CLIMATE LEADERS GREENHOUSE GAS INVENTORY PROTOCOL OFFSET PROJECT METHODOLOGY

for

Project Type: Landfill Methane Collection and Combustion

Climate Protection Partnerships Division/Climate Change Division

Office of Atmospheric Programs

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Table of Contents

Climate Leaders *is an EPA industry-government partnership that works with companies to develop comprehensive climate change strategies. Partner companies commit to reducing their impact on the global environment by setting aggressive greenhouse gas reduction goals and annually reporting their progress to EPA.*

Introduction

An important objective of the Climate Leaders program is to focus corporate attention on achieving cost-effective greenhouse gas (GHG) reductions within the boundary of the organization (i.e., internal projects and reductions). Partners may also use reductions and/or removals which occur outside their organizational boundary (i.e., external reductions or "offsets") to help them achieve their goals. To ensure that the GHG emission reductions from offsets are credible, Partners must ensure that the reductions meet four key accounting principles:

- ***Real:*** The quantified GHG reductions must represent actual emission reductions that have already occurred.
- ***Additional:*** The GHG reductions must be surplus to regulation and beyond what would have happened in the absence of the project or in a business-as-usual scenario based on a performance standard methodology.
- ***Permanent:*** The GHG reductions must be permanent or have guarantees to ensure that any losses are replaced in the future.
- ***Verifiable:*** The GHG reductions must result from projects whose performance can be readily and accurately quantified, monitored and verified.

This paper provides a performance standard (accounting methodology) for greenhouse gas (GHG) offset projects that introduce methane (CH_4) collection and combustion at a landfill. The accounting methodology presented in this paper addresses the eligibility of landfill methane collection and combustion projects as greenhouse gas offset projects and provides measurement and monitoring guidance. Program design issues (e.g., project lifetime, project start date) are not within the scope of this guidance and are addressed in the Climate Leaders offset program overview document: Using Offsets to Help Climate Leaders Achieve Their GHG Reduction Goals.[1]

A common method for reducing emissions from landfills is the collection and combustion of landfill gas. At some landfills, gas is combusted by flaring; at others, gas is combusted for energy or heat production. For the purposes of the performance standard described in this paper, any energy or heat producing technology should be considered solely as a combustion device. The methodology does not apply to quantification of emission reductions from the use of landfill gas to generate electricity or heat energy, resulting in the displacement of GHG emissions from fossil fuel

[1] Please visit http://www.epa.gov/climateleaders/resources/optional-module.html to download the overview document.

combustion. A separate paper will present the methodology to be used for quantifying the GHG emissions avoided by a fuel substitution end use project.

Description of Project Type

Most municipal solid waste (MSW) in the United States is deposited in landfills, where bacteria decompose the organic material. A product of the bacterial decomposition is landfill gas, which is composed of CH_4 and carbon dioxide (CO_2) in approximately equal concentrations, as well as smaller amounts of non-methane volatile organic compounds (NMVOC), nitrogen oxides (NO_X), and carbon monoxide (CO). If not collected and combusted, over time, this landfill gas is released to the atmosphere. In the United States, landfills are one of the largest sources of anthropogenic emissions of CH_4, accounting for 23 percent of total CH_4 emissions.[2]

This section provides information on the general parameters that the proposed landfill gas methane collection and combustion project must match to use this performance standard.

Technology/Practice Introduced. This guidance document addresses the installation of a gas collection system at a landfill to collect and convey CH_4 to a flare or gas utilization project. These collection systems typically consist of wells, pipes, blowers, caps and other technologies that enable or enhance gas collection. At some landfills, a flare will be the only site where landfill gas is destroyed. At landfills that install energy or process heat technologies that combust landfill gas, such as turbines, reciprocating engines, boilers, heaters, or kilns, these devices will be the main sites where landfill gas is combusted. For safety and regulatory purposes, most projects that produce energy or process heat also include a flare in their design to combust gas during periods when the gas utilization project is down for repair or maintenance.

Project Size/Output. This accounting methodology applies to landfills regardless of size or waste acceptance rate.

Project Boundary. This section provides guidance on which physical components, and associated greenhouse gases, must be included in the project boundary for a landfill methane collection and combustion project. This methodology relies on the assumption that all CH_4 that is collected enters the combustion device.

Physical Boundary. The physical boundary of the GHG offset project includes the following components of the landfill operation (see Figure 1):

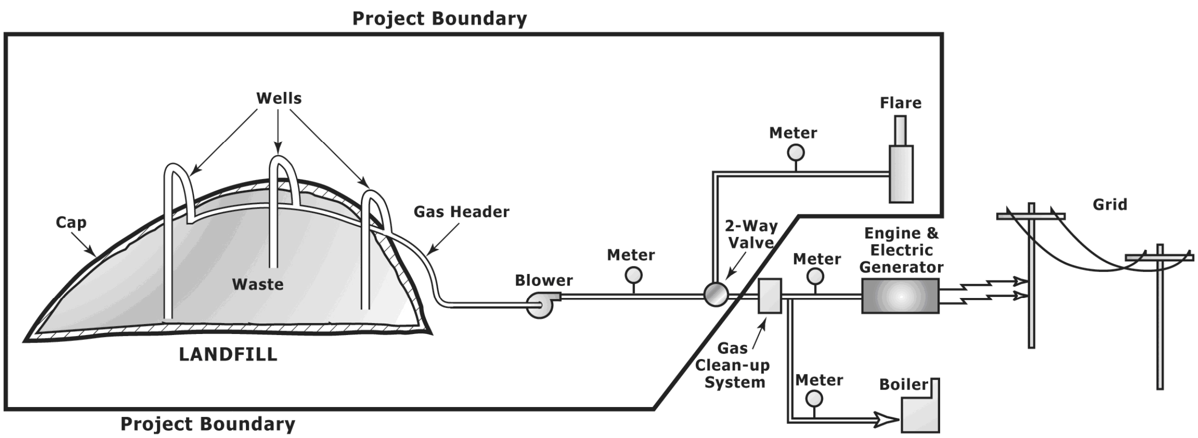
- landfill;

[2] EPA (2008) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. U.S. Environmental Protection Agency, Office of Atmospheric Programs, Washington, DC. USEPA #430-R-08-002.

- gas collection wells and piping;
- blowers; and,
- flares.

All project-related construction activities (e.g., equipment used for installing gas collection wells and piping) must also be included in the physical boundary. For a GHG offset project at a landfill that is currently collecting and combusting landfill gas (e.g., to address lateral migration of landfill gases), the components of the physical boundary must be considered separately from any existing equipment used for collection and combustion.

Figure 1. Physical Boundary for Landfill Methane Collection and Combustion Projects



GHG Accounting Boundary. The GHG accounting boundary for the collection and combustion of landfill gas includes emissions of CH_4 generated at the landfill (including that portion that is microbially oxidized to CO_2).[3] Avoided emissions from fuel displacement with landfill gas at an end use (energy) technology are not included in the project boundary. Any emissions of CO_2, CH_4, and N_2O that result from the combustion of fuel used for the blower and any fuel combusted from the operation of equipment during construction of the gas collection system must also be included. Any GHG emissions from fuel used to assist and maintain flare operation are to be included as well.

CO_2 emitted directly from the landfill or from onsite combustion of the landfill gas is not included in the GHG accounting boundary because the CO_2 produced

[3] A small portion of the CH_4 generated in landfills (around 10%) is naturally oxidized to CO_2 by methanotrophic bacteria in the cover soils of managed landfills.

at landfills is primarily from biogenic sources and, therefore, these CO_2 emissions do not increase concentrations of CO_2 in the atmosphere.[4]
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 CH_4 emissions would have occurred absent the project.

Temporal Boundary. An annual accounting cycle should be used for landfill gas projects, however, the temporal boundary should also include all emissions associated with construction of the landfill gas collection system.

Leakage. Leakage is an increase in greenhouse gas 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 offsetting 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 – the displacement of activities and their associated GHG emissions outside of the project boundary.

Landfill methane collection and combustion projects are not expected to result in leakage of greenhouse gases outside the project boundary. If it is determined, however, that significant emissions that are reasonably attributable to the project occur outside the project boundary, these emissions must be quantified and included in the calculation of reductions, however, no specific quantification methodology is required. All associated activities determined to contribute to leakage should be monitored.

Regulatory Eligibility

The performance standard subjects greenhouse gas offset projects to a regulatory "screen" to ensure that the emission reductions achieved would not have occurred in the absence of the project due to federal, state or local regulations. In order to be eligible as a GHG offset project, GHG emissions must be reduced below the level effectively required by any existing federal, state, or local policies, guidance, or regulations. This may also apply to consent decrees, other legal agreements, or federal and state programs that compensate voluntary action.

Federal Regulations. There are several EPA regulations for municipal solid waste landfills that have a bearing on the eligibility of methane collection and combustion projects as GHG offset projects. These regulations include:

[4] While some of the wastes disposed in landfills contain carbon that is not considered biogenic in origin (e.g. tires, glass), these wastes do not easily degrade or dissimilate and therefore contribute only a very small portion of the carbon in landfill gas.

- New Source Performance Standards (NSPS) for Municipal Solid Waste Landfills, codified in 40 CFR 60 subpart WWW – Targets landfills that commenced construction or made modifications after May 1991.
- Emission Guidelines (EG) for Municipal Solid Waste 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 combustion is a common NMOC management technique employed at regulated landfills.

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

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, EG and the NESHAP. Landfills above the size cutoff must calculate their annual NMOC emissions using equations in the rules. If the calculated uncontrolled NMOC emissions reach 50 megagrams per year, the landfill must install a gas treatment system to reduce emissions of NMOC.

Control of emissions from the collection and combustion of LFG at landfills that are required to install gas collection and control systems under the CAA, including the *Standards of Performance for New Stationary Sources* (NSPS) (40 CFR 60 subpart WWW) and *Guidelines for Control of Existing Sources* (40 CFR 60 subpart Cc, as implemented by state and federal plans contained in 40 CRF part 62)*,* and the 2003 *National Emission Standards for Hazardous Air Pollutants* (NESHAP) (40 CFR 63 subpart AAAA) are not eligible as greenhouse gas offset projects. RCRA subtitle D rules do not generally require landfill gas control systems; but if a landfill has been specifically required by EPA or a state agency implementing RCRA rules to collect and combust landfill gas (e.g., to address site-specific gas migration issues or explosion hazards), then emissions reductions from the required collection and control system are not eligible as an offset project.

Landfills subject to NSPS/EG with a design capacity of at least 2.5 million Mg and 2.5 million cubic meters that have not reached the 50 Mg NMOC/yr emission rate threshold for installing collection and control systems, will be required to annually test or calculate NMOC emissions, using NSPS/EG procedures, to determine when the NMOC emission rate meets or exceeds 50 Mg.[5] Based upon these annual NMOC calculations, once a MSW landfill meets or exceeds the NMOC limit, the project no longer passes the regulatory screen and is no longer eligible as an offset project.

State and Local Regulations. 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. It is also possible that some landfills that exceed applicable emission thresholds will require site-specific permits requiring controls under the New Source Review (NSR) 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 combustion system, or the destruction of volatile organic compounds (VOC), NMOC, or CH_4 earlier, or at smaller facilities, than the federal regulations would require.

Local governments may also regulate municipal solid waste landfills, for example, by putting in place nuisance laws or requiring solid waste facilities, smaller than the facilities regulated by the CAA or RCRA Subtitle D, to obtain permits and control landfill gas. Other regulations may require minimal gas collection to prevent lateral migration of the landfill gas to neighboring properties.

Collection and combustion activities at landfills regulated under NSPS, EG, the NESHAP, CAA or RCRA Subtitle D are not eligible as greenhouse gas offset projects.[6] Collection and combustion projects at landfills that have minimal gas collection systems in place (i.e., to address local nuisance laws or to prevent lateral migration of the landfill gas to neighboring properties but that are not required to control NMOCs) are eligible as GHG offset projects for those reductions resulting from collection and combustion of landfill gas beyond that from the system currently in place.

Determining Additionality - Applying the Performance Threshold

This section describes the performance threshold (additionality determination) that a landfill methane collection and combustion project meeting the above regulatory

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[5] The procedure for calculating NMOC emissions under NSPS/EG provides three tiers of calculation or testing. Landfills exceeding the NMOC limit using the Tier 1 calculations can test to obtain site specific values using Tier 2 or 3. Tier 1 requires calculating emissions with default k, L_o, and C_{NMOC} values. Tier 2 uses the same equations with site specific measured C_{NMOC} values, determined by performing EPA Method 25C or Method 18. Tier 3 allows substitution of site-specific values for k and C_{NMOC}. The site-specific methane generation rate (k) is determined by using gas flow testing (Method 2E). For detailed information see: http://frwebgate.access.gpo.gov/cgi-bin/get-cfr.cgi?TITLE=40&PART=60&SECTION=754&TYPE=PDF.

[6] If an indication exists that a non-NSPS landfill will be subject to NSPS regulations in the near-future, a greenhouse gas offset project may not provide enough potential to proceed.

eligibility requirements must also meet or exceed in order to be eligible as a GHG offset project.

Additionality Determination. The additionality determination represents a level of performance that, with respect to emission reductions or removals, or technologies or practices, is significantly better than average compared with similar recently undertaken practices or activities in a relevant geographic area. Any project that meets or exceeds the performance threshold is considered "additional" or beyond that which would be expected under a "business-as-usual" scenario.

The type of performance threshold used for eligible landfill methane collection and combustion projects is practice-based. The practice-based performance threshold represents a level of "performance" that is beyond that expected of a typical un-regulated landfill (e.g., a landfill that is not required to control NMOCs) and is based on the range of current practices in the management of landfill gas at un-regulated landfills[7]. A minority of the unregulated landfills have landfill gas collection and combustion systems. Therefore, installing collection and combustion systems at un-regulated landfills is considered "beyond business-as-usual" and, therefore, additional.

The first determinant of additionality, therefore, is whether there is already collection and combustion of landfill gas at the proposed project site. There are two possible scenarios under which the practice-based performance threshold is applied:

1. If the landfill is not currently collecting and combusting any landfill gas, the project is considered additional.

2. If the landfill is currently collecting and combusting a minimal amount of landfill gas, two conditions must be met for the project to be considered additional. First, only the landfill gas combusted beyond that resulting from the existing collection and combustion system is considered additional (i.e., those reductions resulting from the implementation of the GHG offset project). Second, the GHG project must either be designed to be entirely separate from the existing collection system or must be monitored separately from the existing system. These conditions will ensure that the reductions resulting from the GHG project can be accounted for separately from current collection and combustion.

Quantifying Emission Reductions

Quantifying emission reductions from landfill methane collection and combustion projects encompasses four steps: two are pre-project implementation (selecting the emissions baseline and estimating project emission reductions) and two are post-project implementation (monitoring and calculating actual project reductions).

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7 The data set used in the development of the performance threshold is included in Appendix I.

Estimating Project Emission Reductions. The greenhouse gas emissions reductions from a landfill methane collection and combustion project can be estimated using the procedures presented in Appendix II.

The initial step in estimating project emission reductions is to estimate the quantity of CH_4 produced by the waste in the landfill for each year in the life of the project. EPA has developed a mathematical model for estimating the landfill gas generation rate from landfills, the Landfill Gas Emissions Model (LandGEM).[8] With a limited amount of data from the landfill, LandGEM estimates the quantity of CH_4 produced by the landfill during each year in the life of the landfill and for approximately 100 years following the closing of the landfill.

Selecting and Setting an Emissions Baseline. The emission baseline for a GHG project at a landfill that is not already collecting and combusting landfill gas is zero. This assumes that all of the CH_4 generated at the landfill will be emitted to the atmosphere, except for the 10% that is oxidized through the soil. In the case of a landfill where there is currently minimal collection and combustion, the assumption is also made that any CH_4 beyond that being collected by the existing system would be emitted to the atmosphere (minus the 10% oxidized).

Monitoring

Monitoring of landfill gas collection and combustion projects is by direct measurements. Measurements should be taken of the volume of gas that flows to the flares and any end use devices, and the CH_4 concentration of that gas. For greenhouse gas offset projects at un-regulated landfills that were already collecting and combusting landfill gas before the installation of the project activity, monitoring of the project must be done separately from the existing collection system.

All landfill collection and combustion greenhouse gas offset projects must also monitor any regulatory requirements (or changes in regulatory requirements) that might affect the continued eligibility of the project as a greenhouse gas offset project.

Direct Measurement Method(s) for Determining Methane Destruction at Landfills. Direct-measurement methods depend on two measurable parameters: 1) the rate of landfill gas flow to the combustion device; and 2) the CH_4 content in the gas flow. These can be quantified by directly measuring the landfill gas stream to the destruction device(s).

Continuous Metering. The instrumentation recommended for continuous measurement measures both flow and gas concentration. Several direct

[8] LandGEM can be downloaded from http://www.epa.gov/ttn/catc/products.html#software.

measurement instruments also use a separate recorder to store and document the data.

A fully-integrated system that directly reports CH_4 content requires no other calculation than summing the results of all monitoring periods for a given year. Internally, the instrumentation is performing its calculations using algorithms similar to Equation A below.

Monthly Sampling. The two primary instruments used in the monthly monitoring method are a gas flow meter and a gas composition meter. The gas flow meter must be installed as close to the landfill gas combustion device as possible to measure the amount of gas reaching the device. Two procedures are used for data collection in the monthly monitoring method:

1. Calibrate monitoring instrument in accordance with the manufacturer's specifications.
2. Collect four sets of data: (flow rate (scfm); CH_4 concentration (%); temperature (^oR); and pressure (atm) from the inlet landfill gas (before any treatment equipment using a monitoring meter specifically for CH_4 gas.)

The amount of CH_4 destroyed during the month is calculated using *Equation A.* Monthly data for V, C, T, P and t are summed in order to calculate an annual total.

Equation A.

$$CH_4\ Combusted_{project} = V \times (C/100) \times 0.0422 \times (520/T) \times (P/1) \times (t) \times 0.99 \times (0.454/1000)$$

Where:

V	= Total volumetric flow in cfm
C	= CH_4 concentration of flow (in %)
0.0423	= lb. CH_4/scf (at 520R or 60F)
T	= Temperature at which flow is measured (^oR)
P	= Pressure at which flow is measured (atm)
t	= Time period since last monthly measurement (min)
0.99	= Destruction efficiency
0.454/1000	= Conversion factor, lbs. to metric tons

Calculating Actual Project Emission Reductions. Quantifying project GHG emission reductions occurs after the project has been implemented and monitored. Actual monitored values for CH_4 combusted at the project (see Equation A) must be used to quantify project emission reductions. Project-related energy emissions and any emissions resulting from leakage must also be quantified.

The following data are required in order to calculate project emission reductions:

- CH_4 combusted by the project;
- CH_4 combusted in the baseline;
- CH_4 oxidized by methanotrophic bacteria; and,
- CO_2, CH_4, and N_2O emitted during any project-related electricity use and fuel combustion.

Project-related Energy Emissions. Emissions from project-related fuel consumption and electricity use must be quantified in order to determine total project emission reductions (Equation B).

Equation B.

Project Energy Emissions = Fuel type * fuel-specific emission factor[9] / 1000 (kg/ton)

Where:

Fuel Type	= Quantity of each specific fuel, or electricity, used for construction-related activities and operation of collection and combustion equipment, and transportation (MMBtu or MWh)
Fuel-specific emission factor	= factor for CO_2, CH_4, and N_2O emitted from any fuel consumption or electricity-use (kg CO_2e/ MMBtu or MWh)

Leakage. Increases in greenhouse gas emissions caused by the project but not accounted for within the project boundary must also be quantified in order to determine total project emission reductions.

Equation C.

Emissions from Leakage = Fuel type * fuel specific emissions factor / 1000 (kg/ton)

Where:

Fuel Type	= Quantity of each specific fuel, or electricity, used for activities outside of the project boundary (MMbtu, MWh)

[9] If available, project-specific emissions factors should be used; if not, emission factors should be drawn from the latest edition of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks,* U.S. Environmental Protection Agency, available at http://www.epa.gov/climatechange/emissions/index.html, or Appendix III of this protocol.

Fuel-specific emission factor = factor for CO_2, CH_4, and N_2O emitted from any fuel consumption or electricity-use ($kgCO_2e$/MMBtu or MWh)

Using the outputs of Equations A, B, and C, calculate emission reductions using Equation D below.

Equation D.

Total Project Emission Reductions (TCO_2e) = (CH_4 combusted$_{project}$ * 0.90 * 21) – Project energy emissions (TCO_2e) – Emissions from Leakage (TCO_2e)

Appendix I. Development of the Performance Threshold - Dataset

The primary data source for the performance threshold is the database of almost 2,000 landfills in the United States developed and maintained by EPA's Landfill Methane Outreach Program (LMOP). This database was supplemented and crosschecked with data from the Energy Information Administration (EIA) and from selected flare vendors. In that gas collection and combustion at regulated landfills are not eligible as greenhouse gas offset projects (see previous discussion), detailed data on these landfills are not included here.

Of the 1,819 landfills in the U.S., 664 are NSPS/EG and approximately 1,155 landfills are non-NSPS/EG (not required to combust landfill gas). As shown in Table I.a, approximately 21% of the non-regulated landfills have gas recovery systems resulting in some type of combustion. Of the non-regulated landfills with combustion, 67% have flaring projects, 23% have electricity projects, and 10% have direct-use gas projects (see Table I.b).

Table I.a. Summary Information on U.S. Landfills (NSPS/EG and Non-NSPS/EG).

	# Landfills	% Landfills	# With Gas Collection and Control	% With Gas Collection and Control
NSPS/EG	664	37	664	100
Non-NSPS/EG	1,155	63	240	21
Total	1,819	100	906	50

Table I.b. Summary of Information on Non-NSPS/EG Landfills.

Non-NSPS/EG landfills	Number of landfills	Percent of landfills
Flares	161	13.9
Electricity projects	55	4.8
Gas projects*	24	2.1
Subtotal	**240**	**21**
No gas recovery and combustion	915	79
Total	1,155	100

*Gas projects are those non-electricity projects labeled in LMOP as direct thermal, boiler, leachate evaporation, etc.

Spatial Area. The spatial area for this performance threshold includes all landfills in the United States. Table I.c shows the distribution of landfill projects by region.

Table I.c. Distribution of Landfills by Geographic Location.

Geographic region	Number of Landfills		Non-NSPS/EG Landfills with Gas Collection and Combustion			Percent with projects (%)
	Total	Non-NSPS/EG	With flares	With LFGTE	Total	
Northeast	145	81	13	8	21	26
Mid-Atlantic	210	118	30	10	40	34
South	339	229	38	9	47	21
Mid-West	414	225	31	31	62	28
South Central	184	111	12	7	19	17
West Central	122	99	3	1	4	4
West	405	292	34	13	47	16

Northeast: CT, MA, ME, NH, NY, RI, VT
Mid-Atlantic: DE, MD, NJ, PA, VA, WV
South: AL, FL, GA, KY, MS, NC, SC, TN
Mid-West: IA, IL, IN, MI, MN, MO, OH, WI
South Central: AR, AZ, LA, NM, OK, TX
West Central: CO, KS, MT, ND, NE, SD, UT, WY
West: AK, CA, HI, ID, NV, OR, WA

Temporal range. The temporal range of the data set includes all landfills that are currently open or, landfills that closed within the last five years.

Appendix II. Calculations for Estimating Emissions Reductions

Equation IIa.

$$\textbf{Gas Combusted}_{project} = \textbf{Gas Generated}_{project} \times CE \times DE \times 21$$

Where:

Gas $Combusted_{project}$	= CH_4 combusted from project (TCO_2e)
Gas $Generated_{project}$	= CH_4 generated at landfill (estimate, e.g., from LandGEM) (metric tons CH_4)
CE	= Collection efficiency (fraction of CH_4 generated at the landfill that is delivered to combustion device)
DE	= Destruction efficiency of CH_4 combustion technology (0.99)
21	= Global warming potential of CH_4

Equation IIb.

$$\textbf{Emission Reductions}_{,CH4} = (\textbf{Gas Combusted}_{project} - \textbf{Gas Combusted}_{baseline}) \times 0.90$$

Where:

Emission $Reductions_{,CH4}$	= CH_4 reductions (TCO_2e)
Gas $Combusted_{project}$	= CH_4 combusted by project (TCO_2e)
Gas $Combusted_{baseline}$	= Measured value of CH_4 combustion in the baseline (TCO_2e, 0 if no gas combustion in baseline)
0.90	= Oxidation factor

Equation IIc.

Project Energy Emissions = Fuel type * fuel-specific emission factor[10] / 1000 (kg/ton)

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[10] If available, project-specific emissions factors should be used; if not then emission factors should be drawn from the latest version of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. U.S. Environmental Protection Agency, available at http://www.epa.gov/climatechange/emissions/index.html, or Appendix III of this protocol.

Where:

Fuel Type	= Quantity of each specific fuel, or electricity, used for construction-related activities and operation of collection and combustion equipment
Fuel-specific emission factor	= CO_2, CH_4, and N_2O emitted from any fuel consumption or electricity use (kgCO_2e/MMbtu or MWh)

Equation IId.

Emissions from Leakage = Fuel type * fuel specific emissions factor / 1000 kg/ton

Where:

Fuel Type	= Quantity of each specific fuel used for activities outside of the project boundary (MMBTU, MWh)
Fuel-specific emission factor	= factor for CO_2, CH_4, and N_2O emitted from any fuel consumption or electricity-use (kg CO_2e/MMbtu or MWh)

Total Estimated Project Emission Reductions

Total Estimated Project Emission Reductions (TCO_2e) = Emission Reductions $_{CH4}$ – Project energy emissions (TCO_2e)– Emissions from Leakage (TCO_2e)

Appendix III. Default Emission Factors for other Energy Use

Table IIIa. CO_2 Emission Factors for Various Fuels

Fuel Type	kg CO_2/MMBtu
Natural Gas	53.06
Distillate Fuel Oil	73.15
Residual Fuel Oil	78.80
Coal	93.98

Note: Industrial coal value based on Year 2006 "Industrial Other Coal" value.
Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006, April 2008. U.S. Environmental Protection Agency.

Table IIIb. Default CH_4 and N_2O Emission Factors for Natural Gas, and Fuel Oil, Coal

Fuel Type	Greenhouse Gas	Emissions per Unit of Fuel Input (kg CO_2e/MMBtu)
Natural Gas	CH_4	0.105
	N_2O	0.031
Petroleum (Commercial sector)	CH_4	0.231
	N_2O	0.186
Petroleum (Industrial sector)	CH_4	0.063
	N_2O	0.186
Coal	CH_4	0.231
	N_2O	0.496

Sources: Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006. U.S. Environmental Protection Agency, April 2008.

Table IIIc. Default CH_4 and N_2O Emission Factors for Electricity

Fuel Type	Greenhouse Gas	Emissions per Unit of Fuel Input (kg CO_2e/MMbtu)
Natural Gas	CH_4	0.021
	N_2O	0.031
Petroleum	CH_4	0.063
	N_2O	0.031
Coal	CH_4	0.021
	N_2O	0.496

Note: Electricity emissions of CH_4 and N_2O relate to the fuel used to produce the electricity. Information on fuel type will be needed to estimate CH_4 and N_2O.
Sources: Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006. U.S. Environmental Protection Agency, April 2008.

Table IIId. Emission Factors for Electricity Use by Project Equipment by eGRID Subregion (2004)

eGRID Subregion	States included in eGRID Subregion	NERC Region	Emission factor for electricity used by project equipment (kg CO2/kWh)
AKGD* (Alaska Grid)	AK	ASCC	0.604
AKMS (Alaska Miscellaneous)	AK	ASCC	0.630
AZNM (WECC- Southwest)	AZ, CA, NM, NV, TX	WECC	0.634
CAMX (WECC- California)	CA, NV, UT	WECC	0.572
ERCT (Texas)	TX	ERCOT	0.600
FRCC (Florida)	FL	FRCC	0.612
HIMS (Hawaii- Miscellaneous)	HI	HICC	0.738
HIOA* (Hawaii- Oahu)	HI	HICC	0.783
MORE (Midwest- East)	MI, WI	MRO	1.005
MROW (Midwest- West)	IA, IL, MI, MN, MT, ND, NE, SD, WI, WY	MRO	1.050
NEWE (New England)	CT, MA, ME, NH, NY, RI, VT	NPCC	0.641
NWPP (WECC- Northwest)	CA, CO, ID, MT, NV, OR, UT, WA, WY	WECC	0.770
NYCW (New York- NYC, Westchester)	NY	NPCC	0.788
NYLI (New York- Long Island)	NY	NPCC	0.686
NYUP (New York- Upstate)	NJ, NY, PA	NPCC	0.821
RFCE (RFC- East)	DC, DE, MD, NJ, PA, VA	RFC	0.800
RFCM (RFC- Michigan)	MI	RFC	0.880
RFCW (RFC- West)	IL, IN, KY, MD, MI, OH, PA, TN, VA, WI, WV	RFC	0.951
RMPA (WECC- Rocky Mountains)	AZ, CO, NE, NM, SD, UT, WY	WECC	0.778
SPNO (SPP- North)	KS, MO	SPP	1.007
SPSO (SPP- South)	AR, KS, LA, MO, NM, OK, TX	SPP	0.699
SRMV (SERC- Mississippi Valley)	AR, LA, MO, MS, TX	SERC	0.634
SRMW (SERC- Midwest)	IA, IL, MO, OK	SERC	0.979
SRSO (SERC- South)	AL, FL, GA, MS	SERC	0.847
SRTV (SERC- Tennessee Valley)	AL, GA, KY, MS, NC, TN	SERC	0.941
SRVC (SERC- Virginia/Carolina)	GA, NC, SC, VA, WV	SERC	0.890

Note: The emission factors in Table II.d reflect variations in electricity use by project equipment across regions and load type (i.e., base versus non-baseload). Coincident peak demand factors from a 2007 ACEEE study were combined with EPA's eGRID emission factors for baseload and non-baseload power to derive the emission factors presented in this table.[11,12]

[11] York, D. Kushler, M. Witte, P. "Examining the Peak Demand Impacts of Energy Efficiency: A Review of Program Experience and Industry Practice." American Council for and Energy-Efficient Economy (ACEEE). February 2007. http://www.aceee.org/pubs/u071.htm.

[12] The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive inventory of environmental attributes of electric power systems, available at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

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