Quantification Protocol for Landfill Gas Capture and Combustion

Carbon Competitiveness Incentive Regulation

Version 3.0
November 2018

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Disclaimer:	This document is not a substitute for legal requirements. Emission offset project developers must comply with all applicable laws, including but not limited to those set out in the Climate Change and Emissions Management Act (the Act), the Carbon Competitiveness Incentive Regulation (the Regulation), and Part 1 of the Standard for Greenhouse Gas Emission Offset Project Developers (the Standard). If there is a conflict between this quantification protocol and the Act, the Regulation or Part 1 of the Standard, the Act, Regulation or Standard prevails over the quantification protocol. All quantification protocols are subject to review as deemed necessary, and will be revised periodically to ensure they reflect best available scientific knowledge and practices. For information regarding the withdrawal and replacement of quantification protocols, please see the Standard.

Summary of Revisions

Version	Date	Summary of Revisions
3.0	October 2018	• The **Protocol Scope** was updated to exclude emissions from fuels subject to the carbon levy under the *Climate Leadership Act* from the emission offsets calculation. Displacement of emissions from fuels with a carbon levy exemption certificate is an eligible activity under this protocol. • The **Baseline Condition** was updated to quantify emissions from fossil fuel use for landfill gas capture and combustion for projects with applicable baseline conditions. • The **Quantification** was updated by adding equations to quantify net reductions, offset-eligible reductions and levied emissions. • The **Quantification Methodology** was updated to: o account for methane emissions from landfill gas combustion. o revise the quantification method to determine nitrous oxide emissions from landfill gas combustion. o account for emissions from the combustion of fossil fuel used to supplement the flare. o account for end-use landfill gas combustion emissions when place into a pipeline network. • Standard conditions for gas quantification are now explicitly defined and gas densities have been revised to align with standard conditions. • **Appendix A** was updated to differentiate the default destruction efficiency for unassisted and steam/air assisted flares and to include methane densities at different reference temperatures.
2.0	July 2015	• The **Protocol Flexibility** mechanisms were reduced and modified. • Former flexibility mechanism 1 allowing project developers to use alternative monitoring methodologies and/or equipment and flexibility mechanism 4 allowing the opportunity to generate emission offsets for upgrading an open flare to a controlled flare were removed. • Former flexibility mechanism 2 allowing landfill gas to be sent to pipeline no longer requires the use of a flexibility mechanism. • The **Baseline Condition** was updated to include Methane Surface oxidation of methane as it travels through the landfill cover and emissions associated with project fossil fuel use. • The **Project Condition** was updated to use site specific destruction efficiencies for combustion devices and include emissions from fossil fuel energy use. • **Project Sources and Sinks** were updated to reflect current industry

		practice. • The **Quantification Methodology** was clarified to provide for quantifying on-site and off-site heat and electricity generation and use. • The protocol was updated to clarify **Documents and Records** requirements. The contingent data collection procedures were removed. Minimum data requirements specified in the protocol must be met.
1.0	September 2007	• Quantification Protocol for Landfill Gas Capture and Combustion was published for use in the Alberta emission offset system.

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Alberta Climate Change Office and Other Related Publications

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- Technical Guidance for Offset Protocol Development and Revision
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- Code of Practice for Landfills

1.0 Introduction

Anaerobic decomposition of organic waste materials in a landfill generates greenhouse gases including methane. Over time these gases migrate to the surface where they are vented to the atmosphere.

The installation of landfill gas (LFG) capture and combustion technology can convert the methane to carbon dioxide resulting in a reduction in greenhouse gas (GHG) emissions. Combustion with energy recovery can further reduce GHG emissions by displacing fossil fuel sourced energy used to generate electricity and heat.

1.1 Protocol Scope

The scope of this protocol enables generation of emission offsets for:

- landfill gas capture and combustion, and/or
- combustion of landfill gas in an energy recovery system that displaces electricity.

Fossil fuels that are subject to the Alberta carbon levy, such as levied fuels used for heating, are included in the quantification and reporting but are not eligible for generation of emission offsets. Fossil fuels that are subject to the carbon levy must be tracked and reported to ensure project eligibility.

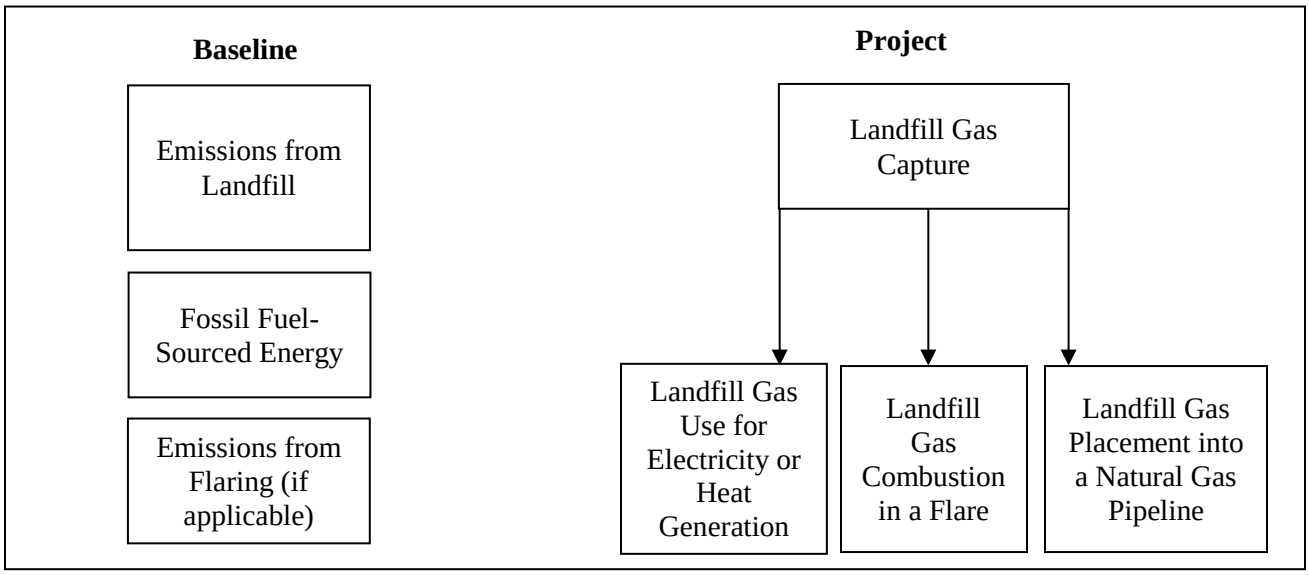
The project must clearly delineate and where applicable, measure the baseline condition for the three years immediately prior to the project start date. This protocol prescribes three baseline conditions, namely:

1. A project may have a baseline condition where landfill gas is passively emitted from the landfill or a portion of the landfill to the atmosphere. Project conditions may include landfill gas capture and combustion in a flare, combustion in an energy recovery system or placement into a natural gas pipeline.
2. A project may have a baseline condition where landfill gas is captured and combusted in a flare. In this scenario the project condition would be combustion of landfill gas in an energy recovery system that displaces electricity.
3. A project may have a baseline condition that is a combination of the aforementioned baselines. In this scenario the project condition would be combustion of landfill gas in an energy recovery system that displaces electricity.

Placement of the landfill gas into a natural gas transmission or distribution pipeline is considered eligible as combustion, so long as the proponents are able to prove ownership of the emission offsets. Energy recovery systems may use dual generating fuels (supplemental fossil fuel and landfill gas) providing it is clear how much energy is being produced by the landfill gas alone.

Figure 1 provides an overview of the components of the landfill gas protocol.

Figure 1: General Representation of the Baseline and Project Conditions



Eligible project conditions include the following:

- Projects must install a landfill gas capture and controlled combustion system;
- Projects may either combust landfill gas to displace fossil fuel sourced for heat and/or electricity, combust the landfill gas in a flare (if there was no combustion by flare in the baseline condition), or place the landfill gas into a natural gas pipeline;
- Landfill facilities must meet Alberta Environment and Park's registration and approval authorization requirements; and
- The project cannot adversely affect other waste diversion policies or initiatives.

This protocol does not estimate or quantify the total GHG emissions from a landfill. Rather, the GHG calculation is based on the measured volume and composition of landfill gas collected and combusted. The greenhouse gases affected by the activities described in this protocol include methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O). The applicable Global Warming Potential (GWP) for each gas is available in the Carbon Offset Emission Factors Handbook.

Table 1 describes the project scenarios eligible under this protocol and their respective baseline scenarios. For instance, a project that captures and combusts landfill gas in a flare in the baseline condition can generate emission offsets for combusting the landfill gas in an energy recovery system in the project condition.

Table 1: Eligible Project Scenarios

Baseline Scenarios	Baseline			Project	
	Emissions	Fossil Fuel Use	Methane Surface Oxidation	LFG Combustion	Energy Recovery
Passive venting of LFG to atmosphere	CO_2, CH_4, N_2O	If project condition displaces fossil fuel energy generation	Yes	Yes	Yes or No
LFG combustion	CO_2, Trace CH_4, N_2O	Yes	No	Yes	Yes
Combination of two scenarios	CO_2, CH_4, N_2O	Yes	Yes	Yes	Yes

1.2 Protocol Applicability

Project developers must be able to demonstrate the emission offset project meets the requirements of the Carbon Competitiveness Incentive Regulation, published documents or standards for the Alberta emission offset system and this quantification protocol.

In particular, the project developer must provide sufficient evidence to demonstrate that:

1. The combustion is carried out under controlled conditions as demonstrated by a description of the landfill gas (LFG) end use and specifications of the combustion device in use;
2. Destruction efficiencies from flares or other combustion equipment must be site specific if the information is available. That is, destruction efficiencies used must be obtained from manufacturer or vendor specifications unless otherwise justified;
3. If applicable, the energy produced from landfill gas is offsetting fossil fuel-generated energy in the form of heat and/or electricity or the landfill gas is processed and placed in a pipeline for use;
4. Metering of gas volume takes place downstream from capture within a reasonable distance of either the combustion device or point of inclusion in the off-site pipeline network such that the meter will account for potential fugitive emissions as demonstrated by project schematics;
5. Reductions achieved by the project are based on actual measurement and monitoring, as per this protocol; and,
6. This protocol does not include emission offset eligibility for the displacement of emissions from fuels subject to the carbon levy. It is still a requirement to quantify these emissions with a reasonable level of assurance. However, displacement of emissions from fuels subject to the carbon levy may be eligible for consideration under this protocol with a carbon levy exemption certificate under the *Climate Leadership Act*.

1.3 Protocol Flexibility

The protocol prescribes using site specific, manufacturer specified landfill gas destruction efficiencies as they result in higher accuracy relative to using generic destruction efficiencies. Flexibility is allowed through the use of the generic destruction efficiencies listed in Appendix A where there is insufficient information to support site specific landfill gas destruction efficiencies for quantification. Justification for use of the generic destruction efficiencies must be provided in the project plan.

1.4 Glossary of Terms

Anaerobic Decomposition	A biological process in which bacteria break down organic matter in the absence of oxygen.
Cogeneration	The combined production of heat and electricity for use in industrial facilities. Electricity not used within the plant may be offered to the competitive electricity market.
Combustion	The oxidation of fuel/biomass that forms water and carbon dioxide in an exothermic reaction.
Destruction Efficiency	The efficiency of the combustion device in oxidizing the methane to carbon dioxide.
Heat	The useful thermal energy that is generated in a heat generation plant (e.g., a boiler, a cogeneration unit, thermal solar panels, etc.) and transferred to a heat carrier (e.g., hot liquids, hot gases, steam, etc.) for use in thermal applications and processes, including electricity generation but excluding waste heat.
Landfill	A waste management facility for the intentional placement of waste on or in land as the waste's final resting place (as per section 2(1)(i) of the *Environmental Protection and Enhancement Act* Activities Designation Regulation).
Landfill Gas (LFG)	Gas resulting from the decomposition of organic wastes placed in a landfill comprised primarily of methane, carbon dioxide, and other trace compounds.
Methane Surface Oxidation	The process that results when methanotrophic bacteria metabolize methane to carbon dioxide under aerobic conditions.
Municipal Solid Waste (MSW)	Non-hazardous waste materials picked up by a municipality or self-hauled to depots, transfer stations and disposal facilities. Municipal solid waste is composed of residential and non-residential materials from construction, renovation, and demolition or commercial and institutional waste.
Standard temperature and pressure	Standard conditions are defined to be 15 °C and 101.325 kPa (1 atm).
Waste	Any solid or liquid material or combination that is or is intended to be treated or disposed of or that is intended to be stored and then treated or disposed of, but does not include recyclables.
Waste Management Facility	A facility registered under the Alberta Code of Practice for Landfills or approved under Alberta's *Environmental Protection and Enhancement Act* or other legislation for the collection, storage, treatment or disposal of waste. In Alberta, all waste must be disposed in a waste management facility.

2.0 Baseline Condition

The baseline is the most appropriate and best estimate of GHG emissions that would have occurred in the absence of the project. The three baseline conditions that exist for this activity are:

1. Landfill gas that is passively vented to atmosphere
2. Landfill gas that is combusted in a flare; or
3. A combination of the two above scenarios.

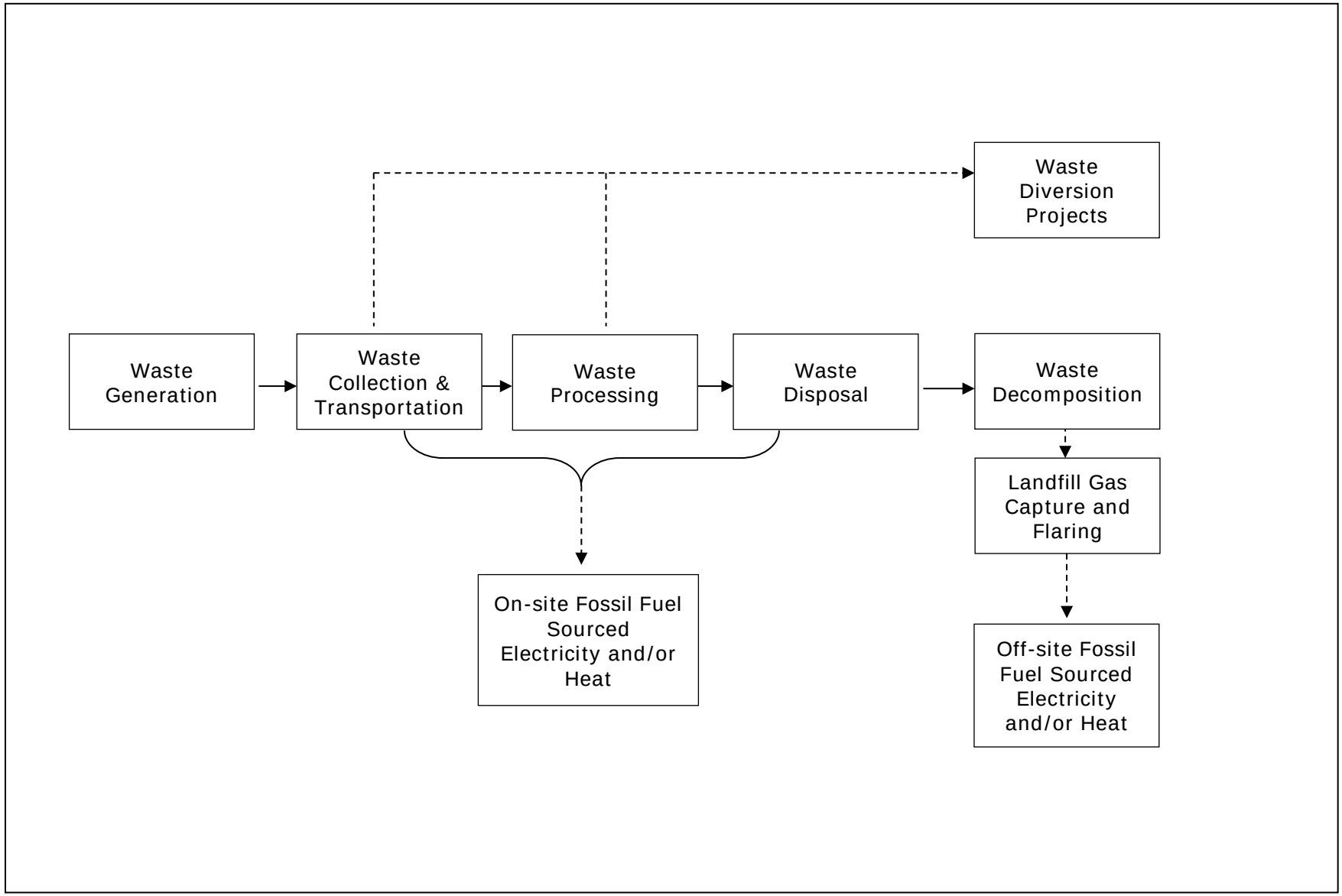
Emissions associated with heat and electricity generation, as well as on- and off-site energy, are quantified separately to ensure that the appropriate emission factors are used.

The protocol uses a dynamic, projection-based baseline for quantifying avoided landfill methane emissions. That is, baseline landfill gas emissions are projected based on the volume of landfill gas combusted in a flare or energy recovery device in the project condition with application of a methane oxidation factor to account for oxidation of methane by methanotropic bacteria as it passes through the landfill cover. Baseline fossil fuel use is calculated based on the net energy generation in the project and fossil fuel use in the baseline and project conditions. In baseline scenarios which include flaring of landfill gas, three years of records are required to support the extent of landfill gas flaring when determining the baseline condition.

The baseline GHG emissions are then calculated annually based on the net amount of landfill gas sourced energy generated in the project condition and the equivalent volume of fossil fuels that would have been used to meet the same energy needs in the absence of the project.

A simplified process flow diagram for possible baseline conditions is shown in Figure 2. More detail on each of these sources/sinks is provided in Section 2.1.

Figure 2: Simplified Process Flow Diagram for Possible Baseline Conditions



2.1 Identification of Baseline Sources and Sinks

The identification of sources and sinks in the baseline condition is based on ISO 14064-2:2006[1]: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements. Sources and sinks are determined to be either controlled, related or affected by the project and are defined as follows:

Controlled:	The behaviour or operation of a controlled source and/or sink is under the direction and influence of a project developer through financial, policy, management or other instruments.
Related:	A related source and/or sink has material and/or energy flows into, out of or within a project but is not under the reasonable control of the project developer.
Affected:	An affected source and/or sink is influenced by the project activity through changes in market demand or supply for projects or services associated with the project.

All sources and sinks were identified by reviewing the relevant process flow diagrams, consulting with technical experts and reviewing best practice guidance. This iterative process confirmed that sources/sinks in the process flow diagrams covered the full scope of eligible activities under this protocol.

Based on the process flow diagram provided, the baseline sources/sinks were organized into life cycle categories as provided in Figure 3. A description of each source/sink and its classification as controlled, related or affected is provided in Table 2.

[1] International Organization for Standardization. 2006. ISO 14064-2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements.

Figure 3: Baseline Sources and Sinks for Landfill Gas Capture and Combustion

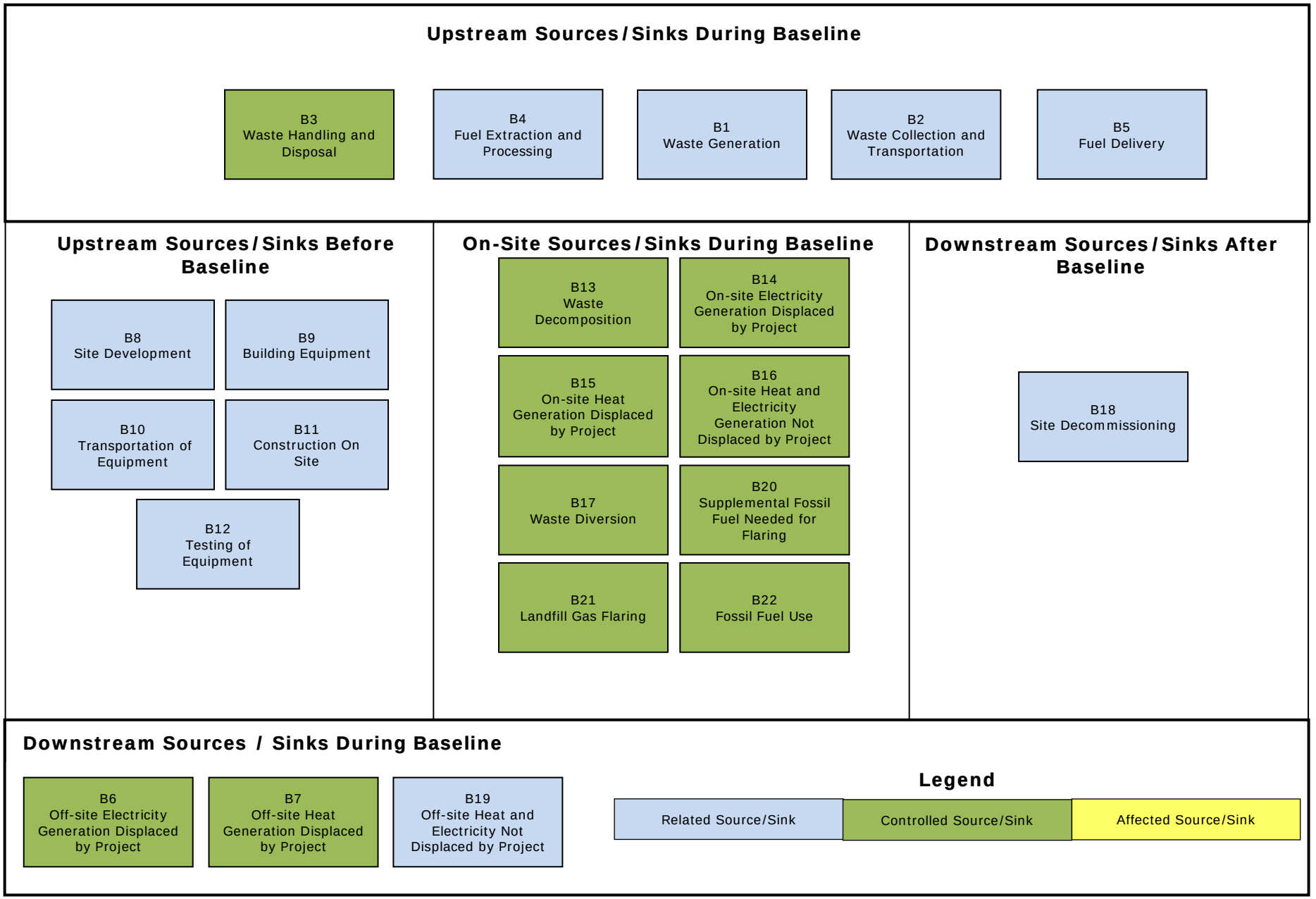


Table 2: Baseline Sources and Sinks

Sources/Sinks	Description	Controlled, Affected, Related
Upstream Sources and Sinks Before Baseline		
B8 - Site Development	Baseline site development could include: civil infrastructure such as access to electricity, natural gas and water supply, sewer, etc; clearing, grading, building access roads, etc; and building of structures for the facility such as storage areas and offices, and structures to enclose, support and house any equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site including, but not limited to graders, backhoes, trenching machines, etc.	Related
B9 - Building Equipment	Equipment may need to be built either on site or off site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabrication and assembly.	Related
B10 - Transportation of Equipment	Equipment built off site and the materials to build equipment on site need to be delivered to the site. Transportation may be completed by train, truck or other transportation. Greenhouse gas emissions are primarily attributed to the use of fossil fuels for transportation.	Related
B11 - Construction On Site	Site construction uses a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment has associated greenhouse gas emission from the use of fossil fuels and electricity.	Related
B12 - Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using fossil fuels in order to ensure that the equipment runs properly. These activities result in greenhouse gas emissions associated with the combustion of the test fuels and the use of electricity.	Related
Upstream Sources and Sinks During Baseline		
B1 - Waste Generation	Waste is generated when post-consumer and other wastes are sent for permanent disposal in a landfill.	Related

Sources/Sinks	Description	Controlled, Affected, Related
B2 - Waste Collection and Transportation	Solid waste may be transported to the project site by truck and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink. Type of equipment, number of loads and distance traveled would be used to evaluate functional equivalence with the project condition.	Related
B3 - Waste Handling and Disposal	Waste may be handled at a disposal site by transferring the waste from the transportation container, spreading, burying, processing, and otherwise dealing with the waste using a combination of loaders, conveyors and other mechanized devices. Greenhouse gas emissions result from the combustion of fossil fuel to operate the equipment. Volumes and types of fuels must be tracked.	Controlled
B4 - Fuel Extraction and Processing	Greenhouse gas emissions are associated with fossil fuel extraction and processing. Emissions are attributed to the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site sources/sinks are considered under this source/sink. Volumes and types of fuels must be tracked.	Related
B5 - Fuel Delivery	This source/sink accounts for emissions associated with transporting each of the fuels used on site to the site. This may include shipment by truck, rail or pipeline. Fuel sourced by taking equipment to an existing commercial fuelling station is excluded as the fuel used to take the equipment to the site is captured under other source/sinks.	Related
On-site Sources and Sinks During Baseline		
B13 - Waste Decomposition	This source/sink is applicable for projects that passively vent landfill gas to the atmosphere in the baseline condition. Waste decomposing in the landfill results in the production of methane. GHG emissions from waste decomposition are accounted by measuring the volume of landfill gas collected and combusted or included in a natural gas pipeline network to determine the amount of landfill gas that would have been released in the absence of an operating landfill gas capture system. A methane oxidation factor is applied to account for oxidation of methane by methanotrophic bacteria as methane travels through the landfill cover system.	Controlled
B14 - On-site Electricity Generation Displaced by Project	This source represents the emissions from on-site generation that occurred in the baseline that would have been replaced by the project. This could be all or part of the historic electricity generation onsite. The emissions from this source are calculated using site specific emission factors.	Controlled

Sources/Sinks	Description	Controlled, Affected, Related
B15 - On-site Heat Generation Displaced by Project	This source/sink represents the emissions from on-site heat generation that has been replaced by the project. This could be all or part of the historic heat generation on site. The emissions from this source/sink are calculated using site specific factors for the baseline heat production on-site. Changes in the heat demand or other forms of efficiency that reduce the heat load of the facility are not included, but may be eligible under other offset protocols.	Controlled
B16 - On-Site Heat and Electricity Generation Not Displaced by Project	On-site emissions related to electricity and heat use which continue after the project is implemented. These emissions are a continuation of the baseline condition and are not impacted by the project.	Controlled
B17 - Waste Diversion	Waste management facilities manage wastes through a number of on- and off-site initiatives including waste disposal, waste diversion and waste minimization. Waste diversion programs must be documented and must not be adversely impacted by the installation of the landfill gas capture project, but emissions associated with waste diversion are excluded from the greenhouse gas quantification.	Controlled
B20 - Supplemental Fossil Fuel Needed for Flaring	This source/sink is applicable for projects that have flaring in the baseline condition. This source/sink represents the emissions resulting from additional fossil fuel needed to increase the heat content of gas sent to flare to meet the destruction efficiency for the flare.	Controlled
B21 - Landfill Gas Flaring	This source/sink is applicable for projects that have flaring in the baseline condition. Carbon dioxide, methane and nitrous oxide are emitted as a result of landfill gas flaring. Methane and nitrous oxide produced from landfill gas flaring will be included in this source/sink.	Controlled
B22 - Fossil Fuel Use	This source/sink is applicable for projects that have flaring in the baseline condition. This source/sink includes the greenhouse gas emissions resulting from fossil fuel used for the operation of the landfill gas capture and combustion system. This may also include emissions associated with upgrading of landfill gas for flare.	Controlled
Downstream Sources and Sinks During Project		
B6 - Off-site Electricity Generation Displaced by Project	Emissions associated with generation of electricity off-site which have been displaced through the project activity. This occurs either through the export of electricity off site and/or reduced import of grid electricity.	Controlled

Sources/Sinks	Description	Controlled, Affected, Related
B7 - Off-site Heat Generation Displaced by Project	Emissions associated with generation of heat off-site which have been displaced through the project activity. This occurs through the export of heat off-site and/or reduced import of heat that was generated off-site.	Controlled
B19 - Off-site Heat and Electricity Not Displaced by Project	The remainder of off-site emissions associated with heat and electricity generation which has not been displaced in the project condition.	Related
Downstream Sources and Sinks After Project		
B18 - Site Decommissioning	Once the facility is no longer operational, the site must be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off site. Greenhouse gas emissions are primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

3.0 Project Condition

The project condition is the capture and combustion of landfill gas in a flare, for energy generation, or placement into a natural gas pipeline. GHG emission reductions are achieved through the combustion of methane in landfill gas and, if applicable, the displacement of fossil fuel energy. Projects that were passively venting methane in the baseline can combust landfill gas in a flare, combust landfill gas for energy generation, or place landfill gas into a natural gas pipeline. Projects that were capturing and flaring landfill gas in the baseline condition may implement an on-site energy recovery project and qualify for emission offsets for the energy displacement.

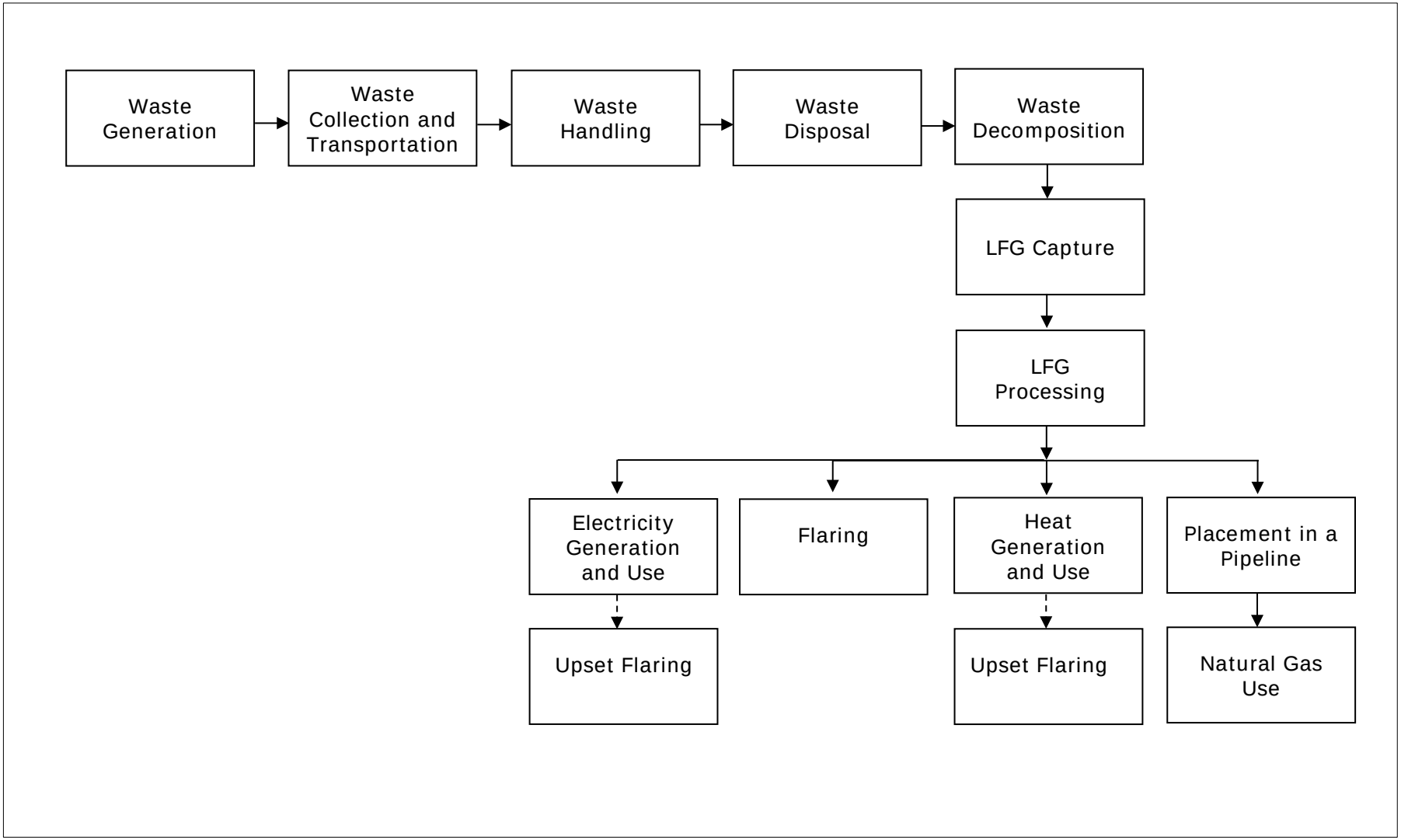
Projects that are upgrading and placing landfill gas into a natural gas pipeline where the ownership of the reduction is established[2] can qualify for emission offsets for the reductions that are achieved through the destruction of methane. Such projects may also be eligible for the end-user's displacement of fossil fuel energy with the landfill gas sourced energy as long as the project proponent can clearly demonstrate the end-user fuel use is the landfill gas.

In all cases, the destruction efficiency provided by the manufacturer must be used. If the device has no known destruction efficiency, the project proponent must reference default destruction efficiencies from Table A1: Default Values for Methane Destruction Efficiency to quantify greenhouse gas emission reductions for landfill gas combustion. Justification for using the default destruction efficiency in Table A1 must be provided.

A process flow diagram for the project condition is provided in Figure 4. More detail on each of these sources/sinks is provided in Section 3.1.

[2] Must be able to demonstrate that no other credits are being claimed for methane destruction.

Figure 4: Simplified Process Flow Diagram for Possible Project Condition



3.1 Identification of Project Sources and Sinks

Figure 5 provides a list of sources and sinks associated with landfill gas capture and combustion projects. All included sources and sinks applicable to the project must be identified in the project plan. If a source or sink is not applicable to the project, sufficient justification must be provided to support the exclusion.

Based on the process flow diagram provided in Figure 4, the project sources and sinks were organized into life cycle categories as provided in Figure 5. Descriptions of each of the sources and sinks and their classification as controlled, related or affected are provided in Table 3.

Figure 5: Project Conditions Sources and Sinks for Landfill Gas Capture and Combustion

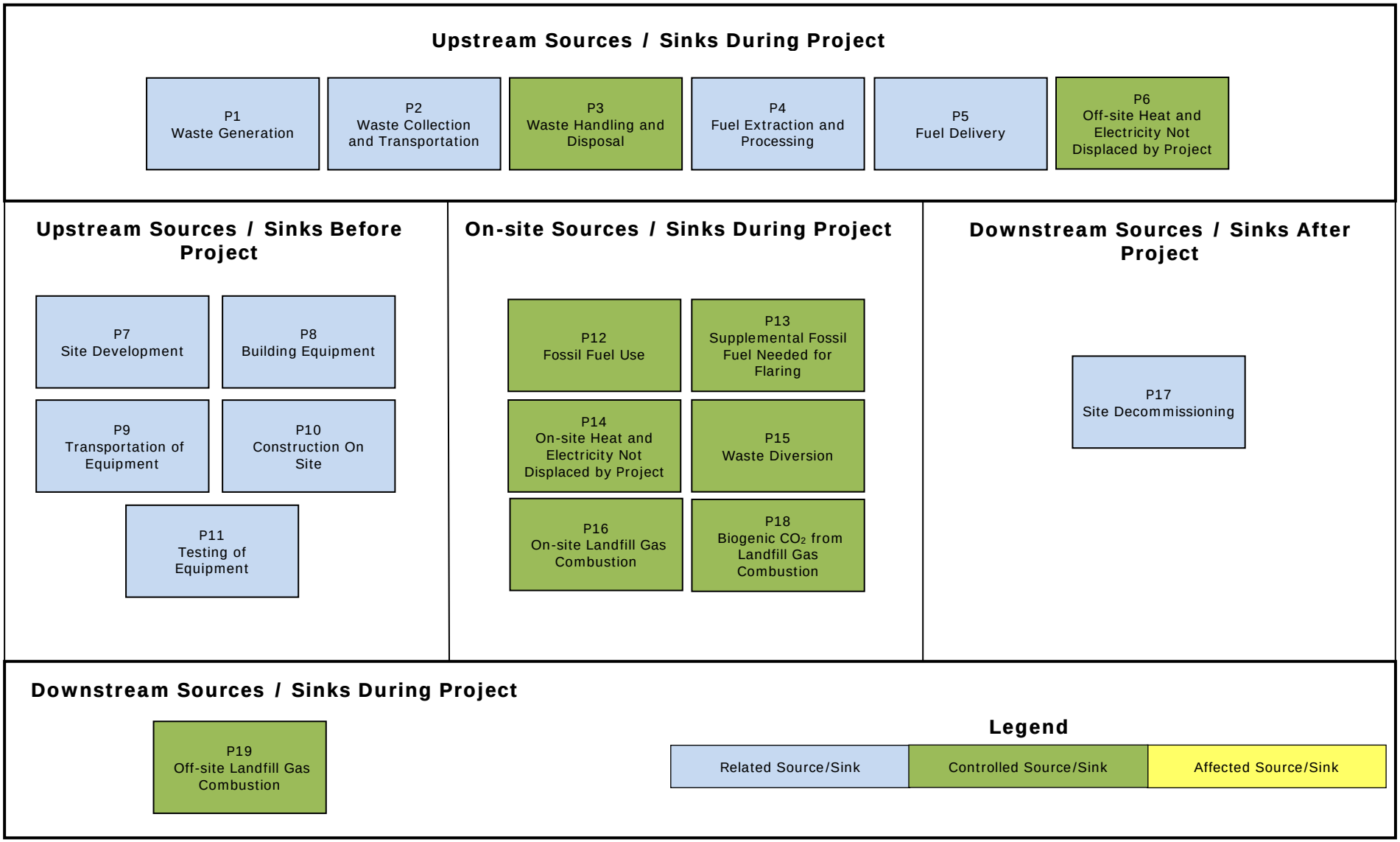


Table 3: Project Condition Sources and Sinks

Sources/Sinks	Description	Controlled, Affected, Related
Upstream Sources and Sinks Before Project		
P7 - Site Development	Greenhouse gas emissions associated with site preparation and development for the landfill gas capture and combustion system results are associated with preparing civil infrastructure such as access to electricity, natural gas, water supply, sewer, clearing, grading, building access roads, construction of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, and enclose, support and house the equipment.	Related
P8 - Building Equipment	New equipment may need to be built, either on or off site. This includes all of the components of the new system, including, but not limited to, storage, handling, processing, combustion, air system controls and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. These activities generate greenhouse gas emissions from the use of fossil fuels and electricity to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
P9 - Transportation of Equipment	Greenhouse gas emissions are associated with fuel combustion to transport equipment and materials to the site. Transportation may be completed by train, truck or combination.	Related
P10 - Construction On-Site	Greenhouse gas emissions are associated with the use fossil fuels and electricity to power heavy equipment, smaller power tools, cranes and generators used to construct the site.	Related
P11 - Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
Upstream Sources and Sinks During Project		
P1 - Waste Generation	Waste is generated when post-consumer and other wastes are sent for permanent disposal in a landfill.	Related
P2 - Waste Collection and Transportation	Solid waste may be transported to the project site by truck and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink. Type of equipment, number of loads and distance traveled would be used to evaluate functional equivalence with the baseline condition.	Related
P3 - Waste Handling and	Waste may be handled at a disposal site by transferring the waste from the transportation container, spreading, burying, processing or otherwise dealing with the waste using a combination of loaders,	Controlled

Sources/Sinks	Description	Controlled, Affected, Related
Disposal	conveyors and other mechanized devices. Greenhouse gas emissions result from the combustion of fossil fuel to operate the equipment. Volumes and types of fuels must be tracked.	
P4 - Fuel Extraction and Processing	Greenhouse gas emissions are associated with fossil fuel extraction and processing. Emissions are attributed to the various processes involved in the production, refinement, and storage of the fuels. The total volumes of fuel for each of the on-site sources/sinks are considered under this source/sink. Volumes and types of fuels must be tracked.	Related
P5 - Fuel Delivery	This source/sink accounts for emissions associated with transporting each of the fuels used on site to the site. This may include shipment by truck, rail or pipeline. Fuel sourced by taking equipment to an existing commercial fuelling station is excluded as the fuel used to take the equipment to the site is captured under other source/sinks.	Related
P6 - Off-site Heat and Electricity Not Displaced	Emissions associated with off-site electricity and heat generation that has not been displaced by the project activity.	Controlled
On-site Sources and Sinks During Project		
P12 - Fossil Fuel Use	This source/sink includes the greenhouse gas emissions resulting from fossil fuel used for the operation of the landfill gas capture and combustion system. This may also include emissions associated with upgrading of landfill gas for flare.	Controlled
P13 - Suppemental Fossil Fuel Needed for Flaring	This represents the emissions resulting from additional fossil fuel needed to increase the heat content of gas sent to flare to meet the destruction efficiency for the flare.	Controlled
P14 – On-site Heat and Electricity Not Displaced	The emissions associated with pre-existing and non-project related on-site heat and electricity generation that have not been displaced by heat or electricity produced by the project.	Controlled
P15 - Waste Diversion	Waste management facilities manage wastes through a number of on- and off-site initiatives including waste disposal, waste diversion and waste minimization. Waste diversion programs must be documented, and must not be adversely impacted by the installation of the landfill gas capture project, but emissions associated with waste diversion are excluded from the greenhouse gas quantification.	Controlled

Sources/Sinks	Description	Controlled, Affected, Related
P16 – On-site Landfill Gas Combustion	Carbon dioxide, methane and nitrous oxide are emitted as a result of on-site combustion of landfill gas. Methane and nitrous oxide produced from the combustion of landfill gas will be included in this source/sink.	Controlled
P18 – Biogenic CO_2 from Landfill Gas Combustion	Carbon dioxide, methane and nitrous oxide are emitted as a result of combustion of landfill gas. The carbon dioxide produced is biogenic, and will be included in this source/sink. This will include the biogenic carbon dioxide for both on and off-site landfill gas combustion.	Controlled
Downstream Sources and Sinks During Project		
P19 – Off-site Landfill Gas Combustion	If the landfill gas is placed into a natural gas pipeline, carbon dioxide, methane and nitrous oxide are emitted as a result of downstream combustion of the landfill gas. Methane and nitrous oxide produced from the downstream combustion of landfill gas will be included in this source/sink.	Controlled
Downstream Sources and Sinks After Project		
P17 - Site Decommissioning	Once the facility is no longer operational, the site must be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off site. Greenhouse gas emissions are primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

4.0 Quantification

Baseline and project conditions were assessed against each other to determine the scope for reductions quantified under this protocol. Sources and sinks were either included or excluded depending on how they were impacted by the project condition. Sources that are not expected to change between baseline and project conditions are excluded and not quantified as it is assumed that excluded activities will occur at the same magnitude and emission rate during the baseline and project.

Emissions that increase or decrease as a result of the project must be included and associated greenhouse gas emissions must be quantified as part of the project condition.

Table 4 lists all sources and sinks as included or excluded and provides rationale, whereas Table 5 outlines the quantification methodologies for all included sources and sinks.

Table 4: Comparison of Sources and Sinks

Identified Sources and Sinks	Baseline (C, R, A)*	Project (C, R, A)*	Include or Exclude from Quantification	Justification
Upstream Sources and Sinks Before Project				
B8 – Site Development	R	N/A	Exclude	Emissions associated with site development are minimal relative to overall project emissions and are expected to be comparable between baseline and project site development.
P7 – Site Development	N/A	R		
B9 – Building Equipment	R	N/A	Exclude	Emissions associated with building equipment are expected to be similar between the baseline and project condition.
P8 – Building Equipment	N/A	R		
B10 – Transportation of Equipment	R	N/A	Exclude	Emissions associated with the transportation of equipment are expected to be similar in the baseline and project condition.
P9 – Transportation of Equipment	N/A	R		
B11 – Construction On Site	R	N/A	Exclude	Emissions associated with construction on site are expected to be similar in the baseline and project condition.
P10 – Construction On Site	N/A	R		
B12 – Testing of Equipment	R	N/A	Exclude	Emissions associated with the testing of equipment are expected to be similar in the baseline and project condition.
P11 – Testing of Equipment	N/A	R		
Upstream Sources and Sinks During Project				
B1 – Waste Generation	R	N/A	Exclude	The generation of solid waste is not impacted by the project. Emissions during the baseline and project are expected to be equivalent.
P1 – Waste Generation	N/A	R		
B2 – Waste Collection and Transportation	R	N/A	Exclude	The generation of greenhouse gas emissions due to transportation of waste is expected to be equivalent in the baseline and project condition.
P2 – Waste Collection and Transportation	N/A	R		

Identified Sources and Sinks	Baseline (C, R, A)*	Project (C, R, A)*	Include or Exclude from Quantification	Justification
B3 – Waste Handling and Disposal	C	N/A	Exclude	The generation of greenhouse gas emissions due to waste processing and disposal is expected to be equivalent in the baseline and project condition.
P3 – Waste Handling and Disposal	N/A	C		
B4 – Fuel Extraction and Processing	R	N/A	**Include**	Included to take into account emissions resulting from fuel extraction and processing for fuels used to operate landfill gas combustion by flaring in the baseline condition.
P4 – Fuel Extraction and Processing	N/A	R	**Include**	Included to take into account emissions resulting from fuel extraction and processing for fuels used to operate the project activity.
B5 – Fuel Delivery	R	N/A	Exclude	The emissions from fuel delivery are expected to be the same in the baseline and project condition.
P5 – Fuel Delivery	N/A	R		
P6 – Off-site Fossil Fuel Generated Heat and Electricity Not Displaced by Project	N/A	R	Exclude	The emissions for this generation will be the same in the baseline and project condition.
On-site Sources/Sinks During Project				
B13 – Waste Decomposition	C	N/A	**Include**	This source/sink is applicable for projects that passively vent methane to the atmosphere in the baseline condition. The avoided emissions resulting from waste decomposition are quantified by measuring the volume of landfill gas combusted or placed into a natural gas pipeline (in the project condition).
B14 – On-site Electricity Generation Displaced by the Project	C	N/A	**Include**	These emissions occur from fossil fuel-generated heat and electricity generated on-site in the baseline condition that are displaced by on-site heat and electricity generation in

Identified Sources and Sinks	Baseline (C, R, A)*	Project (C, R, A)*	Include or Exclude from Quantification	Justification
B15 – On-site Heat Generation Displaced by the Project	C	N/A		the project condition.
B22 – Fossil Fuel Use	C	N/A	**Include**	The consumption of fossil fuels is subject to the carbon levy under the *Climate Leadership Act*. This source/sink is required to be quantified but is not eligible for emission offsets. The emissions resulting from fossil fuel used to run the landfill gas combustion and recovery system are included.
P12 – Fossil Fuel Use	N/A	C	**Include**	The consumption of fossil fuels is subject to the carbon levy under the *Climate Leadership Act*. This source/sink is required to be quantified but is not eligible for emission offsets. The emissions resulting from fossil fuel used to run the landfill gas combustion and recovery system are included.
B20 – Supplemental Fossil Fuel Needed for Flaring	C	N/A	**Include**	This source/sink is applicable for projects that have flaring in the baseline condition. These emissions result from fossil fuel used to maintain the heat content of the landfill gas to ensure destruction efficiency of the flare.
P13 – Supplemental Fossil Fuel Needed for Flaring	N/A	C	**Include**	These emissions result from fossil fuel used to maintain the heat content of the landfill gas to ensure destruction efficiency of the flare.
B16 – On-site Heat and Electricity Not Displaced by Project	C	N/A	Exclude	These emissions are from on-site heat or electricity generation that are not displaced by the project and remain the same between the baseline and project condition.
P14 – On-site Heat and Electricity Not Displaced by Project	N/A	C		

Identified Sources and Sinks	Baseline (C, R, A)*	Project (C, R, A)*	Include or Exclude from Quantification	Justification
B17 – Waste Diversion P15 – Waste Diversion	C N/A	N/A C	Exclude	These emissions are associated with waste diversion initiatives and are excluded. The project developer must document waste diversion initiatives. The project cannot result in adverse impacts on waste diversion initiatives.
B21 – Landfill Gas Flaring	C	N/A	**Include**	This source/sink is applicable for projects that have flaring in the baseline condition. These emissions result from flaring landfill gas. Methane and nitrous oxide are quantified under this source/sink.
P16 – On-site Landfill Gas Combustion	N/A	C	**Include**	These emissions result from on-site landfill gas combustion by flaring or in energy recovery systems. Methane and nitrous oxide are quantified under this source/sink.
P18 – Biogenic CO_2 from Landfill Gas Combustion	N/A	C	**Include**	These emissions result from landfill gas combustion by flaring or in energy recovery systems. Carbon dioxide is quantified under this source/sink and is considered to be biogenic.
Downstream Sources/Sinks During the Project				
P19 – Off-site Landfill Gas Combustion	N/A	C	**Include**	These are emissions from downstream landfill gas combustion resulting from placement into a natural gas pipeline network. Methane and nitrous oxide are quantified under this source/sink.
B6 – Off-site Electricity Generation Displaced by Project	C	N/A	**Include**	Included as these emissions displaced through the export of electricity off site or the reduction of grid electricity use as a result of the project.

Identified Sources and Sinks	Baseline (C, R, A)*	Project (C, R, A)*	Include or Exclude from Quantification	Justification
B7 – Off-site Heat Generation Displaced by Project	C	N/A	**Include**	Included as these are the off-site fossil fuel generated emissions displaced through the export of heat off site as a result of the project.
B19 – Off-site Heat and Electricity Not Displaced by Project	R	N/A	Exclude	The emissions for this generation will be the same in the baseline and project condition.
Downstream Sources/Sinks After the Project				
B18 – Site Decommissioning	R	N/A	Exclude	These emisions are from decommissioning and are not material given the long project life.
P17 – Site Decommissioning	N/A	R		

* Where C is Controlled, R is Related, and A is Affected.

4.1 Quantification Methodology

Net emission reductions are quantified by calculating emissions from included sources and sinks in both the baseline and in the project and then calculating the net change. Outlined below is the general approach to quantifying greenhouse gas emission reductions and offset eligible emissions reductions, as stated in ISO 14064-2:2006.

4.1.1 Net Emission Reductions

Net emission reductions are the emission reductions calculated by comparing all quantified sources and sinks in the baseline and project conditions. The net emission reduction of a project can be calculated by using the following equation.

$$\textbf{Net Emissions Reductions} = \textbf{Emissions}_{\textbf{Baseline}} - \textbf{Emissions}_{\textbf{Project}}$$

where:

$\text{Emissions}_{\text{Baseline}}$ = $\text{Emissions}_{\text{Fuel Extraction/Processing}}$ + $\text{Emissions}_{\text{Off-site Electricity Displacement}}$ + $\text{Emissions}_{\text{Off-site Heat Generation}}$ + $\text{Emissions}_{\text{Waste Decomposition}}$ + $\text{Emissions}_{\text{On-site Electricity Displacement}}$ + $\text{Emissions}_{\text{On-site Heat Generation}}$ + $\text{Emissions}_{\text{Fuel for Flare}}$ + $\text{Emissions}_{\text{LFG Flaring}}$ + $\text{Emissions}_{\text{Fossil Fuel Use}}$

$\text{Emissions}_{\text{Baseline}}$ = sum of the emissions under the baseline condition

= Emissions from B4 Fuel Extraction and Processing
+Emissions from B6 Off-site Electricity Generation Displaced by Project
+ Emissions from B7 Off-site Heat Generation Displaced by Project
+ Emissions from B13 Waste Decomposition
+ Emissions from B14 On-site Electricity Generation Displaced by Project
+ Emissions from B15 On-site Heat Generation Displaced by Project
+ Emissions from B20 Supplemental Fossil Fuel Needed for Flaring
+ Emissions from B21 Landfill Gas Flaring
+ Emissions from B22 Fossil Fuel Use

and

$\text{Emissions}_{\text{Project}}$ = $\text{Emissions}_{\text{Fuel Extraction/Processing}}$ + $\text{Emissions}_{\text{Fossil Fuel Use}}$ + $\text{Emissions}_{\text{Fuel for Flare}}$ + $\text{Emissions}_{\text{On-site LFG Combustion}}$ + $\text{Emissions}_{\text{Off-site LFG Combustion}}$ + $\text{Emissions}_{\text{Biogenic LFG Combustion}}$

$\text{Emissions}_{\text{Project}}$ = sum of the emissions under the project condition

= Emissions from P4 Fuel Extraction and Processing
+ Emissions from P12 Fossil Fuel Use
+ Emissions from P13 Supplemental Fossil Fuel Needed for Flaring
+ Emissions from P16 On-site Landfill Gas Combustion
+ Emissions from P19 Off-site Landfill Gas Combustion

4.1.2 Offset Eligible Reductions

Offset eligible reductions are the emission reductions eligible for generating emission offsets calculated by comparing offset eligible sources and sinks in the baseline and project conditions. The offset eligible emission reductions can be calculated by using the following equation.

Offset Eligible Emissions Reductions = Emissions $_{\text{Non-levied Baseline}}$ – Emissions $_{\text{Non-levied Project}}$

where:

$\text{Emissions}_{\text{Non-levied Baseline}}$ = $\text{Emissions}_{\text{Waste Decomposition}}$ + $\text{Emissions}_{\text{Fuel Extraction/Processing}}$ + $\text{Emissions}_{\text{Off-site Electricity Displacement}}$ + $\text{Emissions}_{\text{On-site Electricity Displacement}}$ + $\text{Emissions}_{\text{LFG Flaring}}$

$\text{Emissions}_{\text{Non-levied Baseline}}$ = sum of the emissions under the baseline condition that are not subject to the carbon levy

= Emissions from B13 Waste Decomposition
+ Emissions from B4 Fuel Extraction and Processing
+ Emissions from B6 Off-site Electricity Generation Displaced by Project
+ Emissions from B14 On-site Electricity Generation Displaced by Project
+ Emissions from B21 Landfill Gas Flaring

and

$\text{Emissions}_{\text{Non-levied Project}}$ = $\text{Emissions}_{\text{Fuel Extraction/Processing}}$ + $\text{Emissions}_{\text{On-site LFG Combustion}}$ + $\text{Emissions}_{\text{Off-site LFG Combustion}}$

$\text{Emissions}_{\text{Non-levied Project}}$ = sum of the emissions under the project condition that are not subject to the carbon levy

= Emissions from P4 Fuel Extraction and Processing
+ Emissions from P16 On-site Landfill Gas Combustion
+ Emissions from P19 Off-site Landfill Gas Combustion

4.1.3 Levied Fuel Emissions (reported but not included in offset calculation)

Levied fuel emissions are quantified by calculating the levied fuel sources and sinks as outlined in Table 5. The levied fuel emission reductions can be calculated by using the following equation.

Levied Emissions Reductions = Emissions $_{\text{Levied Baseline}}$ – Emissions $_{\text{Levied Project}}$

where:

$\text{Emissions}_{\text{Levied Baseline}}$ = $\text{Emissions}_{\text{On-site Heat Generation}}$ + $\text{Emissions}_{\text{Off-site Heat Generation}}$ + $\text{Emissions}_{\text{Fuel for Flare}}$ + $\text{Emissions}_{\text{Fossil Fuel Use}}$

Emissions $_{\text{Levied Baseline}}$ = sum of the emissions under the baseline condition that are subject to the carbon levy.

= Emissions from B15 On-site Heat Generation Displaced by Project
+ Emissions from B7 Off-site Heat Generation Displaced by Project
+ Emissions from B20 Supplemental Fossil Fuel Needed for Flaring
+ Emissions from B22 Fossil Fuel Use

and

Emissions $_{\text{Levied Project}}$ = Emissions $_{\text{Fossil Fuel Use}}$ + Emissions $_{\text{Fuel for Flare}}$

Emissions $_{\text{Levied Project}}$ = sum of the emissions under the project condition that are subject to the carbon levy

= Emissions from P12 Fossil Fuel Use
+ Emissions from P13 Supplemental Fossil Fuel Needed for Flaring

4.1.4 Biogenic CO_2 Emissions (reported but not included in offset calculation)

Biogenic CO_2 emissions are quantified by calculating the biogenic CO_2 sources and sinks as outlined in Table 5. The biogenic CO_2 emission reductions can be calculated by using the following equation.

Biogenic CO_2 Emissions = Emissions $_{\text{Biogenic Project}}$

where:

Emissions $_{\text{Biogenic Project}}$ = Emissions $_{\text{Biogenic LFG Combustion}}$

Emissions $_{\text{Biogenic Project}}$ = sum of the biogenic CO_2 emissions under the project condition.

= Emissions from P18 Biogenic CO_2 from Landfill Gas Combustion

The quantification equations provided in Table 5 on the following pages calculate total emissions in carbon dioxide equivalent (tonnes CO_2e). The project developer will be required to calculate emissions for each source and sink in the baseline and project condition for each relevant greenhouse gas (carbon dioxide, methane, and nitrous oxide).

Table 5: Quantification Methodology

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
Baseline Condition						
B13 - Waste Decomposition	$Emissions_{Waste\ Decomposition} = Vol_{LFG} * F_{CH4} * \rho_{CH4} * (1 - OX) * GWP_{CH4}$					
	$Emissions_{Waste\ Decomposition}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol_{LFG} Volume of Landfill Gas Combusted or Placed into Pipeline	m^3_{LFG}	Measured (measured or adjusted to represent at standard temperature and pressure)	Direct measurement of landfill gas volume	Continuous metering	Frequency of metering is at highest level possible. Frequency of reconciliation provides for reasonable diligence.
	F_{CH4} Average Fraction of Methane in the Landfill Gas	m^3_{CH4} / m^3_{LFG}	Measured	Direct measurement	Monthly sampling or more frequent	Landfill gas composition should remain relatively stable during steady-state operation.
	ρ_{CH4} Density of methane	tonnes CH_4 / m^3_{CH4}	Estimated	0.0006785 at standard temperature and pressure	N/A	If this value is used, all volumes must be adjusted for standard temperature and pressure. Agreement must be achieved between volume and density of methane in the measurement. Values for CH_4 density at other reference temperatures can be found in Table A2.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	OX Methane Oxidation	%	Estimated	Provided in the Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP $_{CH4}$ Global Warming Potential for CH_4	Unitless	Estimated	Provided in the Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
B15 - On-site Heat Generation Displaced by Project	If ($Hg_{proj} - Hc_{proj}$) < 0, then: $Emissions_{On\text{-}site\ Heat\ Generation} = 0$ Otherwise: $Emissions_{On\text{-}site\ Heat\ Generation} = EF_{HO} *$ lesser of [($Hg_{proj} - Hc_{proj}$), $Hg_{historic}$]					
	Emissions $_{On\text{-}site\ Heat\ Generation}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Hg_{proj} Heat Generated by Project	GJ	Measured	Direct metering of heat produced by the project	Continuous Metering	Continuous direct metering represents the industry practice and the highest level of detail. Pressure, temperature, and flow rate are measured to provide heat generated.
	Hc_{proj} Heat Consumed by the Project	GJ	Measured	Direct metering of all heat consumed by the project	Continuous Metering	Continuous direct metering represents the industry practice and the highest level of detail.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$Hg_{historic}$ Historic Level of On-site Heat Generation	GJ	Calculated	Average of measured on-site generation for three years preceding the project	Continuous Metering	Historic heat generated must be shown to go to a useful purpose. The baseline for new facilities assumes that heat was produced on site using natural gas.
	EF_{HO} Heat Emissions Factor	tonnes CO_2e per GJ	Estimated	Calculated based on historic performance of on-site heat generation (emissions of three previous years for heat generation divided by total generation for three previous years)	Annual	This site specific emissions factor must be used.
B7 - Off-site Heat Generation Displaced by Project	$Emissions_{Off\text{-}site\ Heat\ Generation} = EF_{HE} * \text{maximum of } [(Hg_{proj} - Hc_{proj} - Hg_{historic}), 0]$					
	$Emissions_{Off\text{-}site\ Heat\ Generation}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated. Heat exported must be shown to go to a useful purpose.
	Hg_{proj} Heat Generated by Project	GJ	Measured	Direct metering of all heat produced by the project	Continuous Metering	Continuous direct metering represents the industry practice and the highest level of detail. Pressure, temperature, and flow rate are measured to provide heat generated.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Hc_{proj} Heat Consumed by the Project	GJ	Measured	Direct metering of all heat consumed by the project	Continuous Metering	Continuous direct metering represents the industry practice and the highest level of detail.
	$Hg_{historic}$ Historic Level of On-site Heat Generation	GJ	Calculated	Average of measured on-site generation for three years preceding the project	Continuous Metering	Historic heat generated must be shown to go to a useful purpose.
	EF_{HE} Heat Export Emissions Factor	tonnes CO_2e per GJ	Calculated	Calculated based on historic performance of off-site heat generation (emissions of three previous years for heat generation divided by total generation for three previous years)	Annual	This site specific emissions factor must be used.
B4 – Fuel Extraction and Processing	$Emission_{Fuel\ Extraction/Processing} = [\sum (Vol_{Fuel\ i} * EF_{i\ CO2}) + \sum (Vol_{Fuel\ i} * EF_{i\ CH4} * GWP_{CH4}) + \sum (Vol_{Fuel\ i} * EF_{i\ N2O} * GWP_{N2O})\ ] / 1000$					
	$Emission_{Fuel\ Extraction/Processing}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Vol_{Fuel\ i}$ Volume of Fuel Combusted (In B20 and B22)	L, m^3, or Other	Measured	Direct metering or reconciliation of volume in storage (including volumes received)	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$EF_{i\ CO2}$ CO_2 Emission Factor for Extraction and Processing of Each Fuel	kg CO_2 per L, m^3, or other	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	$EF_{i\ CH4}$ CH_4 Emission Factor for Extraction and Processing of Each Fuel	kg CH_4 per L, m^3, or other	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	$EF_{i\ N2O}$ N_2O Emission Factor for Extraction and Processing of Each Fuel	kg N_2O per L, m^3, or other	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP_{CH4} Global Warming Potential for CH_4	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP_{N2O} Global Warming Potential for N_2O	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
B6 – Off-site	$Emissions_{Off\text{-}site\ Electricity\ Displacement} = EF_{EG} * (Eg_{proj} – Ec_{proj})$					

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
Electricity Generation Displaced by Project	Emissions $_{\text{Off-site Electricity Displacement}}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Eg_{proj} Electricity Generated by Project	MWh	Measured	Direct metering of all electricity produced by the project	Continuous Metering	Continuous direct metering represents the industry practice and the highest level of detail.
	Ec_{proj} Electricity Consumed by the Project	MWh	Measured	Direct metering of all electricity consumed by the project	Continuous Metering	Continuous direct metering represents the industry practice and the highest level of detail.
	EF_{EG} Electricity Grid Displacement Factor	tonnes CO_2e per MWh	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
B14 – On-site Electricity Generation Displaced by Project	If $(Eg_{proj} - Ec_{proj}) < 0$, then: $\text{Emissions}_{\text{On-site Electricity Displacement}} = EF_{EG} * (Eg_{proj} - Ec_{proj})$ or $EF_{EO} * (Eg_{proj} - Ec_{proj})$ Otherwise: $\text{Emissions}_{\text{On-site Electricity Displacement}} = EF_{EO} *$ lesser of $[(Eg_{proj} - Ec_{proj}), Eg_{historic}]$					

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Emissions $_{\text{On-site Electricity Displacement}}$	tCO_2e	N/A	N/A	N/A	Quantity being calculated. B14 can result in negative values if the project consumes more electricity than it generates, and makes up the deficit via on-site electricity generation or import from the grid. Site specific or grid factor must be used accordingly.
	Eg_{proj} Electricity Generated by Project	MWh	Measured	Direct metering of all electricity produced by the project	Continuous Metering	Continuous direct metering represents the industry practice and the highest level of detail.
	Ec_{proj} Electricity Consumed by the Project	MWh	Measured	Direct metering of all electricity consumed by the project	Continuous Metering	Continuous direct metering represents the industry practice and the highest level of detail.
	$Ec_{historic}$ Historic Level of On-site Electricity Generation	MWh	Calculated	Average of measured on-site generation for three years preceding the project	Continuous Metering	On-site displacement should not exceed historic levels of on-site generation.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF_{EO} Electricty Emissions On-site Factor	tCO_2e / MWh	Estimated	Calculated based on historic performance of on-site electricity generation (emissions of three previous years for electricity generation divided by total generation for three previous years)	Annual	This site specific emission factor must be used. New builds must use the grid factor published by the department.
	EF_{EG} Electricty Emissions Grid Factor	tCO_2e / MWh	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
B20 – Supplemental Fossil Fuel Needed for Flaring	$Emissions_{Fuel\ for\ Flare} = Vol_{Fuel} * EF_{CO2} / 1000 + Vol_{Fuel} * F_{CH4} * \rho_{CH4} * (1 - DE_{CH4}) * GWP_{CH4} + Vol_{Fuel} * EF_{N2O} * GWP_{N2O} / 1000$					
	$Emissions_{Fuel\ for\ Flare}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol_{Fuel} Volume of supplemental fossil fuel used	m^3	Measured	Direct metering or reconciliation of volumes transferred	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	F_{CH4} Average Volume Fraction of Methane in the Supplemental Fossil Fuel	m^3_{CH4} / m^3_{NG}	Estimated or measured based on invoicing	At standard conditions	Estimated or measured each invoicing interval	According to the supplier's specifications
	ρ_{CH4} Density of methane	tonnes CH_4 / m^3_{CH4}	Constant	0.0006785 at standard temperature and pressure	N/A	If this value is used, all volumes must be adjusted for standard temperature and pressure. Agreement must be achieved between volume and density of methane in the measurement. Values for CH_4 density at other reference temperatures can be found in Table A2.
	DE Destruction Efficiency of the flare	%	Estimated	Methane destruction efficiency of the combustion device. To be obtained from manufacturer or vendor's specifications (or from Appendix A: Default Values for Methane Destruction Efficiency)	N/A	The manufacturer or vendor's specifications represent the industry practice and the highest level of detail.
	GWP_{CH4} Global Warming Potential for CH_4	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF_{CO2} Emission factor for carbon dioxide as a result of fossil fuel combustion	kg CO_2 / m^3	Constant	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	EF_{N2O} Emission factor for nitrous oxide as a result of fossil fuel combustion	kg N_2O / m^3	Constant	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP_{N2O} Global Warming Potential for N_2O	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
B21 – Landfill Gas Flaring	$Emissions_{LFG\ Flaring} = Vol_{LFG} * F_{CH4} * \rho_{CH4} * (1 – DE) * GWP_{CH4} + Vol_{LFG} * EF_{N2O} * GWP_{N2O} / 1000$					
	$Emissions_{LFG\ Flaring}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol_{LFG} Volume of LFG combusted in the flare	m^3_{LFG}	Direct metering (measured or adjusted to represent at standard temperature and pressure)	Continuous metering	Continuous	Direct metering represents the industry practice and the highest level of detail.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	F_{CH4} Average Fraction of Methane in the Landfill Gas	m^3_{CH4} / m^3_{LFG}	Measured	Direct measurement	Monthly sampling or more frequent	Landfill gas composition should remain relatively stable during steady-state operation.
	ρ_{CH4} Density of methane	tonnes CH_4 / m^3_{CH4}	Constant	0.0006785 at standard temperature and pressure	N/A	If this value is used, all volumes must be adjusted for standard temperature and pressure. Agreement must be achieved between volume and density of methane in the measurement. Values for CH_4 density at other reference temperatures can be found in Table A2.
	DE Destruction Efficiency of the flare	%	Estimated	Methane destruction efficiency of the combustion device. To be obtained from manufacturer or vendor's specifications (or from Appendix A: Default Values for Methane Destruction Efficiency)	N/A	The manufacturer or vendor's specifications represent the industry practice and the highest level of detail.
	GWP_{CH4} Global Warming Potential for CH_4	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF_{N2O} Emission factor for nitrous oxide as a result of landfill gas combustion	kg N_2O / m^3	Constant	N/A	N/A	Reference value in Greenhouse Gas Inventory Guidance: Direct Emissions from Stationary Combustion Sources published by the United States Environmental Protection Agency, 2016
	GWP_{N2O} Global Warming Potential for N_2O	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
B22 - Fossil Fuel Use	$Emissions_{Fossil\ Fuel\ Use} = [\sum (Vol_{Fuel\ i} * EF\ Fuel_{i\ CO2}) + \sum (Vol_{Fuel\ i} * EF\ Fuel_{i\ CH4} * GWP_{CH4}) + \sum (Vol_{Fuel\ i} * EF\ Fuel_{i\ N2O} * GWP_{N2O})] / 1000$					
	$Emissions_{Fossil\ Fuel\ Use}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Vol_{Fuel\ i}$ Volume of Each Type of Fuel used to run the landfill gas capture and flaring system	m^3	Measured	Direct metering or reconciliation of volumes transferred	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	$EF\ Fuel_{i\ CO2}$ CO_2 Emission Factor for Each Fuel Combusted	kg CO_2 / m^3	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF Fuel $_{i\ CH4}$ CH_4 Emission Factor for Each Fuel Combusted	kg CH_4 / m^3	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{i\ N2O}$ N_2O Emission Factor for Each Fuel Combusted	kg N_2O / m^3	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP $_{CH4}$ Global Warming Potential for CH_4	Unitless	Estimated	Provided Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP $_{N2O}$ Global Warming Potential of N_2O	Unitless	Estimated	Provided Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
Project Condition						
P4 - Fuel Extraction and Processing	Emissions $_{Fuel\ Extraction/Processing}$ = [$\sum$ (Vol $_{Fuel\ i}$ * EF $_{i\ CO2}$) + $\sum$ (Vol $_{Fuel\ i}$ * EF $_{i\ CH4}$ * GWP $_{CH4}$) + $\sum$ (Vol $_{Fuel\ i}$ * EF $_{i\ N2O}$ * GWP $_{N2O}$)] / 1000					
	Emissions $_{Fuel\ Extraction/Processing}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol $_{Fuel\ i}$ Volume of Fuel Combusted (In P12 and P13)	L, m^3, or Other	Measured	Direct metering or reconciliation of volume in storage (including volumes received)	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$EF_{i\ CO2}$ CO_2 Emission Factor for Extraction and Processing of Each Fuel	kg CO_2 per L, m^3, or other	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	$EF_{i\ CH4}$ CH_4 Emission Factor for Extraction and Processing of Each Fuel	kg CH_4 per L, m^3, or other	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	$EF_{i\ N2O}$ N_2O Emission Factor for Extraction and Processing of Each Fuel	kg N_2O per L, m^3, or other	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP_{CH4} Global Warming Potential for CH_4	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP_{N2O} Global Warming Potential for N_2O	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
P12 - Fossil Fuel Use	$Emissions_{Fossil\ Fuel\ Use} = [\sum (Vol_{Fuel\ i} * EF\ Fuel_{i\ CO2}) + \sum (Vol_{Fuel\ i} * EF\ Fuel_{i\ CH4} * GWP_{CH4}) + \sum (Vol_{Fuel\ i} * EF\ Fuel_{i\ N2O} * GWP_{N2O})] / 1000$					

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Emissions $_{\text{Fossil Fuel Use}}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol $_{\text{Fuel i}}$ Volume of Each Type of Fuel used to run the landfill gas combustion and recovery system	m^3	Measured	Direct metering or reconciliation of volumes transferred	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	EF Fuel $_{\text{i CO2}}$ CO_2 Emission Factor for Each Fuel Combusted	kg CO_2 / m^3	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{\text{i CH4}}$ CH_4 Emission Factor for Each Fuel Combusted	kg CH_4 / m^3	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{\text{i N2O}}$ N_2O Emission Factor for Each Fuel Combusted	kg N_2O / m^3	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP $_{\text{CH4}}$ Global Warming Potential for CH_4	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP $_{\text{N2O}}$	Unitless	Estimated	Provided Carbon Offset	N/A	Reference value in Carbon

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Global Warming Potential for N_2O			Emission Factors Handbook		Offset Emission Factors Handbook.
P13 - Supplemental Fossil Fuel Needed for Flaring	$Emissions_{Fuel\ for\ Flare} = Vol_{Fuel} * EF_{CO2} / 1000 + Vol_{Fuel} * F_{CH4} * \rho_{CH4} * (1 - DE_{CH4}) * GWP_{CH4} + Vol_{Fuel} * EF_{N2O} * GWP_{N2O} / 1000$					
	$Emissions_{Fuel\ for\ Flare}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol_{Fuel} Volume of supplemental fossil fuel used	m^3	Measured	Direct metering or reconciliation of volumes transferred	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	F_{CH4} Average Volume Fraction of Methane in the Supplemental fossil fuel	m^3_{CH4} / m^3_{NG}	Estimated or measured based on invoicing	At standard conditions	Estimated or measured each invoicing interval	According to the supplier's specifications

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	ρ_{CH4} Density of methane	tonnes CH_4 / m^3_{CH4}	Constant	0.0006785 at standard temperature and pressure	N/A	If this value is used, all volumes must be adjusted for standard temperature and pressure. Agreement must be achieved between volume and density of methane in the measurement. Values for CH_4 density at other reference temperatures can be found in Table A2.
	DE Destruction Efficiency of the combustion device	%	Estimated	Methane destruction efficiency of the combustion device. To be obtained from manufacturer or vendor's specifications (or from Appendix A: Default Values for Methane Destruction Efficiency)	N/A	The manufacturer or vendor's specifications represent the industry practice and the highest level of detail.
	EF_{CO2} Emission factor for carbon dioxide as a result of fossil fuel combustion	kg CO_2 / m^3	Constant	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP_{CH4} Global Warming Potential for CH_4	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF_{N2O} Emission factor for nitrous oxide as a result of fossil fuel combustion	kg N_2O / m^3	Constant	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
	GWP_{N2O} Global Warming Potential for N_2O	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
P16 – On-site Landfill Gas Combustion	$Emissions_{On\text{-}site\ LFG\ Combustion} = Vol_{LFG} * F_{CH4} * \rho_{CH4} * (1 - DE) * GWP_{CH4} + Vol_{LFG} * EF_{N2O} * GWP_{N2O} / 1000$					
	$Emissions_{LFG\ Combustion}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol_{LFG} Volume of LFG combusted in the combustion device (either a flare or energy recovery system)	m^3_{LFG}	Direct metering (measured or adjusted to represent at standard temperature and pressure)	Continuous metering	Continuous	Direct metering represents the industry practice and the highest level of detail.
	F_{CH4} Average Fraction of Methane in the Landfill Gas	m^3_{CH4} / m^3_{LFG}	Measured	Direct measurement	Monthly sampling or more frequent	Landfill gas composition should remain relatively stable during steady-state operation.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	ρ_{CH4} Density of methane	tonnes CH_4 / m^3_{CH4}	Constant	0.0006785 at standard temperature and pressure	N/A	If this value is used, all volumes must be adjusted for standard temperature and pressure. Agreement must be achieved between volume and density of methane in the measurement. Values for CH_4 density at other reference temperatures can be found in Table A2.
	DE Destruction Efficiency of the combustion device	%	Estimated	Methane destruction efficiency of the combustion device. To be obtained from manufacturer or vendor's specifications (or from Appendix A: Default Values for Methane Destruction Efficiency)	N/A	The manufacturer or vendor's specifications represent the industry practice and the highest level of detail.
	GWP_{CH4} Global Warming Potential for CH_4	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF_{N2O} Emission factor for nitrous oxide as a result of landfill gas combustion	kg N_2O / m^3	Constant	N/A	N/A	Reference value in Greenhouse Gas Inventory Guidance: Direct Emissions from Stationary Combustion Sources published by the United States Environmental Protection Agency, 2016
	GWP_{N2O} Global Warming Potential for N_2O	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
P19 – Off-site Landfill Gas Combustion	$Emissions_{Off\text{-}site\ LFG\ Combustion} = Vol_{LFG} * F_{CH4} * \rho_{CH4} * (1 – DE) * GWP_{CH4} + Vol_{LFG} * EF_{N2O} * GWP_{N2O} / 1000$					
	$Emissions_{LFG\ Combustion}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol_{LFG} Volume of LFG Placed into a Natural Gas Pipeline Network	m^3_{LFG}	Direct metering (measured or adjusted to represent at standard temperature and pressure)	Continuous metering	Continuous	Direct metering represents the industry practice and the highest level of detail.
	F_{CH4} Average Fraction of Methane in the Landfill Gas	m^3_{CH4} / m^3_{LFG}	Measured	Direct measurement	Monthly sampling or more frequent	Landfill gas composition should remain relatively stable during steady-state operation.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	ρ_{CH4} Density of methane	tonnes CH_4 / m^3_{CH4}	Constant	0.0006785 at standard temperature and pressure	N/A	If this value is used, all volumes must be adjusted for standard temperature and pressure. Agreement must be achieved between volume and density of methane in the measurement. Values for CH_4 density at other reference temperatures can be found in Table A2.
	DE Destruction Efficiency of the combustion device	%	Estimated	Methane destruction efficiency of the combustion device. To be obtained from Appendix A: Default Values for Methane Destruction Efficiency. If the combustion device is not known the most conservative value must be used.	N/A	If placed into a natural gas pipeline network, the combustion device will likely not be known therefore the most conservative value in Table A1 must be used.
	GWP_{CH4} Global Warming Potential for CH_4	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF_{N2O} Emission factor for nitrous oxide as a result of landfill gas combustion	kg N_2O / m^3	Constant	N/A	N/A	Reference value in Greenhouse Gas Inventory Guidance: Direct Emissions from Stationary Combustion Sources published by the United States Environmental Protection Agency, 2016
	GWP_{N2O} Global Warming Potential for N_2O	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Reference value in Carbon Offset Emission Factors Handbook.
P18 – Biogenic CO_2 from Landfill Gas Combustion	$Emissions_{Biogenic\ LFG\ Combustion} = Vol_{LFG} * F_{CH4} * \rho_{CH4} * DE * 44/16$					
	$Emissions_{Biogenic\ LFG\ Combustion}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol_{LFG} Volume of LFG combusted in the combustion device (either a flare or energy recovery system) or placed into a natural gas pipeline.	m^3_{LFG}	Direct metering (measured or adjusted to represent at standard temperature and pressure)	Continuous metering	Continuous	Direct metering represents the industry practice and the highest level of detail.
	F_{CH4} Average Fraction of Methane in the Landfill Gas	m^3_{CH4} / m^3_{LFG}	Measured	Direct measurement	Monthly sampling or more frequent	Landfill gas composition should remain relatively stable during steady-state operation.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	ρ_{CH4} Density of methane	tonnes CH_4 / m^3_{CH4}	Constant	0.0006785 at standard temperature and pressure	N/A	If this value is used, all volumes must be adjusted for standard temperature and pressure. Agreement must be achieved between volume and density of methane in the measurement. Values for CH_4 density at other reference temperatures can be found in Table A2.
	DE Destruction Efficiency of the combustion device	%	Estimated	Methane destruction efficiency of the combustion device. To be obtained from manufacturer or vendor's specifications (or from Appendix A: Default Values for Methane Destruction Efficiency)	N/A	The manufacturer or vendor's specifications represent the industry practice and the highest level of detail.
	44/16 Molar Mass Ratio of Carbon Dioxide to Methane	Unitless	Constant	N/A	N/A	N/A

5.0 Documents and Records

Documentation (documents and records) are a key element to project development. The types of documents and records required to demonstrate that an offset project meets regulatory and protocol requirements can vary by project. It is the project developer's responsibility to ensure the project plan clearly outlines documents and records for the offset project.

The verification process relies heavily on the quality and availability of documentation to support the GHG assertion. Projects are audited to a reasonable level of assurance. A list of required objective evidence of project implementation is outlined in Table 7. Attestation is not considered objective evidence and is not accepted as proof that an activity took place.

Documents and records are required to be:

- Legible, identifiable, traceable;
- Centrally located;
- Dated;
- Easily located (easily searched);
- Orderly;
- Retained as per section 29(4) of the Carbon Competitiveness Incentive Regulation; and,
- Prevented from loss.

In the case of aggregated projects, subproject owners and the aggregator must both retain records as required above.

Project developers, including aggregators, are required to retain copies of all required records and any additional records needed to support the GHG reduction. The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily verification/re-verification can be conducted for the project.

5.1 Documents

Documents are the instructions or plan on how a certain activity is carried out.

Documents may be required to demonstrate that an offset project meets program criteria, eligibility, baseline eligibility and project offset quantification. Examples of documents include offset project plan, procedures, specifications, drawings, regulations, standards, guidelines, etc. These documents must include a list of records available to the verifier that demonstrate the offset criteria have been met. The offset project documents should also indicate how the records will be managed (i.e., retention, storage and access).

Documents may be stand-alone or interdependent. Documents may be subject to change or periodic update. The project developer must be able to demonstrate that the most current quantification version of a document is being used. Older versions applicable to specific GHG assertions must be retained as part of the project documentation as per section 29(4) of the Carbon Competitiveness Incentive Regulation.

In addition to the criteria outlined in this protocol, the emission offset project developer is required to provide documents to show that general offset criteria in the Standard for Greenhouse Gas Emission Offset Project Developers have been met. These criteria are summarized in Table 6.

Table 6: Examples of Documents Required to Meet Offset Criteria

Offset Criterion	Example of Document
Counted once	Written explanation of where the risks of double counting may be and mitigation strategies to ensure that no double counting occurs. Mitigation strategies should include a methodology for assuring no double counting.
Beyond business as usual (BAU) and sector common practice	Requirements outlined in the Carbon Competitiveness Incentive Regulation and future additionality directives are met.
No leakage	Written explanation of how the project ensures there is no leakage of greenhouse gase emissions.
Permanence	Written explanation of how permanence is addressed.
Project eligibility	Written explanation of how the project is eligible to generate emission offsets. Criteria include demonstrating ownership, project location within Alberta, and adherence to an approved protocol.
Baseline condition	Methodology used to measure baseline condition stated in the protocol (this is the baseline practice over the three year period immediately prior to the offset project start date). The baseline condition must address the level of service, frequency and duration of measurement, units, emissions factors, and default values for quantifying baseline emissions.
Project quantification	Methodology used to measure the project condition over the entire project period. Project quantification includes the frequency and duration of the measurement, units, emissions factors, frequency of calibration, default values for quantifying emissions, and other relevant criteria stated in the protocol.

5.2 Records

Records are required to prove completion of the project as planned. Records include, but are not limited to, invoices, contracts, metered results, maintenance logs, calculations, databases, photographs, calibration records, etc.

Records must be retained according to the requirements outlined in Section 5.0 and as indicated in the offset project plan. In the case of an aggregated project, the individuals and the aggregator must both retain sufficient records to demonstrate that the offset criteria have been met. Table 7 outlines examples of records that are required to support this protocol. Records must be available and be disclosed to a verifier and/or government re-verifier upon request.

Table 7: Record Requirements and Examples of Records

Record Requirement	Examples of Records
Project in Alberta	• Evidence that the project has occurred in Alberta.
Activity start date on or after January 1, 2002	• Evidence that the reduction activity started on or after January 1, 2002 such as a work order, invoice, or dated procedure.
Ownership	• Evidence that the emission offsets are clearly owned or allowed to be collected by the project developer, which may include agreements, contracts, etc.

Measurement equipment	• Description of meters used, meter model number, serial number, manufacturer's calibration procedures and calibration records or standards of calibration. • For commercial purchases, proof of commercial grade metering from the supplier is required. • For computer control system data, a description of the data.
Baseline calculations	• Raw data in database and/or spreadsheet format, including all necessary information and records for the project's baseline condition as defined by the protocol. • Baseline data must include three years that immediately precede the project. • If sampling was used, summary statistics and methods used to calculate statistics. • A record of all adjustments made to raw baseline data with justifications and support on how adjustments are in alignment with the protocol.
Project calculations	• Raw data and calculations in database and/or spreadsheet format, including all necessary information and records for the project's project condition as defined by the protocol. • If sampling was used, summary statistics and methods used to calculate statistics. • A record of all adjustments made to raw project data with justifications and support on how adjustments are in alignment with the protocol.
Protocol applicability	• Evidence to demonstrate that the project is implemented in alignment with protocol applicability requirements

Note: Attestations are not considered sufficient proof that an activity took place and do not meet verification requirements.

5.3 Quality Assurance / Quality Control Considerations

Quality Assurance/Quality Control (QA/QC) procedures are applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

- Ensuring that the changes to operational procedures continue to function as planned and achieve GHG reductions;
- Ensuring that the measurement and calculation system and GHG reduction reporting remains in place and accurate;
- Checking the validity of all data before it is processed, including emission factors, static factors and acquired data;
- Performing recalculations of quantification procedures to reduce the possibility of mathematical errors;
- Storing the data in its raw form so it can be retrieved for verification;
- Protecting records of data and documentation;
- Recording and explaining any adjustment made to raw data in the associated report and files;
- A contingency plan for potential data loss;
- Instrument calibration performed regularly to ensure accuracy; and,
- Sampling protocols are followed to ensure accuracy.

5.4 Liability

Carbon offset projects must be implemented according to the approved protocol and in accordance with government regulations. The department reserves the right to re-verify emission offsets and associated projects submitted to the department for compliance under the Carbon Competitiveness Incentive Regulation and may require corrections based on re-verification findings.

Any comments or questions regarding the content of this document may be directed to:

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APPENDIX A: Quantification Parameters

Methane Destruction Efficiency

The methane destruction efficiency (DE_{CH4}) is defined as the efficiency of the combustion device in oxidizing methane in landfill gas to carbon dioxide. The following default values are taken from the Technical Guidance for the Quantification of Specified Gas Emissions from Landfills which refers to the USEPA for non–halogenated species[3]. They are distinguished between boiler/steam and gas turbines, flares and internal combustion (IC) engines.

Table A1: Default Values for Methane Destruction Efficiency (USEPA)

Type of LFG Control Device	Methane Destruction Efficiency	
	Range (%)	Average (%)
Boiler / Steam Turbines	67-99+	99.8
Gas Turbines	97-99+	98.2
Unassisted Flares	38-99+	98.0
Air or Steam Assisted Flares^	38-99+	99.5
IC Engines	25-99+	86.1* (98+)
Passive Venting		0

*A recent review of literature and experiences from members of the Landfill Gas Working Group have shown average destruction efficiencies for IC engines of 98% or greater.
^Must be properly operated and highly turbulent

Methane Density

The appropriate methane density can be selected from Table A2 based on the desired reference temperature.

Table A2: Density of CH_4 at 1 atm/101.325kPa

Temperature (°C)	Temperature (K)	Density (kg/m^3)[4]
0	273.15	0.718
5	278.15	0.705
10	283.15	0.692
15	288.15	0.680
20	293.15	0.668
25	298.15	0.657

[3] United States Environmental Protection Agency. (1998). 2.4 Municipal Solid Waste Landfills. In AP-42. Retrieved from https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s04.pdf

[4] Setzmann, U., & Wagner, W. (1991). A New Equation of State and Tables of Thermodynamic Properties for Methane Covering the Range from the Melting Line to 625 K at Pressures up to 1000 MPa.J. Phys. Chem. Ref. Data, 20(6):1061-1151.