LANDFILL GAS DESTRUCTION AND BENEFICIAL USE PROJECTS

VERSION 1.0

March 2017

LANDFILL GAS DESTRUCTION AND BENEFICIAL USE PROJECTS

VERSION 1.0

March 2017

American Carbon Registry®

WASHINGTON DC OFFICE
c/o Winrock International
2121 Crystal Drive, Suite 500
Arlington, Virginia 22202 USA
ph +1 703 302 6500

CALIFORNIA OFFICE
800 J Street, Suite 539
Sacramento, California 95814 USA

ACR@winrock.org
americancarbonregistry.org

ABOUT AMERICAN CARBON REGISTRY® (ACR)

A leading carbon offset program founded in 1996 as the first private voluntary GHG registry in the world, ACR operates in the voluntary and regulated carbon markets. ACR has unparalleled experience in the development of environmentally rigorous, science-based offset methodologies as well as operational experience in the oversight of offset project verification, registration, offset issuance and retirement reporting through its online registry system.

ACKNOWLEDGEMENTS

The Methodology was developed by ACR with technical support from the US EPA's Landfill Methane Outreach Program (LMOP).

ACRONYMS

CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
Offsets	Carbon Offset Credits
CAA	Clean Air Act
CNG	Compressed Natural Gas
ERT	Emission Reduction Tonne
GCCS	Gas Collection and Control System
SSR	GHG Source, Sink, or Reservoir
GWP	Global Warming Potential
LFG	Landfill Gas
LFGTE	Landfill Gas-to-Energy
LNG	Liquefied Natural Gas
CH_4	Methane
MSW	Municipal Solid Waste Landfill
NMOC	Non-Methane Organic Compound
NSPS	New Source Performance Standard
RCRA	Resource Conservation & Recovery Act
WIP	Waste in Place

CONTENTS

1. BACKGROUND AND APPLICABILITY

1.1 SUMMARY DESCRIPTION OF THE METHODOLOGY

Table 1: Eligible LFG Activities

Project Activity	Description
Destruction in a flare	Burning LFG onsite in an open or an enclosed flare.
Landfill gas to energy	Converting LFG in an engine, turbine or boiler to energy to be used on- or off-site.
Natural gas pipeline injection	Processing of LFG for injection into a natural gas pipeline.

The collection and combustion of landfill gas (LFG) is an effective method for decreasing the greenhouse gas (GHG) emissions from landfills that would have otherwise been vented to the atmosphere. This Methodology provides the quantification and accounting frameworks, including eligibility and monitoring requirements, for the creation of carbon offset credits from the reductions in GHG emissions resulting from the destruction or utilization of landfill gas at eligible landfills. The Methodology is intended to be used as an incentive to increase these activities and utilizes a flexible additionality framework which is based on either a performance standard or ACR's three-prong additionality test, as stipulated in Section 3.

1.2 APPLICABILITY CONDITIONS

Projects that reduce methane emissions as a result of the combustion or beneficial use of landfill gas in any of the following activities are considered a "project activity" under this Methodology:

- The destruction of landfill gas in an open or closed flare;
- The conversion of landfill gas in a turbine, boiler or generator to energy;
- The enhancement of landfill gas for injection into a natural gas pipeline; and
- The enhancement of landfill gas for use in fleet vehicles, trucks and cars.

In addition to satisfying the latest ACR program eligibility requirements as found in the *ACR Standard*, project activities must satisfy the following conditions for this Methodology to be applicable:

- The project is located in the United States; and
- The project is not required by any regulatory agency.

1.3 START DATE

The Start Date is the date that the landfill gas project became operational. For purposes of this Methodology, a project is considered to be operational when methane is continuously destroyed following a start-up period which may be a maximum of 6 months after the date of project commissioning. Project commissioning is the first day which the GCCS and respective destruction device(s) are fully operational and either destroying or enhancing landfill gas.

1.4 CREDITING PERIOD

A Crediting Period is the finite length of time for which a GHG Project Plan is valid, and during which a project can generate offsets against its baseline scenario. The crediting period for a project activity shall be ten years.

Projects that have previously generated carbon offsets in a GHG Program other than ACR and whose crediting period has expired may apply for a new crediting period under the ACR program. As with all projects, the requirements of this Methodology must be met and the project must receive a positive validation opinion.

1.5 REPORTING PERIOD

A Reporting Period is the portion of time during the crediting period for which the project is reporting emission reductions to be verified and issued. Reporting periods shall not exceed five (5) years.

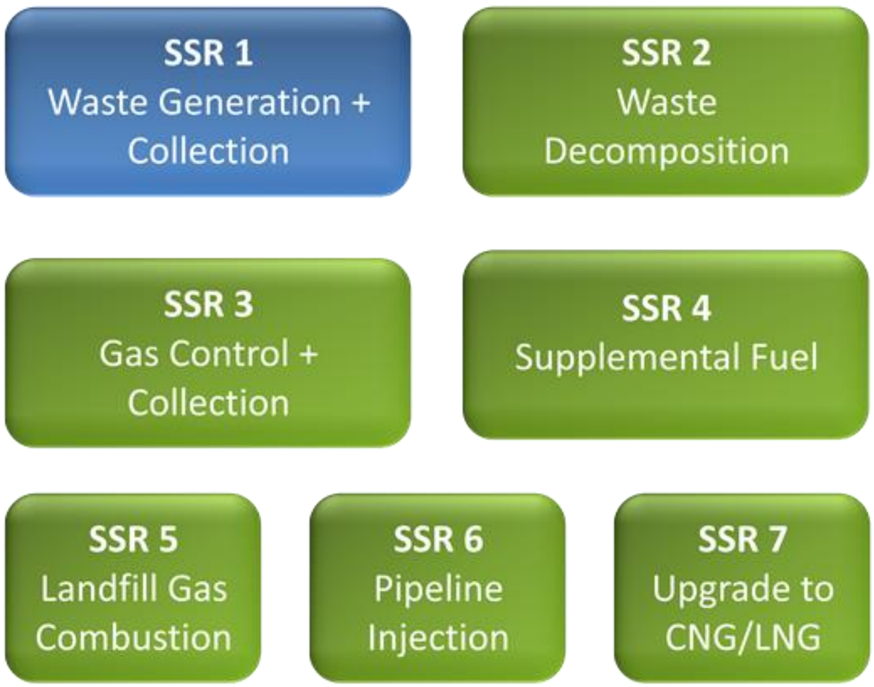
1.6 PERIODIC REVIEWS AND REVISIONS

ACR may require revisions to this Methodology to ensure that monitoring, reporting, and verification systems adequately reflect changes in the project's activities. This Methodology may also be periodically updated to reflect regulatory changes, emission factor revisions, or expanded applicability criteria. Before beginning a project, the project proponent should ensure that they are using the latest version of the Methodology.

2. PROJECT BOUNDARIES

2.1 GEOGRAPHIC BOUNDARY

Figure 1: Project Boundary Diagram for Landfill Gas Projects



The Blue SSR represents emission sources outside of the project boundary while the green SSRs are those included in the project boundary. Within the boundaries, the sources of GHG emissions and removals are from the waste decomposition, landfill gas collection and control system, the maintenance or operations of the destruction or combustion device(s), and any emissions associated with the enhancement of LFG. Table 2 lists the GHG sources included and excluded depending on whether the sources are within or outside project boundaries.

Table 2: Greenhouse Gases and Sources

SSR		Source Description	Gas	Included (I) Or Excluded (E)	Comments
1	Waste Generation & Collection	Emissions from the generation and hauling of waste to the landfill	CO_2	E	Emissions resulting from this SSR should be equivalent in both the project and baseline scenarios.
			CH_4	E	
			N_2O	E	
2	Waste Decomposition	Emissions from the decomposition of waste at the landfill	CO_2	E	Emissions are assumed to be de minimis.
			CH_4	I	Primary GHG affected by the project.
			N_2O	E	Emissions are assumed to be de minimis.
3	Gas Collection & Control	Emissions associated with the energy consumed to collect and process LFG	CO_2	I	Emissions resulting from the GCCS shall be included.
			CH_4	E	Emissions are assumed to be de minimis.
			N_2O	E	
4	Supplemental fuel	Combustion of fossil fuels to supplement the destruction or use of LFG	CO_2	I	Emissions resulting from the use of supplemental fuel shall be included.
			CH_4	I	
			N_2O	E	Emissions are assumed to be de minimis.
5	Landfill Gas Combustion	The combustion of LFG in an eligible destruction device	CO_2	E	Emissions are assumed to be de minimis.
			CH_4	I	Emissions resulting from the incomplete combustion of LFG shall be included.
			N_2O	E	Emissions are assumed to be de minimis.
6	Pipeline Injection	The enhancement of LFG to be injected into a natural gas pipeline	CO_2	I	Emissions resulting from the enhancement of LFG shall be included.
			CH_4	I	
			N_2O	E	Emissions are assumed to be de minimis.
7	CNG/LNG Upgrade	The enhancement of LFG to be used in fleet vehicles, trucks or cars.	CO_2	I	Emissions resulting from the enhancement of LFG shall be included.
			CH_4	E	Emissions are assumed to be de minimis.
			N_2O	E	

3. BASELINE DETERMINATION AND ADDITIONALITY

3.1 BASELINE DETERMINATION

The baseline for a project activity is determined utilizing industry standards and represents the most commonly used practices and technologies. Landfill gas destruction and beneficial use projects are not eligible to generate Emission Reduction Tons (ERT) in instances where the collection and destruction of landfill gas can be considered a standard business practice or is required by law or as a result of any other legally binding framework. The baseline determination shall be consistent with the pre-project activity prior to the start date.

For projects that are or have previously employed ineligible project activities, such as a passive flare, or have an eligible project activity that was implemented prior to the specified start date, emission reductions associated with these activities shall be accounted for in the baseline emission calculations. Project proponents shall submit a proposed method for quantifying pre-project emission reductions to ACR for approval. Emission reductions resulting from ineligible project activities shall be accounted for in Equation 2 as NE_{device}.

3.2 ADDITIONALITY ASSESSMENT

Emission reductions from the project must be additional, or deemed not to occur in the "business-as usual" scenario. Assessment of the additionality of a project will be made based on passing a practice-based performance standard and a regulatory surplus test OR ACR's three-prong additionality test (which, as a first step, includes a regulatory surplus test).

Projects shall demonstrate conformance with the full requirements found in Section 3.2.1 OR 3.2.2 only once at the beginning of a crediting period. However, projects shall demonstrate regulatory surplus during verification activities for each reporting period. For more information on the development of the practice-based performance standard, please see Appendix A.

3.2.1 Practice-Based Performance Standard

Projects with the characteristics described below may apply the practice-based performance standard to demonstrate that the project activity is not common practice and is therefore considered additional pending the outcome of the regulatory surplus test:

- Project activities located in non-arid counties (defined as counties with more than 25 inches of precipitation historically) implemented at landfills with equal to or less than 500,000 tons of waste in place; or

- Project activities located in arid counties (defined as counties with less than 25 inches of precipitation historically) implemented at landfills with equal to or less than 1,500,000 tons of waste in place.

Appendix A shall be used to determine if a project is located in a non-arid or arid county.

3.2.1.1 Regulatory Surplus Test

For projects applying the performance standard discussed in Section 3.2.1, a regulatory surplus test shall also be applied. To pass the regulatory surplus test, a project must not be mandated by existing laws, regulations, statutes, legal rulings, or any other regulatory frameworks that directly or indirectly affect the GHG emissions associated with a project such as the CAA or RCRA. The project proponent must demonstrate that there is no existing law, regulation, statute, legal ruling, or other regulatory framework that mandates the project or effectively requires the GHG emission reductions associated with the installation of a destruction device or the infrastructure necessary for enhancing the landfill gas.

The project proponent shall provide evidence including all supporting documentation necessary to prove that landfill gas destruction, abatement or mitigation is not required.

3.2.2 ACR's Three-Prong Additionality Test

For project activities that do not automatically qualify under the practice-based performance standard outlined in Section 3.2.1, ACR's Three-Prong additionality test shall be applied. The first step in the Three-Prong additionality test, as stated above, is the application of a regulatory surplus test which is followed by a common practice assessment and description of implementation barriers. Landfill gas projects may only demonstrate a financial implementation barrier(s) and may not apply technological or institutional barriers. For a complete description of the ACR Three-Prong Additionality Test, please refer to the ACR Standard.

4. QUANTIFICATION OF GHG EMISSION REDUCTIONS

Quantification of project emission reductions requires calculation of baseline emissions and project emissions.

4.1 BASELINE EMISSIONS

Equation 1: Volume of CH_4 Combusted
This is the amount of GHG emissions that would take place without the destruction or beneficial use of the landfill gas. Records of continuous landfill gas flows (in standard cubic feet per minute) shall be matched with continuous methane content data using Equation 1:

$$CH_{4combusted} = [(LFG_{captured} * \%CH_{4,continuous}) + (LFG_{captured} * \%CH_{4,weekly} * (1 - DF_{weekly}))] * (1 - OF)$$

WHERE

$CH_{4combusted}$	Total volume of methane combusted (scf)
$LFG_{captured}$	LFG captured (scf)
$\%CH_{4,\ continuous}$	Methane content of LFG for continuous methane monitoring (%)
$\%CH_{4,\ weekly}$	Methane content LFG for duration weekly methane monitoring (%)
DF_{weekly}	Discount factor for weekly methane content monitoring (a value of 0.1 shall be applied only when weekly readings occurred)
OF	Oxidation factor

The oxidation factor is based on the recommended oxidation rates by the U.S. EPA. The following values shall be applied based on the type of landfill cover and methane flux within the project boundary:

- A value of 0.0 shall be applied to landfills with a synthetic cover;
- A value of 0.10 shall be applied to landfills without a synthetic cover that are not required to determine methane flux or for landfills that do not have a soil cover of at least 24 inches for the majority of landfill area containing waste;

- A value of 0.35 shall be applied to landfills have a soil cover of at least 24 inches for a majority of the landfill area containing waste and for which the methane flux rate is less than 10 grams per square meter per day ($g/m^2/d$);
- A value of 0.25 shall be applied to landfills have a soil cover of at least 24 inches for a majority of the landfill area containing waste and for which the methane flux rate is 10 - 70 grams per square meter per day ($g/m^2/d$); or
- A value of 0.10 shall be applied to landfills have a soil cover of at least 24 inches for a majority of the landfill area containing waste and for which the methane flux rate is greater than 70 grams per square meter per day ($g/m^2/d$).

Equation 2: Net Mass of CH_4 Destroyed

In order to estimate the amount of methane combusted in metric tons, methane combusted needs to be converted to weight using Equation 2:

$$CH_{4total} = \left(\left((CH_{4combusted} * CF) * 16.04 * \left[\frac{1}{10^6}\right] * \left[\frac{1}{24.04}\right] * 28.32\right) * 95\%\right) - NE_{device}$$

WHERE

CH_{4total}	Total methane combusted (metric tons)
$CH_{4combusted}$	Methane combusted (scf – as calculated in Equation 1)
CF	Correction factor – calculated per Equation 3[1]
16.04	Molecular weight of CH_4
$1/10^6$	Conversion to metric tons (MT/g)
1/24.04	Gas constant (mol/L – measured at standard temperature and pressure – defined as 68ºF and 14.7psi)
28.32	Conversion factor (L/cf)
95%	Destruction efficiency of the destruction device[2]
NE_{device}	Emissions from a pre-project, non-eligible device

[1] The correction factor shall only be applied in instances where the project flow meter does not use a standard temperature of 68ºF. Where project flow meters do apply a standard temperature of 68ºF, CF = 1.

[2] In lieu of the default 95% destruction efficiency, project proponents may apply the results of a third-party source test conducted by an organization meeting or exceeding the U.S. Environmental Protection Agency's *Minimum Competency Requirements for Air Emission Testing* rule to determine the actual destruction efficiency of the device.

Equation 3: Correcting LFG Flow Temperature

If the monitoring equipment is set to record landfill gas flow at a temperature other than that defined in Equation 2 (68ºF), the project proponent must normalize the landfill gas flow by using the correction factor calculated in Equation 3:

$$CF = \frac{527.67}{T + 459.67}$$

WHERE

CF	Correction factor
T	Temperature as measured by project flow meters

4.2 PROJECT EMISSIONS

Depending on project-specific circumstances, certain emissions sources shall be subtracted from total project emission reductions using the equations below.

Equation 4a: CO_2 Emissions from Fossil Fuel Combustion

$$Dest_{CO2} = \sum y \left(FF_y * EF_y\right)$$

WHERE

$Dest_{CO2}$	CO_2 emissions from fossil fuel used in methane destruction process (tCO_2)
FF_y	Total quantity of fossil fuel,y, consumed (volume of fuel)
EF_y	Fuel specific emission factor for fuel, y (tCO_2/fuel quantity) – See Appendix B

Equation 4b: CO_2 Emissions from Project Specific Electricity Consumption

$$Elec_{CO2} = \frac{EL_{total} * EF_{EL}}{2204.62}$$

WHERE

$Elec_{CO2}$	Project specific electricity emissions (tCO_2)
EL_{total}	Total grid connected electricity consumption (MWh)
EF_{EL}	Carbon emission factor for grid electricity ($lbCO_2$/MWh) - See Appendix B
2204.62	$lbCO_2/tCO_2$

Equation 5: Project Emissions

$$PE = Elec_{CO2} + Dest_{CO2}$$

WHERE

PE	Project emissions (tCO_2)
$Elec_{CO2}$	Project specific electricity emissions (tCO_2)
$Dest_{CO2}$	CO_2 emissions from fossil fuel used in methane destruction or transportation process (tCO_2)

4.3 LEAKAGE

Leakage is a term that refers to secondary effects where the GHG emission reductions of a project may be negated by shifts in market activity or shifts in materials, infrastructure, or other physical assets associated with the project. ACR does not expect landfill methane projects to result in any additional activities that would augment GHG emissions outside of the project boundary and, therefore, no leakage assessment is required.

4.4 EMISSION REDUCTIONS

Equation 6: GHG Emission Reductions

$$ER = [CH_{4total} * GWP_{CH4}] - PE$$

WHERE

ER	Total Emission Reductions (tCO_2e)
CH_{4total}	Methane combusted (MT)
GWP_{CH4}	Global warming potential of methane[3]
PE	Project emissions (tCO_2)

[3] Project proponents shall refer to the ACR Program Standard for the approved IPCC GWP for methane value, which will be updated periodically as new information becomes available.

5. MONITORING AND DATA COLLECTION

Each project shall include a GHG project plan sufficient to meet the requirements of the ACR Standard. The plan shall collect all data required to be monitored and in a manner which meets the requirements for accuracy and precision of this Methodology. Project Proponents shall use the template for GHG project plans available at www.americancarbonregistry.org. Additionally, projects are required to submit a GHG monitoring report for each reporting period. Project Proponents shall use the template for GHG monitoring reports available at http://americancarbonregistry.org/carbon-accounting/tools-templates.

5.1 DESCRIPTION OF THE GHG PROJECT PLAN

These are expanded upon in the sections below. The project proponent must prepare a GHG project plan describing (for each separately) the following: a) project implementation; b) technical description of the monitoring task; c) data to be monitored and collected; d) overview of data collection procedures; e) frequency of the monitoring; f) quality control and quality assurance procedures; g) data archiving; and h) organization and responsibilities of the parties involved in all the above.

The rationale of monitoring project implementation is to document all project activities implemented by the project that could cause an increase in GHG emissions compared to the baseline scenario.

5.2 DATA COLLECTION AND PARAMETERS TO BE MONITORED

Project monitoring and recording shall include the following parameters:

- Continuous monitoring of landfill gas flow to each destruction device,
- Methane content analysis using a continuous gas analyzer,
- Electricity production records, if applicable,
- Quantity of transport fuel or pipeline quality gas generated, if applicable,
- Destruction device operating hours, if applicable,
- Before and after results of field checks,
- Project-related emission data (grid electricity consumed and/or fossil fuels used by the project), and
- A GCCS downtime log that includes the duration and cause of a GCCS shutdown or malfunction.

5.2.1 Flow Monitoring

Landfill gas flow shall be continuously monitored using an adequate flow meter. Continuous monitoring is defined as one data point recorded at least every 15 minutes. The flow meter shall be installed along the header pipe at a location that provides a straight section of pipe sufficient to establish laminar gas flow, in order to mitigate any turbulence resulting from bends, obstructions, or constrictions in the pipe. This turbulence may result in inaccurate flow measurements. The flow meter shall be located downstream of the blower and upstream of the destruction device. All flow data used to calculate emission reductions must be corrected for standard temperature (68ºF) and standard pressure (14.7psi).

5.2.2 Methane Content Analysis

The methane fraction in the landfill gas shall be continuously monitored using a methane analyzer. Continuous monitoring is defined as one data point at least every 15 minutes.

Weekly readings may be taken using a handheld gas analyzer for no more than two (2) months with a 10% discount for the duration of the weekly readings if the continuous methane analyzer fails or is being serviced. The discount shall be applied in Equation 1 only for the period in which weekly readings were taken in place of continuous readings. Handheld gas analyzers shall meet the calibration and maintenance requirements of Section 5.2.3.

5.2.3 Monitoring Equipment Calibration/Quality Assurance

The following information regarding flow meter and gas analyzer performance shall be maintained:

- Proof of initial calibration for flow meters and gas analyzers;
- Capability to record flow or methane concentration every 15 minutes;
- Means to correct for temperature and pressure (for flow meter, if necessary); and
- Manufacturer's recommended factory calibration frequency.

It is essential that flow meters and gas analyzers operate properly in order to accurately quantify GHG emission reductions. To ensure proper equipment function, annual field checks for flow meter and methane analyzer accuracy shall be performed by a qualified third-party. Annual field checks must meet the following conditions[4]:

[4] Annual field checks must be separated by an elapsed time frame of a minimum of 10 months from the date of the preceding field check but must not exceed 12 months.

- Field checks must be performed in accordance with manufacturer's specifications and methodologies;
- Field checks must be performed by the manufacturer or other appropriately trained third-party personnel;
- All field checks must be documented and made available for review during the validation and verification process. Documentation must include specific results of the field checks including the percent error demonstrated by the instrumentation capturing the before (as-found) and after (as-left) status;
- Should the instrumentation demonstrate an error in the reading or output of either landfill gas flow or methane content that is greater than or equal to 5%, written documentation must be provided as to the correction applied during the field check and the resulting accuracy of the instrumentation. In situations where the flow meter or methane analyzer percent error is greater than or equal to 5%, all data from the previous field check through to the most recent field check shall be scaled by the percent error documented in the most recent field check.

Projects may choose to conduct more than one field check to ensure that the monitoring equipment continuously meets the requirements of Section 5.2.3. If a project elects to conduct more frequent field checks, they must adhere to the requirements of Section 5.2.3. Additionally, manufacturer specifications regarding instrument calibration shall be followed. No ERTs will be granted for periods where the flow meter or gas analyzer have not been maintained in accordance with manufacturer calibration requirements.

5.2.4 Destruction Device Operating Hours

The operating hours for each destruction device must be monitored to ensure that landfill gas destruction is claimed for landfill gas destroyed only during periods when the device(s) was/were operational. Emission reductions may not be claimed for time periods where the destruction device(s) is not operating or thermocouple readings are below 500 degrees Fahrenheit. Operating hours must be continuously monitored and recorded except for non-flare destruction devices (e.g. boilers or engines) that are equipped with an operable safety shut off valve and that impede the flow of landfill gas to the device when it is not in operation. In general, operating hours for a flare are tracked through the use of a thermocouple which monitors the presence and temperature of the flame. Operating hours for other destruction devices such as engines should be tracked through operator logs, electricity production records, or other verifiable means.

Projects that treat landfill gas and inject it into a natural gas pipeline shall only provide evidence of the quantity of gas delivered to the pipeline and are not required to provide evidence of landfill methane destruction.

5.2.5 Project-Related Emissions

Project-related emissions may result from the used of imported electricity or from the use of fossil fuels. Information related to electricity usage and relevant fossil fuel consumption may be obtained from sources such as on-site electricity meters, utility invoices, and fuel purchase records.

5.2.6 Parameters Monitored

Parameter	CH_4%
Units	Percentage
Description	Percent of methane monitored by the gas analyzer.
Relevant Section	4.1
Relevant Equation(s)	1
Source of Data	Gas analyzer/data acquisition device
Measurement Frequency	Continuous or using a handheld analyzer during calibration.

Parameter	$LFG_{captured}$
Units	scfm
Description	Landfill gas flow as measured by the flow meter.
Relevant Section	4.1
Relevant Equation(s)	1
Source of Data	Flow meter/data acquisition device
Measurement Frequency	Continuous

Parameter	Flare Operating Hours
Units	Degrees Fahrenheit
Description	Monitoring of operational activity of destruction device to ensure destruction of landfill gas. Not applicable for pipeline injection projects.
Relevant Section	4.1
Relevant Equation(s)	1
Source of Data	Thermocouple/data acquisition device
Measurement Frequency	Continuous

Parameter	Flare Temperature
Units	Degrees Fahrenheit
Description	Monitoring of temperature of destruction device to ensure destruction of landfill gas. Not applicable for pipeline injection projects.
Relevant Section	4.1
Relevant Equation(s)	1
Source of Data	Thermocouple/data acquisition device
Measurement Frequency	Continuous

Parameter	FF_y
Units	Volume of fuel
Description	Total quantity of fossil fuel,y, consumed.
Relevant Section	4.1.2
Relevant Equation(s)	4a
Source of Data	Utility or fuel Invoices
Measurement Frequency	Collected annually

Parameter	EL_{total}
Units	MWh
Description	Total grid connected electricity consumption.
Relevant Section	4.1.2
Relevant Equation(s)	4b
Source of Data	Electricity Invoices
Measurement Frequency	Collected annually

DEFINITIONS

If not explicitly defined here, the definitions in the latest version of the American Carbon Registry (ACR) Standard apply.

Clean Air Act	A comprehensive federal law designed to regulate both stationary and mobile air emissions in order to improve air quality and human health.
Compressed Natural Gas	Natural gas under pressure, typically used a fuel substitute.
Gas Collection and Control System	A system of wells and pipes designed to collect landfill gas that can be conveyed under vacuum to a combustion device such as a flare or engine.
Landfill Gas	Landfill gas is a product of the decomposition of organic material contained in municipal solid waste landfills.[5]
Landfill Gas-to-Energy	The process of converting landfill gas to electricity, steam or natural gas for fuel.
Liquefied Natural Gas	Natural gas in a liquid state for ease of use or storage.
Municipal Solid Waste Landfill	A designation for landfills that accept household trash.
Non-Methane Organic Compound	Non-methane organic compounds consist of hazardous air pollutants and volatile organic compounds, which when exposed to sunlight may form ground-level ozone or smog.
New Source Performance Standard	Federal rules for U.S. landfills, codified in 40 CFR Subpart WWW, that govern emissions from existing landfills with a design capacity greater than 2.5 million megagrams that began receiving waste or began construction or made modifications after May 30, 1991.

[5] As defined by the U.S. EPA's Landfill Methane Outreach Project. Found at http://www3.epa.gov/lmop/faq/landfill-gas.html.

APPENDIX A: DEVELOPMENT OF PRACTICE-BASED PERFORMANCE STANDARD

While the total number of landfills in the U.S. has declined over time, the amount of waste sent to landfills has increased. As of 2015, landfills accounted for approximately 18% [6]of anthropogenic methane emissions in the U.S. The Environmental Protection Agency's (EPA) Landfill Methane Outreach Program (LMOP) maintains a database of the 2,434 landfills in the U.S. of which there are approximately 1,000 municipal solid waste (MSW) landfills that are subject to the existing New Source Performance Standards (NSPS). Of the 1,000 MSW landfills subject to NSPS, 574 have installed gas collection and control systems (GCCS) as a result of the regulatory requirement, while the remainder are only required to report their annual emissions to the EPA[7]. Only landfills that have a design capacity of 2.5 million metric tons and 2.5 million cubic meters of waste are subject to federal NSPS requirements and landfills are only required to abate emissions if they are found to reach or surpass the 50 megagrams per year of non-methane organic compounds (NMOC) emission threshold or 34 megagrams per year beginning in 2025.

For landfills that have reached or have exceeded the allowable NMOC emission threshold, no credits may be claimed once the landfill is required to install a GCCS. However, landfills that are not subject to NSPS regulations or have not reached the allowable NMOC threshold may participate in a voluntary carbon offset program.

While past landfill gas carbon offset protocols have been predicated upon a low adoption rate for LFG GCCS *nationally* the number of voluntary landfill gas projects has steadily increased to the point where a national, practice-based performance standard is no longer applicable. However, based on analysis of the LMOP database along with assistance from several state or local permitting authorities, ACR has identified that there are still criteria that define landfills with low penetration rates for voluntary landfill gas projects. ACR began by identifying candidate landfills which consisted of the following criteria:

- Landfills that were currently open or had closed within in the last 5 years;
- Landfills that are currently under the waste in place (WIP) threshold for the region (i.e. arid versus non-arid locations, see Table A1; and
- Landfills that are not subject to NSPS or other state/local requirements to install a GCCS.

[6] EPA's Air Rules for Municipal Solid Waste Landfills, Proposed Emission Guidelines for Existing Landfills: Fact Sheet. Found at http://www3.epa.gov/ttn/atw/landfill/20150814egfs.pdf.

[7] EPA's Air Rules for Municipal Solid Waste Landfills, Proposed Emission Guidelines for Existing Landfills: Fact Sheet. Found at http://www3.epa.gov/ttn/atw/landfill/20150814egfs.pdf.

It should be noted that recently closed landfills may generate enough landfill gas to facilitate a project which is why candidate landfills closed in the last 5 years were included.

Given the above criteria, ACR has calculated that voluntary projects at landfills in non-arid regions (regions with more than 25 inches of rain in the last five years) and less than 500,000 tons of WIP, and at landfills in arid regions (regions with less than or equal to 25 inches of rain in the last five years) with less than 1,500,000 tons of WIP, account for less than 15% of candidate landfills in each region (Table A1)[8]. As these adoption rates are low, landfills that meet the criteria stipulated in Section 3.2.1 automatically qualify under the practice-based performance standard. The historical precipitation map in Figure 2 below shall be used to determine if a project is located in an arid or non-arid region.

Table A1: Penetration Rate of Candidate Landfills

	Non-Arid	Arid
WIP Limit	**500,000**	**1,500,000**
Candidate Landfills	90	92
Candidates Landfills with a Voluntary GCCS	13	12
Percent Adoption	14.44%	13.04%

[8] Precipitation zones defined by the EPA (Section 2.4.4.1). Found at https://www3.epa.gov/ttn/chief/ap42/ch02/final/c02s04.pdf.

Figure A1: U.S. Historic Precipitation Map

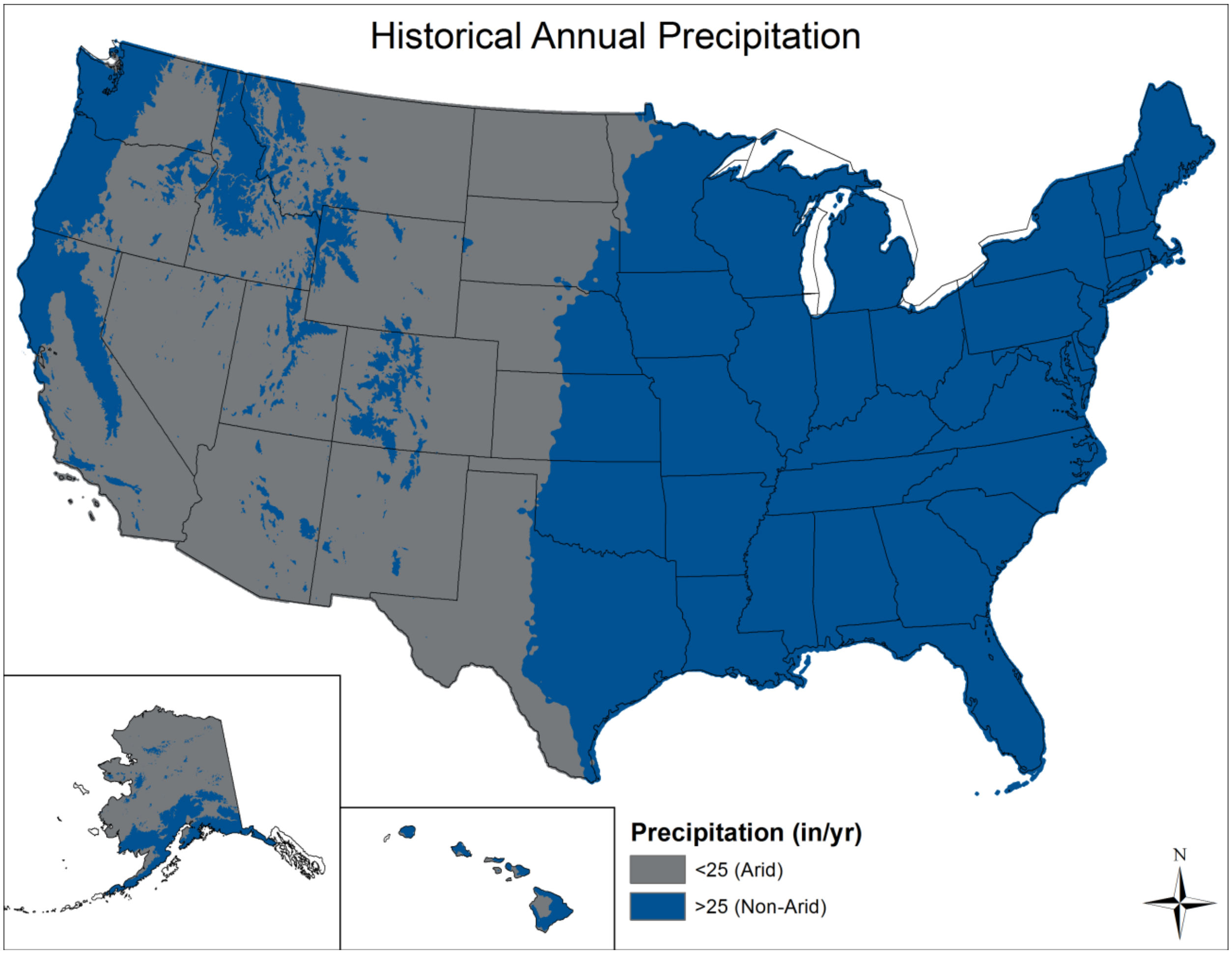


Figure A1 precipitation data sources by region include:

- **Continental U.S.**: PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created Feb 4, 2004.
- **Alaska**: Arctic Landscape Conservation Cooperative, 2012. Baseline (1961-1990) average total precipitation (mm) for Alaska and Western Canada. Created by Arctic Landscape Conservation Cooperative staff; data provided by Scenarios Network for Alaska and Arctic Planning. http://arcticlcc.org/products/spatial-data/show/baseline-1961-1990-rasters.
- **Hawaii**: Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013: Online Rainfall Atlas of Hawai‘i. Bull. Amer. Meteor. Soc. 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1.

APPENDIX B: EMISSION FACTORS

Project proponents shall use the current version of the U.S. Environmental Protection Agency's Power Profiler (http://oaspub.epa.gov/powpro/ept_pack.charts) to determine what regional emission factor should be used in accordance with the Emissions & Generation Resource Integrated Database (eGRID) for EF_{EL}. eGRID emission factors are available at http://www.epa.gov/energy/egrid.

To calculate $Dest_{CO2}$, project proponents shall use the below emission factors for EF_y which will be revised periodically based on updated information.

	CO_2 EF_y					
Fossil Fuel Type	**Pounds (lbs.) CO_2**	**Per Unit**	**Kilo-grams (kg) CO_2**	**Per Unit**	**Lbs. CO_2/ MMBtu**	**kg CO_2/ MMBtu**
Gases						
Propane	12.70	Gallon	5.76	Gallon	139.05	63.07
Butane	14.80	Gallon	6.71	Gallon	143.20	64.95
Butane/Propane Mix	13.70	Gallon	6.21	Gallon	141.12	64.01
Home Heating and Diesel Fuel	22.40	Gallon	10.16	Gallon	161.30	73.16
Kerosene	21.50	Gallon	9.75	Gallon	159.40	72.30
Coal (All types)	4,631.50	Short ton	2,100.82	Short ton	210.20	95.35
Natural Gas	117.10	Thousand cubic feet	53.12	Thousand cubic feet	117.00	53.07
Gasoline	19.60	Gallon	8.89	Gallon	157.20	71.30
Residual Heating Fuel (Businesses only)	26.00	Gallon	11.79	Gallon	173.70	78.79
Flared natural gas	120.70	Thousand cubic feet	54.75	Thousand cubic feet	120.60	54.70
Petroleum coke	32.40	Gallon	14.70	Gallon	225.10	102.10
Other petroleum & miscellaneous	22.09	Gallon	10.02	Gallon	160.10	72.62
Coals						
Anthracite	5,685.00	Short ton	2,578.68	Short ton	228.60	103.70
Bituminous	4,931.30	Short ton	2,236.80	Short ton	205.70	93.30
Subbituminous	3,715.90	Short ton	1,685.51	Short ton	214.30	97.20
Lignite	2,791.60	Short ton	1,266.25	Short ton	215.40	97.70
Coke	6,239.68	Short ton	2,830.27	Short ton	251.60	114.12
Source: U.S. Energy Information Administration, published February 2, 2016.						

APPENDIX C: REFERENCES

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

Intergovernmental Panel on Climate Change, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, June 2001.

Intergovernmental Panel on Climate Change, IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, 2006.

International Organization for Standardization, ISO 14064-2:2006, Greenhouses gases - Part 2: *Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emissions reductions or removal enhancements*, First Edition, March 1, 2006.

International Organization for Standardization, ISO 14064-3:2006, Greenhouses gases - Part 3: *Specification with guidance for the validation and verification of greenhouse gas assertions*, First Edition, March 1, 2006.

United Nations Framework Convention on Climate Change Clean Development Mechanism's approved methodology and supporting tools for ACM0001: *Flaring or use of landfill gas*, Version 16.0, October 16, 2015.

U.S. Environmental Protection Agency - Climate Leaders Greenhouse Gas Inventory Protocol Offset Project Methodology for Project Type: Landfill Methane Collection and Combustion, Version 1.3, August 2008.

U.S. Environmental Protection Agency – EPA's Air Rules for Municipal Solid Waste Landfills, Proposed Emission Guidelines for Existing Landfills: Fact Sheet, August 27, 2015.

U.S. Environmental Protection Agency – Landfill Methane Outreach Program webpage: http://www3.epa.gov/.

U.S. Environmental Protection Agency – AP 42, Fifth Edition, Volume I, Section 2.4: Municipal Solid Waste Landfills, http://www.epa.gov/ttn/chief/ap42/ch02/index.html.

World Resource Institute and World Business Counsel for Sustainable Development, Greenhouse Gas Protocol for Project Accounting, Revised Edition, March 2004.