cost of Flare} = \text{Total NPV Cost of Flare} - \text{Total NPV Cost of Carbon}$$

The difference between the costs of the two systems was next turned into an annuitized monthly cost for each period of the analysis. The excess annuitized monthly cost of the flare represents the amount of money a landfill operator could invest in carbon each month and remain more cost effective than the correspondingly scaled flare system. The last step in the analysis was simply to identify and parameterize the relationship between NMOC mass flow and carbon usage.

To isolate this relationship, the California Registry obtained quotes from two separate carbon vendors. Vendor 1 provided a quote for the pounds of carbon required to treat various levels of NMOC, whereas Vendor 2 provided a direct cost for the required amount of carbon. Both of these analyses follow very similar methodologies, and provide very similar results.

Industry experts indicated that vendor quotes are generally higher than what is ultimately required for effective NMOC management by approximately 20-30%. Therefore, to accurately reflect the decision facing a landfill operator, we discounted the carbon quantities and costs by 30% for this analysis. As indicated in Figure B.1, a regression of these data points shows that the data is a good fit for this analysis.

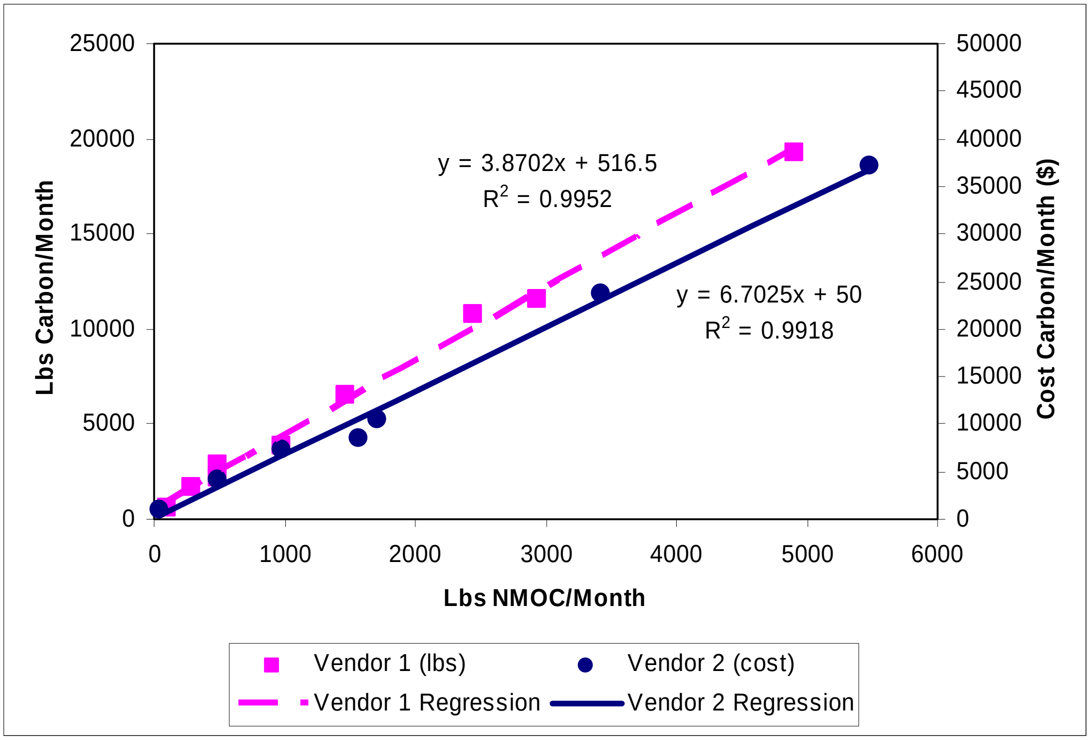

Figure B.1. Regression of vendor-provided NMOC and carbon data.

Vendor 1 Analysis

For Vendor 1, the California Registry had to determine how many pounds of carbon could be purchased for the additional flare cost. The California Registry reviewed the cost of carbon purchase, transportation, and disposal from various sources throughout the country, and considered data submitted by work group members. The California Registry used a net cost of $1.50 per pound of activated carbon, which agreed well with the data obtained from Vendor 2. Using this price, we were then able to calculate the pounds of carbon a landfill control system could use and remain cost effective compared to the flare.

$$\text{Pounds of Carbon} = \frac{\text{Additional Monthly Cost of Flare}}{\$1.50 \text{ per pound}}$$

Next, using the data in Figure B.1, we obtained the following relationships between NMOC mass flow and carbon required for treatment:

$$\text{Carbon/month} = 516.5 + 3.870 \times \text{NMOC/month}$$

or

$$\text{NMOC/month} = \frac{(\text{Carbon/month} - 516.5)}{3.870}$$

Using this relationship, we determined the NMOC mass flow for which all carbon purchased with the additional cost associated with the flare would be saturated. This value represents the "break-even" cost of the two technologies. The results of this analysis are presented in Table B.1 and reveal an NMOC mass flow of 605 pounds per month.

Vendor 2 Analysis

The Vendor 2 data related NMOC mass flow directly to carbon costs. Therefore, the intermediary step of converting the cost of carbon to pounds of carbon was unnecessary. Rather, the California Registry calculated the "break-even" NMOC level through the following relationships which derived from the data in Figure B.1:

$$\text{Cost of Carbon/month} = 50 + 6.703 \times \text{NMOC/month}$$

or

$$\text{NMOC/month} = \frac{(\text{Cost of Carbon/month} - 50)}{6.703}$$

The results of this analysis are presented in Table B.1 and reveal an NMOC mass flow of 639 pounds per month.

Table B.1. Results of NMOC threshold analysis.

Landfill Gas Control System Capacity (SCFM)	Fixed Costs			Cost Differentials			NMOC Required to Saturate Additional Carbon (pounds/month)	
	Cost Categories	Flare System ($)	Carbon System ($)	NPV Add'l Cost of Flare System ($)	Annuitized Add'l Cost per Month ($)	Carbon purch. with add'l flare cost (lbs)	VENDOR 1	VENDOR 2
40	Capital Cost	$351,500	$105,750					
	Monthly O&M	$7,085	$6,208					
	NPV	**$897,443**	**$584,140**	$313,303	$4,066	2,711	572	610
200	Capital Cost	$351,500	$108,800					
	Monthly O&M	$8,010	$6,671					
	NPV	**$968,720**	**$622,829**	$345,891	$4,489	2,993	644	673
300	Capital Cost	$351,500	$136,575					
	Monthly O&M	$8,510	$7,133					
	NPV	**$1,007,248**	**$686,242**	$321,006	$4,166	2,777	589	625
500	Capital Cost	$351,500	$161,750					
	Monthly O&M	$8,992	$7,133					
	NPV	**$1,044,363**	**$711,417**	$332,946	$4,321	2,881	615	648
							605	**639**
							622 pounds NMOC/month	

Therefore, based on the combination of these two analyses, the California Registry has selected a Performance Threshold of 620 pounds NMOC per month for all landfill gas control system capacities.

Appendix C Project Submittal Forms

Please see pages 44 to 50 for the Landfill Project Submittal Forms.

Landfill Project Submittal Forms

Instructions:

This form must be submitted to the Reserve and to the verifier in the first year of reporting prior to verification. In some cases, it may be necessary to update parts of the Project Submittal Form in subsequent years. **All information in this form will be made publicly available.**

These forms are to be used for reporting general Landfill Project information to the California Climate Action Registry in order to initiate the project listing process. All fields must be completed as thoroughly as is possible. If the project in question is still in the planning/development phase, all fields must be completed using best available data and estimations based on the proposed system design. Upon receipt of completed submittal forms, Registry staff will perform a general eligibility screen (in accordance with the most current version of the California Climate Action Registry Landfill Project Reporting Protocol) based on the information provided. Project Developers can expect an Invoice for the $500 project listing fee within 15 days of receipt of the completed forms, and a letter regarding the status of project within 15 days of the receipt of the project listing fee. If a project passes the eligibility screen, it will be officially "listed" with the Climate Action Reserve

This is an interactive PDF form that can be filled out and saved as a PDF. All fields must be completed, if a field is not applicable insert N/A in the space provided. The completed form must be saved and uploaded to your Climate Action Reserve account. Submit all questions regarding the project submittal process to: reserve@climateregistry.org.

Version 2.2
November 2008

Project Name: ____

Project Developer:____

Facility Owner: ____

Technical Consultants:____

Other Parties with a Material Interest:_____________________________________

Date of form completion:____

Form completed by (name): ____

California Climate Action Registry, 523 West 6th Street, Suite 428, Los Angeles, CA 90014

Section 1: General Site Information

1. Name of Landfill:____

2. Approximate Latitude/Longitude of Landfill Project (degrees/minutes/seconds):

____

3. Address (including county):

____

4. Owner of Landfill and owner contact information:

____

5. Type of landfill (sanitary, controlled, or open dump):__________________________

6. Landfill size – designed area for waste placement (acre or hectare):

____

7. Total waste in place (cubic meters or tons):______________________________

8. Designed landfill capacity (cubic meters or tonnes):__________________________

9. Year landfill opened: ____

10. Year landfill closed or estimated date of closure:___________________________

11. Average annual quantity of waste accepted at landfill (cubic meters or tonnes):

____

12. Waste Characteristics Table

Waste Types	Estimated Percent of Waste Stream
Paper and Paperboard	
Glass	
Metals	
Plastics	
Rubber and Leather	
Textiles	
Wood	
Food Scraps	
Yard Trimmings	
Misc. Inorganic Wastes	
Other	

Explain basis of estimates (i.e. site specific information, regional or national studies, EPA, etc.):

____

Section 2: Project Eligibility and Monitoring

13. Initial verification period: ____

14. When did the project first commence operation, or when is the project expected to commence operation?

____

15. Have any vintage reduction tonnes from the project ever been registered with or claimed by another registry or program, or sold to another third party prior to registering with the Reserve?

____

If the answer is yes, you must complete and return a "*Project Transfer*" form.

16. Description of any regulatory framework for landfill methane capture and control (include an estimate of the date which the landfill will meet or exceed the 50 megagrams per year threshold of calculated NMOC emissions per NSPS/EG regulations and the type of testing that justifies the estimate (i.e. Tier 1 or Tier 2 NMOC emission rate estimates)):

---

17. Description and citation of all local and state air and water quality, explosive gas, or other regulations pertinent to the landfill or project:

---

18. Is this project being implemented and maintained as the result of any law, statute, regulation, court order, or other preexisting legally binding mandate?

Yes No

Comments (if any):

---

19. Has a detailed monitoring plan been developed for this project? If not, what date will a monitoring plan be in place?

Section 3: Pre-project landfill gas control system information *(fill out only if there was a landfill gas collection and/or control system in place that is separate from the Project system)*

20. Type of pre-project landfill gas collection and control system in place, if any (e.g., open flare, enclosed flare, energy recovery etc.):

____

i. If Landfill gas collection system is in place, is the system actively collecting or passively venting gas?

____

ii. If flare or energy project is in place, what is the landfill gas flow rate (in scfm) and methane content?

____

iii. Name of system designer, address and other contact information.

____

iv. Supply a copy of the as built drawings for the pre-project system. Be sure to include in the diagram the location of all pre-project wells and/or other collection equipment and the location of all project-related wells and/or other collection equipment. (Attach as a separate PDF file titled: Pre-project LFG System Diagram)

21. When was this pre-project control system installed and operational?

____

22. Provide a summary of the permits obtained to build and operate this Landfill Gas Control System).

____

California Climate Action Registry, 523 West 6th Street, Suite 428, Los Angeles, CA 90014

Section 4: Landfill gas utilization information for project activity

23. Landfill gas utilization (e.g., open-flared, enclosed flare, generation of electricity, use on-site as a boiler or furnace fuel, or sale to a third party):

____

24. When was this combustion/LFG utilization system installed and operational, or when is it expected to be installed and operational?

____

25. If designed to generate electricity:

   i. Type of engine-generator set (e.g., internal combustion engine, micro turbine or fuel cell with the name of the manufacturer, model, power output rating (kW or MJ) for biogas, and nominal voltage :

   ____

   ii. Pretreatment of landfill gas (e.g., none, condensate trap, dryer, hydrogen sulfide removal, etc. with the names of manufacturers, models, etc.):

   ____

   iii. Exhaust gas emission control (e.g., none, catalytic converter, etc.):

   ____

   iv. If interconnected with an electric utility:

      a. Name of the utility: _______________________________

      b. Type of utility contract (e.g., sell all/buy all, surplus sale, or net metering):

   ____

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v. If engine-generator set waste heat utilization:

c. Heat source (e.g., cooling system or exhaust gas or both) and heat recovery capacity (Btu or kJ/hr):

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d. Waste heat utilization (e.g., water heating, space heating, etc.):

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26. If designed to use on-site as a boiler or furnace fuel, a description of the boiler or furnace including manufacturer, model, and rated capacity (Btu or kJ/hr):

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27. If designed for biogas sale to a third party, a description of the methods of processing, transport, and end use:

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i. Pretreatment of Biogas (e.g., none, condensate trap, dryer, hydrogen sulfide removal, etc.) include names of manufacturer, model etc.:

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ii. Exhaust gas emission controls from gas processing step:

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28. Provide a summary and citation of the permits obtained to build and operate this Landfill Gas Utilization System).
