Quantification protocol for

Biogas production and combustion

Version 1.0

Classification: Public

Environment and Parks, Government of Alberta
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Quantification Protocol for Biogas Production and Combustion
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Summary of Revisions

This protocol is a revision and replacement of two previous approved protocols, *Quantification Protocol for the Anaerobic Decomposition of Agricultural Materials* and *Quantification Protocol for Anaerobic Treatment of Wastewater Projects.*

Version	Date	Summary of Revisions
Version 1.0	December 2020	• The Protocol Applicability was revised to combine the requirements from both protocols and to reflect the revised baseline conditions. • Levied and non-levied emissions section was added. The list of related publications was updated. • Added reporting requirements for biogenic carbon dioxide and levied fossil fuel emissions. The requirements for managing fugitive emissions were revised. • The following flexibility mechanism was removed from the former Wastewater protocol, with agreement during the Technical Working Group meeting: ○ Measurement of BOD instead of measurement of COD • The following flexibility mechanism was removed from the former Wastewater protocol, with agreement during the Technical Working Group meeting because the associated baseline scenario is no longer additional: ○ Use of site-specific flare destruction efficiency where baseline condition was flaring of biogas. • The following flexibility mechanism was removed from the former Wastewater protocol because it constitutes a requirement for a deviation request from Alberta Environment and Parks: ○ Modification of measurement and data management procedures to account for the available equipment. • The following two flexibility mechanisms were removed from the former Anaerobic Decomposition of Agricultural Materials protocol because they are redundant; these procedures are already integral to the project development process (but may require a deviation request):

	○ Adding source and sinks back into the protocol in situations where the protocol suggests excluding them. ○ Grouping of sources and sinks for quantification purposes. • The baseline conditions were revised and more clearly articulated for wastewater and organic waste processes. • A new baseline condition for dairy and swine liquid manure was added along with a quantification method (see B3 Organic Waste Storage and Handling). A new project emission quantification requirement for the storage of solid waste (digestate) was added (see P33 Digestate/Sludge Temporary Storage). • Emission factors were updated to reference the Carbon Offset Emission Factors Handbook. • Added the following emission sources: ○ P22 Pricing Fossil Fuel Flaring ○ P23 Biogenic CO_2 Flaring ○ P28 On-site Biogenic CO_2 Emissions ○ P46 End-use Biogenic CO_2 Emissions • Revised and added example records and documents for Project Documentation and Record Keeping requirements.
Version 1.0	• Quantification Protocol for the Anaerobic Decomposition of Agricultural Materials
Version 1.0	• Quantification Protocol for Anaerobic Treatment of Wastewater Projects.

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Related Publications

- *Emissions Management and Climate Resilience Act* (the Act)
- Technology Innovation and Emission Reduction Regulation (the Regulation)
- Specified Gas Reporting Regulation
- Standard for Greenhouse Gas Emission Offset Project Developers (the Standard)
- Standard for Validation, Verification and Audit
- Technical Guidance for Offset Protocol Development and Revision
- Carbon Offset Emission Factors Handbook

1.0 Introduction

This quantification protocol is written for those familiar with wastewater treatment processes and with the operation of anaerobic digesters and biogas utilization systems. Some familiarity with or general understanding of the operation of these projects is expected.

1.1 Protocol Scope

This protocol includes opportunities for generating emission offsets from both solid and liquid waste streams.

For wastewater streams, an opportunity for generating emission offsets arises primarily from the capture and destruction of methane that would have been emitted from wastewater treatment facilities where the baseline practice was the anaerobic treatment of wastewater and venting of any produced methane to the atmosphere.

For wastewater streams where aerobic treatment is the baseline condition, the opportunity for generating emission offsets arises primarily from the production of renewable electricity using biogas produced through anaerobic wastewater treatment in the project condition.

For solid waste streams, an opportunity for generating emission offsets arises from established diversion of waste from landfills to digester systems where biogas is produced and subsequently combusted for a useful purpose.

For both wastewater and solid waste, there is also the opportunity for indirect greenhouse gas (GHG) emission reductions from the use of produced biogas to displace electricity or thermal energy derived from fossil fuels or to displace natural gas in gas transmission systems. All of these emission reductions may not, however, be eligible for generating emission offsets as any priced emission sources are to be included in the quantification and reporting but are not eligible for the generation of emission offsets. Priced emission sources must be tracked and reported to ensure project eligibility. Project developers must ensure they are meeting requirements for priced emissions as outlined in the Standard for Greenhouse Gas Emission Offset Project Developers (the Standard).

Only waste products are eligible as feedstocks for production of biogas as described in this Protocol.

Flaring of biogas is not an eligible emission reduction activity in the project condition for generating emission offsets.

Sections 2.0 and 3.0 provide further information regarding eligible baseline and project conditions respectively.

1.2 Protocol Applicability

To demonstrate that an emission offset project meets the requirements under this protocol, the project developer must demonstrate and provide evidence that their project aligns with the following:

1. Only waste products are eligible as feedstocks for production of biogas as described in this Protocol. A feedstock stream may include multiple types of waste, provided the project developer demonstrates the appropriateness of all referenced factors for the combined feedstock for the quantification of emissions. Biogas produced from anaerobic treatment of municipal wastewater and used for electricity generation is eligible; however, the avoided methane emissions from municipal wastewater is not an eligible activity for producing emission offsets.

2. Projects claiming an emission reduction resulting from diversion of solid organic waste from landfill must produce disposal records for the baseline period.

3. A fugitive emissions management program must be implemented during the project condition. This program must include, at minimum, monitoring, and maintenance procedure for each of the joints, seals, and equipment prone to fugitive emissions based on manufacturer specifications, industry practice, or applicable standards documents. Fugitive emission leak detection and repair must be conducted during commissioning of the project and at minimum annually during the crediting duration.

4. The digestate or sludge does not undergo active windrow composting. Project developers that intend to compost digestate or sludge must contact the department.

5. For wastewater treatment projects applying the passive anaerobic wastewater treatment baseline, the depth of the anaerobic system must be no less than one meter deep throughout to demonstrate that the baseline anaerobic wastewater treatment system (e.g. an uncovered deep lagoon or sludge pit) would have resulted in sufficiently anaerobic (oxygen-free) conditions to result in the formation of methane.

6. If digestate is land spread, land spreading must be conducted in accordance with Alberta regulations. If the feedstock has greater than 50% manure, then the *Agricultural Operation Practices Act* applies; if the feedstock has less than 50% manure, then the *Environmental Protection and Enhancement Act* applies.

7. If sediments are collected and removed from the anaerobic wastewater treatment unit more than once every two years, the project proponent will account for sedimentation COD losses.

8. This protocol does not include eligibility for the displacement of emissions from priced fuels. It is still a requirement to monitor, measure and quantify these emissions with a reasonable level of assurance.

9. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol.

10. The project must meet the requirements for emission offset eligibility as specified in the Regulation and Standards for the Alberta Emission Offset System.

1.3 Protocol Flexibility

Flexibility in applying this quantification protocol is provided to project developers in the following ways. The project developer is responsible for documenting use and will have to justify their approach in detail to apply any of these flexibility mechanisms.

1. For wastewater treatment projects applying the passive anaerobic wastewater treatment baseline where historical wastewater temperatures were not measured prior to the implementation of the methane capture system, a heat transfer model may be developed to estimate the average monthly temperature of the wastewater in the anaerobic treatment unit in the baseline.

   The project developer must justify how the method used represents a reasonable approximation of the baseline temperature of the wastewater within the anaerobic treatment unit that is sufficiently conservative to avoid overestimation of the temperature, and overestimation of the quantity of methane emitted to the atmosphere in the baseline under SS B19 Anaerobic Wastewater Treatment Process.

2. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must ensure reproducibility and accuracy and be robust enough to calculate uncertainty ranges for the site-specific factors.

3. Emissions from temporary storage of sludge from anaerobic wastewater treatment or digestate from anaerobic solid waste treatment (P33 Digestate/Sludge Temporary Storage) may be excluded if the temporary storage is less than 24 hours in duration. This flexibility may be applied for a portion of the reporting period, such as the spring/fall when land is available for land spreading, or the whole reporting period; however, the project developer must provide documentation that clearly substantiates the duration of temporary storage for each load where this is applied.

1.4 Glossary of Terms

Active Windrow Composting:	Windrow composting is the production of compost by the aerobic decomposition of organic matter, such as animal manure and crop residues, piled in long rows (windrows) which may be periodically watered and/or turned.
Anaerobic Digestion	An active and naturally occurring biological process where organic matter is degraded by methanogenic bacteria to yield methane gas and mineralized organic nutrients.
Anaerobic Wastewater Treatment	The processing of wastewater such that it may be released back into the environment. Anaerobic treatment, in particular, includes degradation of organic material using methanogenic bacteria.
Chemical Oxygen Demand (COD)	The amount of a specified oxidant that reacts with the sample under controlled conditions. The chemical oxygen demand (COD) test is a common water quality test used to indirectly measure the total quantity of organic compounds in a water sample using a strong oxidizing agent such as potassium dichromate. A high COD value indicates a high concentration of organic matter in the water sample.
Functional Equivalence	The Project and the Baseline sources and sinks should provide the same function and quality of products or services. This type of comparison requires a common metric or unit of measurement (such as the volume of wastewater treated) for comparison between the Project and Baseline.
Fugitive Emissions:	Intentional and unintentional releases of GHGs from joints, seals, packing, gaskets, etc. within anaerobic digestion systems, including all processing, piping, and treatment equipment.
Land Application:	The beneficial use of agricultural material or stabilized sludge material from the effluent of an anaerobic digester or filter press, applied to cropland based upon crop needs and the composition of the agricultural material, as a source of soil amendment and/or nutrition.
Methane Conversion Factor (MCF)	The methane conversion factor (MCF) represents the extent to which ideal anaerobic conditions are present in the wastewater treatment unit, which is primarily dependent on the depth of the anaerobic treatment unit and the temperature of the system.
Sludge Pit:	The pit or tank that receives untreated liquid sludge in which anaerobic bacteria decompose the liquid sludge, thereby decreasing its organic matter content, and emitting biogas. When the pit is dried out and sludge is stable, solids are removed for use.

2.0 Baseline Condition

Project developers are required to establish a dynamic, project-specific baseline where emission offsets are quantified by calculating emissions in the project conditions relative to the emissions that would have occurred had the same volume of solid waste or wastewater been disposed of or processed in the baseline condition. Therefore, the baseline is recalculated for each reporting period to determine baseline emissions.

The baseline is the most appropriate and best estimate of greenhouse gas emissions that would have occurred in the absence of the project. The scope of this protocol includes wastewater and solid waste treatment. The baseline condition may be aerobic or anaerobic, depending on the brownfield baseline scenario. For green field wastewater treatment projects, an aerobic baseline is assumed. The eligible baseline conditions are described in Table 1 below.

Note that liquid manure treatment follows the solid waste treatment pathway throughout this protocol.

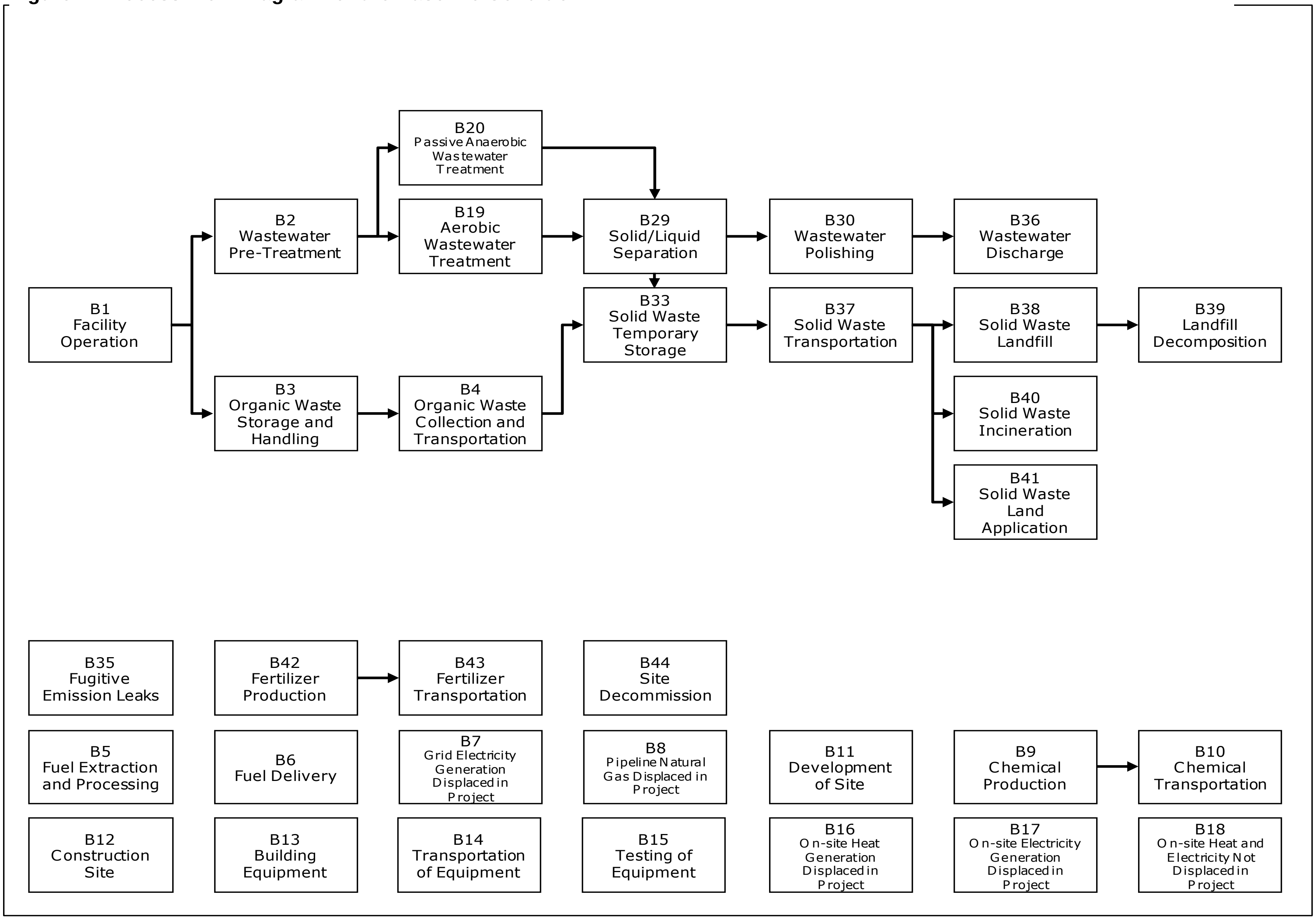
Table 1: Description of Eligible Baseline Conditions

Project Type	Baseline Condition	Description
Brownfield solid waste anaerobic digestion	Solid waste landfill	A reduction of methane emissions from avoided landfill quantified in B39 Solid Waste Landfill is eligible.
	Liquid manure storage	A reduction of methane emissions from avoided/reduced storage of liquid manure quantified in B3 Organic Waste Handling and Storage is eligible.
	Solid waste incineration	The avoided emissions from incineration of solid waste are not eligible to produce emission offsets. This is, however, an eligible baseline scenario. Avoided fossil fuel combustion emissions are quantified under B40 Solid Waste Incineration.
	Solid waste land application	Decomposition of solid waste is assumed to occur completely aerobically; therefore, these emissions are not eligible to produce emission offsets. This is, however, an eligible baseline scenario.
Greenfield solid waste anaerobic digestion	Solid waste landfill	If there are no regulatory restrictions on landfilling, and a project developer has records to substantiate landfill disposal as the baseline condition, emissions from avoided decomposition of organic waste in a landfill from B39 Solid Waste Landfill are eligible.

	Liquid manure storage	If there are no regulatory restrictions on liquid manure storage, this is an eligible baseline scenario for greenfield liquid manure projects. Emissions from avoided or reduced storage or liquid manure in B3 Organic Waste Storage and Handling are eligible.
	Solid waste land application	If landfilling the solid waste material subject to anaerobic digestion in the project is not permitted by regulation, the baseline condition is aerobic decomposition of waste, similar to that which would occur in land application.
Brownfield wastewater treatment	Passive anaerobic wastewater treatment	If requirements for establishing that anaerobic conditions are met, as described in Section 1.2 Protocol Applicability, avoided methane emissions from B20 Passive Anaerobic Wastewater Treatment are eligible.
	Aerobic wastewater treatment	If the project developer cannot establish that anaerobic conditions exist, aerobic wastewater treatment is the baseline condition.
Greenfield wastewater treatment	Aerobic wastewater treatment	Greenfield wastewater treatment projects must use aerobic wastewater treatment as the baseline scenario.

The process flow diagram for the baseline condition including the relevant sources and sinks is shown in Figure 1. Emission sources placed at the bottom and not connected with hard lines are either connected to multiple processes (for example, fugitive emissions) or occur outside the boundary. Details on each of these sources and sinks is provided in Section 2.1.

Figure 1: Process Flow Diagram for the Baseline Condition



2.1 Identification of Baseline Sources and Sinks

The identification of sources and sinks in the baseline condition is based on ISO 14064-2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements (International Organization for Standardization). 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 relevant to the baseline scenario must be identified including upstream, downstream and on-site sources and sinks. All sources and sinks have been arranged by their relation to the project boundary and the time at which the greenhouse gas emissions occur, as shown in Figure 2.

Figure 2: Baseline Sources and Sinks for Treatment of Solid Waste and Wastewater

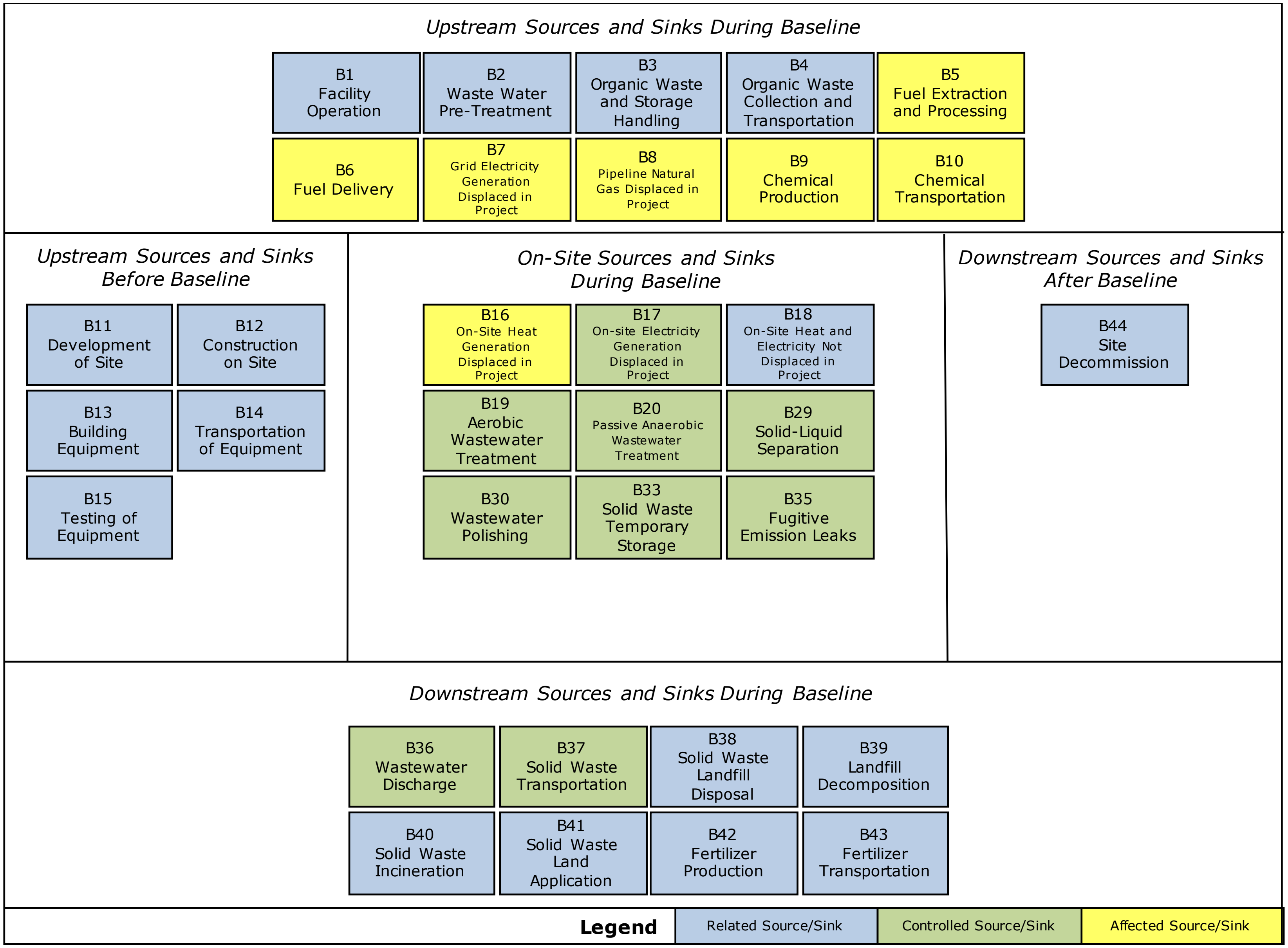


Table 2: Description of Baseline Sources and Sinks

Source / Sink (SS)	Description	Controlled, Related or Affected
Upstream Sources and Sinks during Baseline		
B1 Facility Operation	Organic waste materials are produced by a number of industries and processes. The facility generating the organic waste would have a primary function or product and any number of processes that would require energy inputs and therefore consume fossil fuels as part of the process or unit operation and for material handling. Greenhouse gas emissions may be associated with these industrial processes and the associated waste handling practices, which could include heating, pumping, mixing, sterilization and equalization and could be powered by fossil fuels either directly or indirectly through a centralized boiler or cogeneration unit. Quantities for each of the energy inputs are contemplated to evaluate functional equivalence with the project condition.	Related
B2 Wastewater Pre-treatment	Wastewater may be treated and/or processed prior to being input to the anaerobic treatment system. This could include physical processes such as screening, grit and solids removal, oil-water separation, dissolved air flotation for removal of fats and oils and other processes that adjust the chemical composition of the wastewater. Heavy equipment that operates using diesel or natural gas may be involved in pre-treatment operations. Greenhouse gas emissions are associated with the use of these fossil fuels. Quantities for each of the energy inputs are tracked to evaluate functional equivalence with the project condition.	Related

Source / Sink (SS)	Description	Controlled, Related or Affected
B3 Organic Waste Storage and Handling	Organic waste feedstocks may be stored, for example in animal pens, in windrow, piles (stockpiling) or in enclosed containers. Greenhouse gas emissions may result from the anaerobic decomposition of these materials if storage conditions allow for an oxygen deficient (anaerobic) atmosphere. The vessel size and shape, feedstock composition, and storage duration and management are all pertinent to evaluate functional equivalence with the project condition. These conditions are approximated by the IPCC definition of “liquid/slurry systems without natural crust cover”. Feedstock may then be handled and/or processed prior to transportation. This may involve the use of heavy equipment such as bull-dozers that operate using diesel, natural gas or electricity. Emissions of greenhouse gases are associated with the use of these fossil fuels. Quantities for each of the energy inputs are evaluated for functional equivalence with the baseline condition.	Related
B4 Organic Waste Collection and Transportation	Feedstock may be transported to the project site by truck, barge and/or train. The related energy inputs for fueling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B5 Fuel Extraction and Processing	Each of the fuels used throughout the on-site component of the project will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SSs are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked. Any biogas being injected into the natural gas distribution network in the project condition displaces a volume of natural gas from the pipeline system. Similarly, biogas used for on-site generation of heat or electricity reduces combustion of fossil fuels. Greenhouse gas emissions resulting from the extraction and processing of the equivalent volume of fossil fuels are considered under this SS and may need to be tracked.	Affected

Source / Sink (SS)	Description	Controlled, Related or Affected
B6 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tankers or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fueling station as the fuel used to take the equipment to the site is captured under other SSs and there is no other delivery.	Affected
B7 Grid Electricity Generation Displaced in Project	Fossil fuels are combusted by some electricity generators that are connected to the Alberta Interconnected Electricity Grid. The renewable electricity produced in the Project displaces some of this electricity, which is represented by this SS.	Affected
B8 Pipeline Natural Gas Displaced in Project	Natural gas is combusted by residential, commercial and industrial consumers in the Province, which is supplied to them by the natural gas distribution network. If biogas is injected into the natural gas distribution network in the Project, it displaces some of this natural gas, which is represented by this SS.	Affected
B9 Chemical Production	The production of chemicals from raw materials upstream of the project site may include several material and energy inputs such as natural gas and diesel. Quantities and types of chemicals used at the facility and their associated GHG intensity per unit would be tracked to evaluate functional equivalence with the baseline condition.	Affected
B10 Chemical Transportation	Chemicals used at the project facility may be transported to the project site by truck, barge, train or other method. The related energy inputs for fueling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled are used to evaluate functional equivalence with the baseline condition.	Affected

Source / Sink (SS)	Description	Controlled, Related or Affected
Upstream Sources and Sinks Before Baseline		
B11 Development of Site	The site may need to be developed under the baseline condition. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas and offices, etc., as well as 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 such as graders, backhoes, trenching machines, etc.	Related
B12 Construction on Site	The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emissions from the use of fossil fuels and electricity.	Related
B13 Building Equipment	Equipment may need to be built either on-site or off-site. This can include the baseline components for the storage, handling and processing of the organic material. 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, fabricating and assembly.	Related
B14 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will be delivered to the site. Transportation may be completed by truck, barge and/or train. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related

Source / Sink (SS)	Description	Controlled, Related or Affected
B15 Testing of Equipment	Equipment may be tested to ensure that it is operational. This may result in running the equipment using test organic materials or 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
On-site Sources and Sinks during Project Operation		
B16 On-site Heat Generation Displaced in Project	Heat in the form of steam, hot water, hot glycol or other similar forms is used on-site for various processes. This represents the emissions associated with the proportion of this heat that is displaced by biogas combustion in the Project.	Affected
B17 On-site Electricity Generation Displaced in Project	Electricity may be generated on-site for local use. This represents the emissions associated with the proportion of electricity generation that is displaced by electricity generated with biogas in the Project.	Controlled
B18 On-site Heat and Electricity Not Displaced in Project	The heat and electricity that is not displaced by the combustion of biogas in the Project is represented by this SS. Also see B16 and B17.	Related
B19 Aerobic Wastewater Treatment	Wastewater treatment may follow an aerobic process (bioreactor, aerobic digester, clarifier etc.). There may be multiple energy and chemical inputs to operate equipment for pumping, mixing, coagulation, flocculation and aeration. Additionally, pockets of wastewater may be subject to anaerobic conditions either by design or due to poor mixing, creating additional methane emissions. Quantities and types of fuels, and the potential for anaerobic conditions, are evaluated for functional equivalence with the project condition.	Controlled

Source / Sink (SS)	Description	Controlled, Related or Affected
B20 Passive Anaerobic Wastewater Treatment	Greenhouse gas emissions may occur that are associated with the operation of the baseline anaerobic treatment unit, such as an open anaerobic lagoon. The level of aerobic versus anaerobic conditions in lagoons depends on the design and operation of the lagoon. While some aerobic decomposition will occur in an open lagoon, anaerobic emissions associated with open lagoon treatment systems may exist in the wastewater material.	Controlled
B29 Solid-Liquid Separation	The aggregated particles that have coagulated and been concentrated are generally sent to a filter, press or centrifuge system for de-watering. The resulting solid product is then sent for disposal or land application and the wastewater is usually recycled back to the aerobic treatment process. There may be multiple energy and chemical inputs to operate the solid-liquid separator, pumps and associated equipment. Quantities and types of fuels are evaluated for functional equivalence with the project condition.	Controlled
B30 Wastewater Polishing	The wastewater may undergo some additional chemical adjustments in a polishing step to ensure that the wastewater meets applicable sewer or surface water discharge regulations. Additional chemicals and energy inputs may be required in this step, with associated energy inputs and GHG emissions. Functional equivalence is evaluated relative to the project scenario.	Controlled
B33 Solid Waste Temporary Storage	Greenhouse gas emissions may also result if the solid material (digestate or sludge) is stored on-site for extended periods of time. Further anaerobic decomposition may occur if the material is not fully stabilized resulting in some additional methane emissions. Functional equivalence with the solid waste handling practice used in the project condition are evaluated to determine materiality. If a change in practice from the baseline resulted in incremental quantities of solid waste being stored under anaerobic conditions for long periods of time in the project condition, the stability of the material and methane generation potential are evaluated to evaluate materiality of emissions.	Controlled

Source / Sink (SS)	Description	Controlled, Related or Affected
B35 Fugitive Emission Leaks	Greenhouse gas emissions may also result from fugitive emissions associated with the operation of the biogas capture and flaring system of a baseline anaerobic waste treatment facility. These emissions would primarily be methane emissions associated with leaks through valves, connections and equipment seals as many of the facility components operate under pressure.	Controlled
Downstream Sources and Sinks during Baseline		
B36 Wastewater Discharge	After the wastewater has undergone any remaining chemical adjustments in the polishing stage, it will either be stored indefinitely or discharged to the sewer system or another body of water. If any significant quantities of organic material were remaining in the wastewater stream (likely due to upset conditions), there could be some amount of additional methane produced in the storage pond or downstream of the site.	Controlled
B37 Solid Waste Transportation	Solid organic waste (feedstock in the project condition), or sludge produced from wastewater treatment in a primary or secondary settler or other processes, may be transported to a composting or other anaerobic digestion facility for additional material stabilization, or to a disposal site, or to suitable land for spreading. The related energy inputs for fueling equipment used to transport the waste are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Equipment may include vehicles, pumps, loaders, conveyors and other mechanized devices. This equipment would be fueled by diesel, gas, natural gas or electricity. The type of equipment, number of loads and distance travelled are evaluated for functional equivalence with the baseline condition.	Controlled
B38 Solid Waste Landfill Disposal	Feedstock may be disposed at a landfill disposal site. Disposal and landfill maintenance will involve the use of heavy equipment and mechanical systems fueled by diesel, petroleum, natural gas, or electricity, resulting in greenhouse gas emissions. Other fuels may also be used in some rare cases. Quantities for each of the energy inputs are evaluated for functional equivalence with the project condition.	Related

Source / Sink (SS)	Description	Controlled, Related or Affected
B39 Landfill Decomposition	Residues may decompose in the disposal facility (typically a landfill site) resulting in the production of methane. The methane emitted as a result of landfilling the feedstock must be quantified according to the landfill emissions quantification methods described in the Alberta Carbon Offset Emission Factors Handbook. Disposal site characteristics and mass disposed of at each site are tracked as well as the characteristics of the methane collection and destruction system. If the landfill employs a methane collection and destruction system, and such a system is active in the area of the landfill where this material is being disposed, then this methane collection and destruction are accounted for according to the methods described in the Alberta Carbon Offset Emission Factors Handbook.	Related
B40 Solid Waste Incineration	Feedstock may be incinerated at a disposal site. This will include combusting the materials with a fuel such as natural gas or diesel. Other fuels may also be used in some rare cases. Quantities for each of the energy inputs are evaluated for functional equivalence with the project condition.	Related
B41 Solid Waste Land Application	Fertilizer and/or feedstock that is land applied will require the use of heavy equipment and mechanical systems. This equipment would be fueled by diesel, petroleum, natural gas or electricity, resulting in greenhouse gas emissions. Other fuels may also be used in some rare cases. Quantities for each of the energy inputs are evaluated for functional equivalence with the project condition.	Related
B42 Fertilizer Production	Fertilizer may be produced through a number of chemical, mechanical and amendment processes. This requires several energy inputs such as natural gas, diesel and electricity. Emissions of greenhouse gases are associated with the use of these fossil fuels. Quantities and types for each of the energy inputs are evaluated functional for equivalence with the project condition.	Related

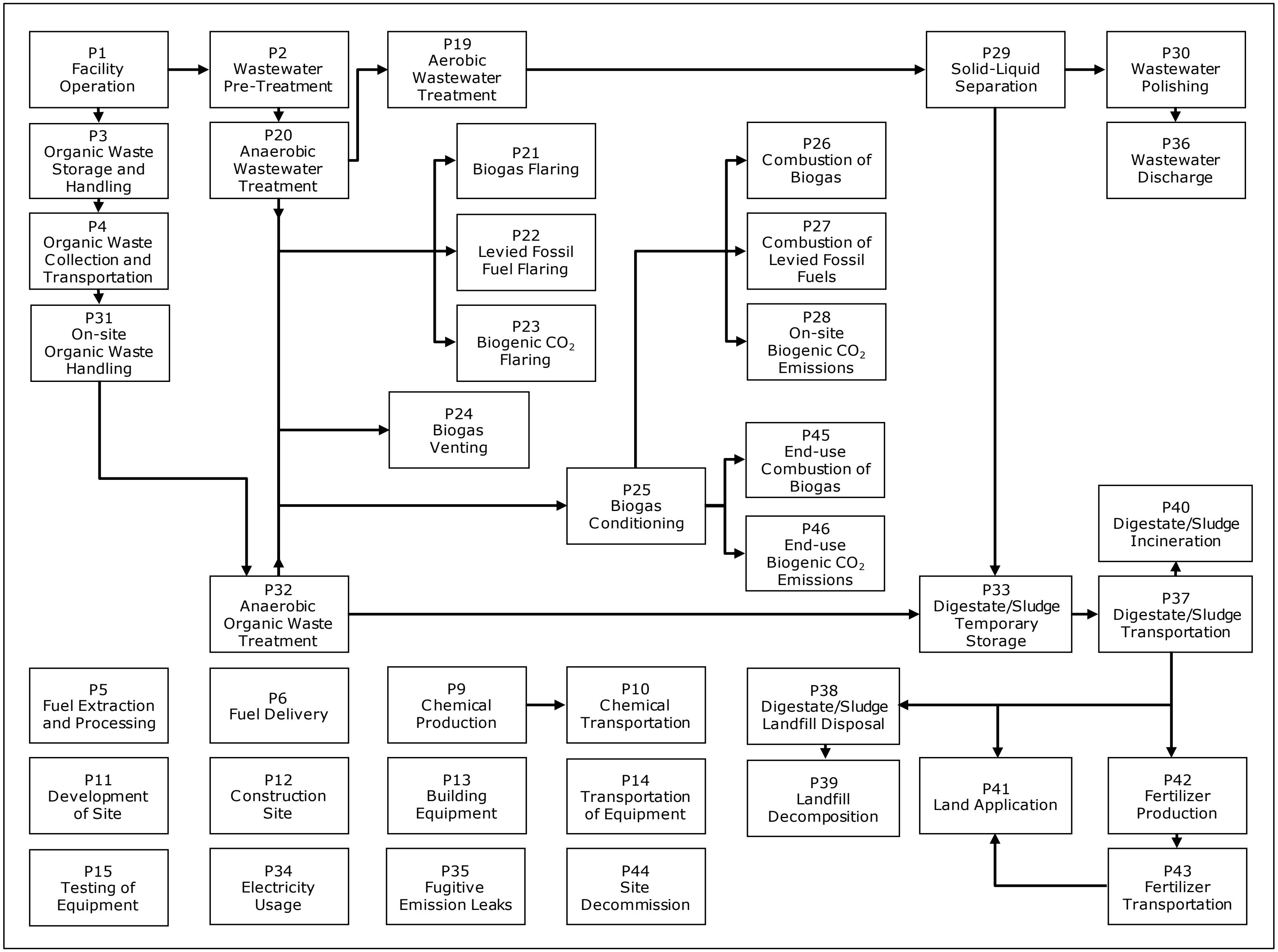
Source / Sink (SS)	Description	Controlled, Related or Affected
B43 Fertilizer Transportation	Fertilizer will need to be transported to customers or distribution points by truck, barge and/or train. The related energy inputs for fueling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled are evaluated for functional equivalence with the project condition.	Related
Downstream Sources and Sinks After Baseline		
B44 Site Decommissioning	Once the facility is no longer operational, the site may need to 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 emission offset project condition is the production of biogas through anaerobic digestion of solid waste or anaerobic wastewater treatment for use in electricity production.

A process flow diagram for the project condition is provided in Figure 3.

Figure 3: Process Flow Diagram for the Project Condition



3.1 Identification of Project Sources and Sinks

Sources and sinks for biogas production and combustion projects were identified based on scientific review. This process confirmed that source and sinks in the process flow diagram (Figure 3) covered the full scope of eligible project activities under this protocol.

These sources and sinks have been further refined according to the life cycle categories identified in Figure 4. These sources and sinks were classified as controlled, related or affected.

All included sources and sinks applicable to the specific project must be identified in the offset project plan. If a source or sink included in this protocol is not applicable to the project, sufficient justification must be provided to support the exclusion.

Figure 4: Project Condition Sources and Sinks for Biogas Production and Combustion Projects

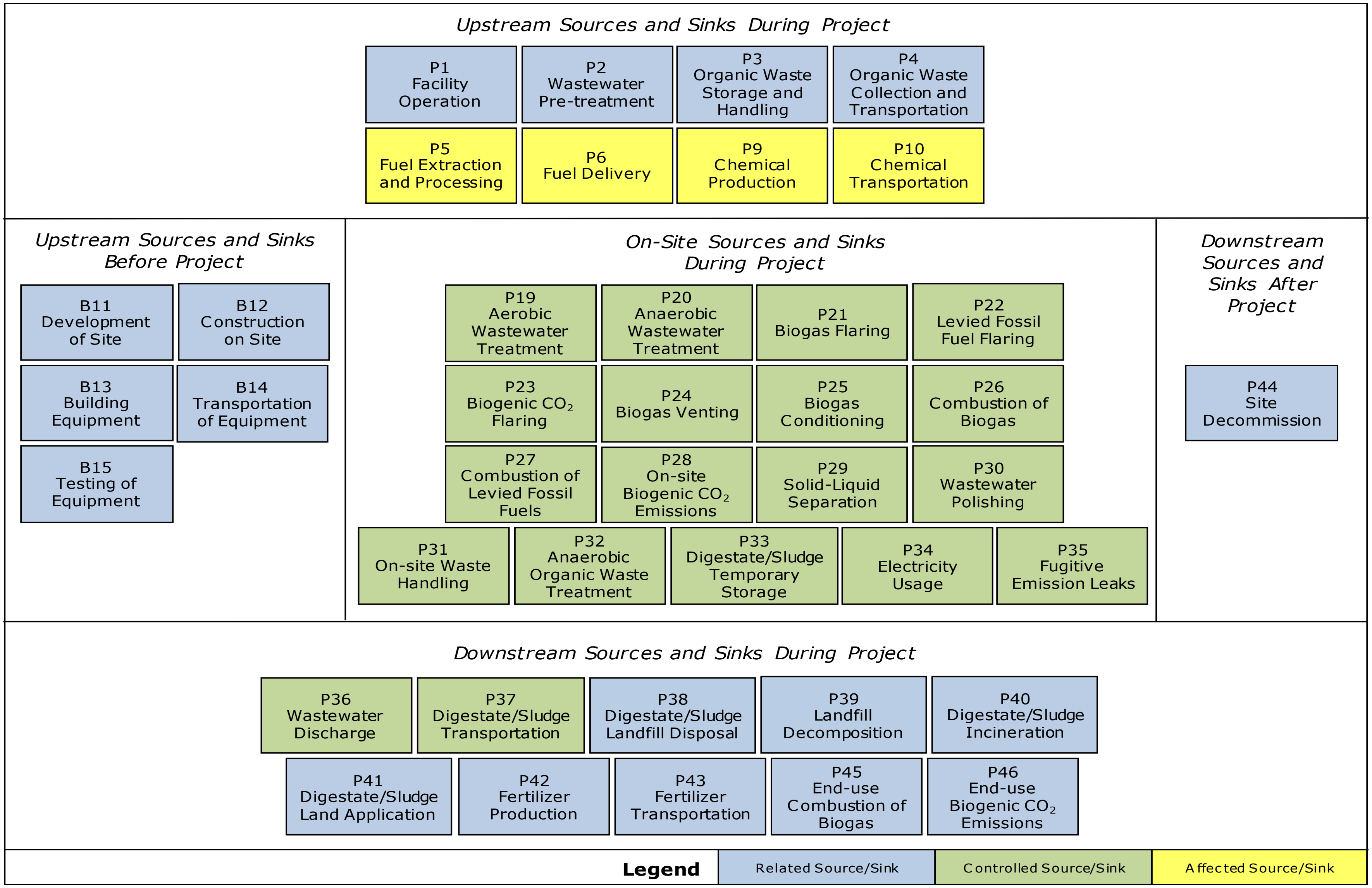


Table 3: Project Condition Sources and Sinks

Sources and Sinks (SS)	Description	Controlled, Related or Affected
Upstream Sources and Sinks During Project		
P1 Facility Operation	Organic waste materials are produced by a number of industries and processes. The facility generating the organic waste would have a primary function or product and any number of processes that would require energy inputs and therefore consume fossil fuels as part of the process or unit operation and for material handling. Greenhouse gas emissions may be associated with these industrial processes and the waste handling practices, which could include heating, pumping, mixing, sterilization and equalization and could be powered by fossil fuels either directly or indirectly through a centralized boiler or cogeneration unit. Quantities for each of the energy inputs are evaluated for functional equivalence with the baseline condition.	Related
P2 Wastewater Pre-treatment	Includes physical processes such as screening, grit and solids removal, oil-water separation, dissolved air flotation for removal of fats and oils and other processes that adjust the chemical composition of the wastewater. This may involve the use of heavy equipment that operates using diesel or natural gas.	Related
P3 Organic Waste Storage and Handling	Organic waste feedstock may be stored, for example in animal pens, in windrow, piles (stockpiling) or in enclosed containers. Greenhouse gas emissions result from the anaerobic decomposition of these materials if storage conditions allow for an oxygen deficient (anaerobic) atmosphere. The characteristics size, shape, composition, duration and management during storage are evaluated for functional equivalence with the project condition. Feedstock may be handled and/or processed prior to transportation. This involves the use of heavy equipment such as pay loaders or excavators that operate using diesel or natural gas. Emissions of greenhouse gases are associated with the use of these energy sources. Quantities for each of the energy inputs are evaluated for functional equivalence with the baseline condition.	Related

Sources and Sinks (SS)	Description	Controlled, Related or Affected
P4 Organic Waste Collection and Transportation	Organic waste feedstock are transported to the project site by truck, barge, train or other method. The related energy inputs for fueling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled are used to evaluate functional equivalence with the baseline condition.	Related
P5 Fuel Extraction and Processing	Each of the fuels used throughout the on-site component of the project are sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are tracked.	Related
P6 Fuel Delivery	Each of the fuels used throughout the on-site component of the project need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fueling station as the fuel used to take the equipment to the site is captured under other SS's and there are no other delivery emissions as the fuel is already going to the commercial fueling station. Distance and means of fuel delivery as well as the volumes of fuel delivered are tracked.	Affected
P9 Chemical Production	The production of chemicals from raw materials upstream of the project site may include several material and energy inputs such as natural gas and diesel.	Affected
P10 Chemical Transportation	Chemicals used at the project facility may be transported to the project site by truck, barge, train or other method. The related energy inputs for fueling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions.	Affected

Sources and Sinks (SS)	Description	Controlled, Related or Affected
Upstream Sources and Sinks Before Project		
P11 Development of Site	The site of the anaerobic waste treatment facility may need to be developed. This could include civil infrastructure such as access to electricity, gas and water supply, sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions are primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	Related
P12 Construction on Site	The process of construction at the site requires a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity.	Related
P13 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 are attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
P14 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by truck, barge and/or train. Greenhouse gas emissions are attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related

Sources and Sinks (SS)	Description	Controlled, Related or Affected
P15 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This results in running the equipment using test anaerobic digestion fuels or 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
On-site Sources and Sinks During Project		
P19 Aerobic Wastewater Treatment	The anaerobic wastewater treatment unit may be followed by an aerobic process (bioreactor, aerobic digester, clarifiers etc.) or an alternating anaerobic-aerobic process to ensure sufficient removal of organic matter from the wastewater stream, beyond the capability of a standalone anaerobic unit. There may be multiple energy and chemical inputs to operate equipment for pumping, mixing, coagulation, flocculation and aeration. Additionally, pockets of wastewater may have anaerobic conditions either by design or due to poor mixing, creating some additional methane emissions.	Controlled
P20 Anaerobic Wastewater Treatment	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the anaerobic treatment unit. This includes running any auxiliary equipment or monitoring systems and may include material handling. Thermal energy systems may be required to maintain the desired temperature for the anaerobic digester. This includes boilers or similar equipment, which requires several energy inputs such as natural gas or diesel.	Controlled

Sources and Sinks (SS)	Description	Controlled, Related or Affected
P21 Biogas Flaring	Flaring of the biogas may be required during upset conditions or during maintenance to any elements downstream of the anaerobic digester. Emissions of greenhouse gases are contributed from the combustion of the biogas. Carbon dioxide emissions from the combustion of biogas are biogenic and therefore, are quantified and reported under SS P23. Emissions from the combustion of any pilot, purge or make-up fuel used in flaring to ensure more complete combustion is quantified and reported under SS P22. Quantities of biogas being flared and the composition of the biogas are tracked.	Controlled
P22 Priced Fossil Fuel Flaring	Emissions from the combustion of any pilot, purge or make-up fuel used in flaring to ensure more complete combustion is quantified and reported under this SS. Quantities of fossil fuels combusted for these purposes are tracked.	Controlled
P23 Biogenic CO_2 Flaring	Carbon dioxide emissions from the combustion of biogas are biogenic and therefore, are quantified and reported under this SS. The quantity and composition of biogas are tracked.	Controlled
P24 Biogas Venting	Venting of the biogas may be required during upset conditions or during maintenance to the elements downstream of the anaerobic digester. Additionally, venting may occur regularly as part of the methane capture system design to include pressure relief valves or passive vents for safety reasons to prevent excessive or unsafe gas build-ups. Emissions of the methane under these circumstances would need to be considered. The duration of the venting condition, methane production rate and the volume of biogas in the digester at the time of venting are tracked.	Controlled

Sources and Sinks (SS)	Description	Controlled, Related or Affected
P25 Biogas Conditioning	Produced biogas will likely have a higher concentration of carbon dioxide and other impurities than may be acceptable to meet the required specifications for its use. Gas conditioning equipment such as separators, filters, knock-out drums, absorption units, adsorption beds, chillers, gas dryers, blowers, condensate pumps and other equipment may be required to treat the biogas and remove impurities in order meet the required specifications. This requires several energy inputs such as natural gas and diesel. Emissions of greenhouse gases are associated with the use of these fossil fuels. Quantities and types of each energy input are tracked.	Controlled
P26 Combustion of Biogas	Biogas may be combusted in thermal or co-generation systems to produce thermal and/or electrical energy for distribution, or use on-site (for example to maintain the desired temperature for the anaerobic digester). Combustion of biogas will result in the release of greenhouse gases that occur as a result of combustion, including nitrous oxide and non-combusted methane. Combustion will also release carbon dioxide which is deemed to be biogenic in origin and is accounted under P28.	Controlled
P27 Combustion of Pricing Fossil Fuels	Biogas may be combusted in thermal or co-generation systems to produce thermal and/or electrical energy for distribution, or use on-site (for example to maintain the desired temperature for the anaerobic digester). The operation of this equipment may require several external energy inputs such as natural gas or diesel. Emissions of greenhouse gases are associated with the use of these fossil fuels. Quantities and types for each of the energy inputs are tracked.	Controlled
P28 On-site Biogenic CO_2 Emissions	The conditioning of biogas and subsequent combustion will cause carbon dioxide emissions. Carbon dioxide emissions associated with the off gas from biogas upgrading, and carbon dioxide fraction of exhaust from biogas combustion are considered biogenic in origin, and are predicted to have occurred without anaerobic digestion and biogas production.	Controlled

Sources and Sinks (SS)	Description	Controlled, Related or Affected
P29 Solid-Liquid Separation	Greenhouse gas emissions may occur that are associated with the separation of the solid and liquid phases of the digestate or sludge. The digester output material is generally sent to a filter, press or centrifuge system for de-watering. In wastewater treatment, the recovered water is usually recycled back to the aerobic treatment process. There may be multiple energy and chemical inputs to operate the solid-liquid separator, pumps and associated equipment which are tracked.	Controlled
P30 Wastewater Polishing	The wastewater may undergo some additional chemical adjustments in a polishing step to ensure that the wastewater meets applicable sewer or surface water discharge regulations. Additional chemicals and energy inputs may be required in this step, with associated energy inputs and greenhouse gas emissions.	Controlled
P31 On-site organic Waste Handling	Feedstock may be handled and/or processed prior to being input to the anaerobic digester. This may involve the use of heavy equipment such as bull-dozers that operate using diesel or natural gas. Emissions of greenhouse gases are associated with the use of these fossil fuels. Quantities for each of the energy inputs are tracked.	Controlled
P32 Anaerobic Organic Waste Treatment	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the anaerobic digestion facility. This may include running any auxiliary or monitoring systems. Quantities and types for each of the energy inputs are tracked.	Controlled
P33 Digestate/Sludge Temporary Storage	Greenhouse gas emissions may result if the digestate/sludge needs to be stored temporarily after being removed from digester and before further processing. Further anaerobic decomposition may occur resulting primarily in methane emissions. Digestate/sludge is considered liquid when the total solids content is less than 20% of the total digestate/sludge weight and solid when total solids is 20% or more.	Controlled

Sources and Sinks (SS)	Description	Controlled, Related or Affected
P34 Electricity Usage	Grid electricity may be utilized to power certain components in the project condition and facility, including pumps, aerators, control systems, conveyors, solid/liquid separation, sensors etc. The grid electricity used to power these components incurs greenhouse gas emissions from electricity production on the Alberta electricity grid, and transmission losses. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of power are tracked as they directly relate to the greenhouse gas emissions.	Controlled
P35 Fugitive Emission Leaks	Greenhouse gas emissions may result from fugitive emissions associated with the operation of the anaerobic digestion facility. These emissions would primarily be methane emissions associated with leaks through valves, connections and equipment seals as many of the facility components operate under pressure. Quantities of fugitive emissions are measured or estimated.	Controlled
Downstream Sources and Sinks During Project		
P36 Wastewater Discharge	After the wastewater has undergone any remaining chemical adjustments in the polishing stage, it will either be stored indefinitely or discharged to the sewer system or another body of water. If any significant quantities of organic material were remaining in the wastewater stream (likely due to upset conditions), there could be some small amount of additional methane produced in the storage pond or downstream of the site.	Controlled
P37 Digestate/Sludge Transportation	Waste materials may be transported to disposal sites by truck, barge, train or other method. The related energy inputs for fueling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled are used to evaluate functional equivalence with the baseline condition.	Controlled

Sources and Sinks (SS)	Description	Controlled, Related or Affected
P38 Digestate/Sludge Landfill Disposal	Digestate/sludge may be disposed at a landfill disposal site. Disposal and landfill maintenance involve the use of heavy equipment and mechanical systems fueled by diesel, petroleum, natural gas, or electricity, resulting in greenhouse gas emissions. Other fuels may also be used in some rare cases. Quantities for each of the energy inputs are evaluated for functional equivalence with the baseline condition.	Related
P39 Landfill Decomposition	Digestate/sludge may decompose in the disposal facility (typically a landfill site) resulting in the production of methane. Disposal site characteristics and mass disposed of at each site are tracked as well as the characteristics of the methane collection and destruction system.	Related
P40 Digestate/Sludge Incineration	Processed waste (digestate) may be incinerated at a disposal site, for example, to comply with *Specified Risk Material* regulations. This process involves the use of machinery to transfer the waste from the transportation container, and otherwise handling the waste using a combination of loaders, conveyors and other mechanized devices. This equipment would be fueled by diesel, gas or natural gas, resulting in greenhouse gas emissions. Other fuels may also be used in some rare cases. The incineration process includes combusting the materials with a fuel such as natural gas or diesel. Other fuels may also be used in some rare cases. Quantities and types for each of the energy inputs are tracked.	Related
P41 Land Application	The process waste (digestate or sludge) may be land applied. This will require the use of heavy equipment and mechanical systems. This equipment is fueled by diesel, gas or natural gas, resulting in greenhouse gas emissions. Other fuels may also be used in some rare cases. Quantities for each of the energy inputs are evaluated for functional equivalence with the baseline condition. Records showing digestate/sludge was land applied must be provided. If no records of land application are available, landfill disposal of digestate/sludge must be assumed.	Related

Sources and Sinks (SS)	Description	Controlled, Related or Affected
P42 Fertilizer Production	Digestate may be converted to fertilizer through mechanical and amendment processes. This requires several energy inputs such as natural gas. Emissions of greenhouse gases are associated with the use of these energy sources. Quantities and types for each of the energy inputs are tracked.	Related
P43 Fertilizer Transportation	Fertilizer produced at the site will need to be transported to customers or distribution points by truck and/or train. The related energy inputs for fueling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled are used to evaluate functional equivalence with the baseline condition.	Related
P45 End-use Combustion of Biogas	Upgraded biogas that is injected into a natural gas distribution network (renewable natural gas) is assumed to ultimately be combusted. The default emission factor for renewable natural gas in this SS is the "pipeline" emission factor given in the Alberta Carbon Offset Emission Factors Handbook, unless otherwise evidenced by the project developer. Some fugitive methane emissions are assumed to occur between injection and use, in addition to non-combusted methane and nitrous oxide emissions occurring as a result of combustion in exhaust gases. See P46 End-use Biogenic CO_2 Emissions for carbon dioxide emissions associated with the combustion of pipeline-injected renewable natural gas.	Related
P46 End-use Biogenic CO_2 Emissions	Upgraded biogas that is injected into a natural gas distribution network (renewable natural gas) is assumed to ultimately be combusted. The default emission factor for renewable natural gas in this source/sink is the "pipeline" emission factor given in the Alberta Carbon Offset Emission Factors Handbook, unless otherwise evidenced by the project developer. The carbon dioxide fraction of the combusted pipeline-injected renewable natural gas is considered biogenic in origin, and is predicted to have occurred without anaerobic digestion and biogas production.	Related
Downstream Sources and Sinks After Project		

Sources and Sinks (SS)	Description	Controlled, Related or Affected
P44 Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This involves 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 attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

4.0 Quantification

The Baseline and Project Conditions were assessed against each other to determine the scope for the emission reductions quantified under this protocol. Sources and sinks were either included or excluded depending on how they were impacted by the project condition. Sources and sinks that are not expected to change between baseline and project condition have been excluded from the quantification. It is assessed that excluded activities will occur at the same magnitude and emission rate during the baseline and project and will therefore not be impacted by the project activity.

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

All sources and sinks were previously identified in Table 2 and Table 3. Table 4 outlines each source and sink as included or excluded with justification.

Table 4: Comparison of Sources/Sinks

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
Upstream Sources and Sinks				
B1 Facility Operation	Related	Related	Excluded	Excluded as in the majority of project configurations the upstream facility operations will not be impacted by the project activity and, therefore, will be functionally equivalent in the baseline and project conditions.
P1 Facility Operation	Related	Related	Excluded	
B2 Wastewater Pre-treatment	Related	Related	Excluded	Excluded as in the majority of project configurations the facility wastewater pre-treatment systems upstream of the anaerobic treatment unit will not be impacted by the project activity and, therefore, will be functionally equivalent in the baseline and project conditions. Note: If there is a change in electricity consumption as a result of the project, baseline and project electricity consumption should be included in the "Electricity Usage" SS.
P2 Wastewater Pre-treatment	Related	Related	Excluded	

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
B3 Organic Storage and Handling P3 Organic Storage and Handling	Related Related	Related Related	Included Excluded	Emissions from this source are excluded in the majority of configurations, where the project condition is equivalent to the baseline scenario. Any organic waste may be processed in the digester, as described in the Protocol Applicability section of this document; however, avoided emissions from upstream waste storage and handling of cattle and swine manure are the only emissions eligible for this emission source. Avoided landfill decomposition emissions are quantified under SS B39. For the baseline scenario, where organic waste is stored either upstream of the digester or on-site prior to processing, baseline emissions are quantified only for the proportion of organic waste that is processed through the anaerobic digester. Emissions resulting from the organic waste that is not processed through the anaerobic digester may be excluded from quantification if it is reasonable to assume they are equivalent in the baseline and project scenarios.
B4 Organic Waste Collection and Transportation P4 Organic Waste Collection and Transportation	Related Related	Related Related	Excluded Excluded	Excluded as in the majority of configurations, the project condition is equivalent to the baseline scenario.

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
B5 Fuel Extraction and Processing	Affected	Affected	Included	Included in both project and baseline condition.
P5 Fuel Extraction and Processing	Affected	Affected	Included	
B6 Fuel Delivery	Affected	Affected	Excluded	Excluded as emissions from these sources are deemed negligible compared to the emission reduction achieved.
P6 Fuel Delivery	Affected	Affected	Excluded	
B7 Grid Electricity Generation Displaced in Project	Affected	N/A	Included	Included in baseline condition.
B8 Pipeline Natural Gas Displaced in Project	Affected	N/A	Included	Included in baseline condition.
B9 Chemical Production	Affected	Affected	Excluded	Excluded as in the majority of configurations, chemical use in the project condition will be equivalent to the baseline scenario as the addition of a methane capture system would not be expected to materially impact chemical usage.
P9 Chemical Production	Affected	Affected	Excluded	
B10 Chemical Transportation	Affected	Affected	Excluded	Excluded as in the majority of configurations, chemical use in the project condition will be equivalent to the baseline scenario as the addition of a methane capture system would not be expected to materially impact chemical usage.
P10 Chemical Transportation	Affected	Affected	Excluded	

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
B11 Development of Site P11 Development of Site	Related Related	Related Related	Excluded Excluded	Emissions from site development are not material for the baseline condition given the minimal site development typically required.
B12 Construction on Site P12 Construction on Site	Related Related	Related Related	Excluded Excluded	Emissions from construction on site are not material for the baseline condition given the minimal construction on site typically required.
B13 Building Equipment P13 Building Equipment	Related Related	Related Related	Excluded Excluded	Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required.
B14 Transportation of Equipment P14 Transportation of Equipment	Related Related	Related Related	Excluded Excluded	Emissions from transportation of equipment are not material for the baseline condition given the minimal transportation of equipment typically required.
B15 Testing of Equipment P15 Testing of Equipment	Related Related	Related Related	Excluded Excluded	Emissions from testing of equipment are not material for the baseline condition given the minimal testing of equipment typically required.
On-site Sources and Sinks				
B16 On-site Heat Generation Displaced in Project	Affected	N/A	Included	Included in baseline condition.

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
B17 On-site Electricity Generation Displaced in Project	Controlled	N/A	Included	Included in baseline condition.
B18 On-site Heat and Electricity Not Displaced in Project	Related	N/A	Excluded	This source represents the on-site heat and electricity that is generated in the Baseline condition, but is not displaced in the Project condition. It is excluded as the emission from these sources are functionally equivalent in the baseline and project scenarios.
B19 Aerobic Wastewater Treatment P19 Aerobic Wastewater Treatment	Controlled Controlled	Controlled Controlled	Excluded Excluded	Excluded as in the majority of project configurations the aerobic wastewater treatment systems downstream of the anaerobic treatment unit will not be impacted by the project activity as the removal of COD in the anaerobic unit will either remain consistent or improve during the project activity and result in decreased treatment requirements downstream; therefore, the baseline and project conditions will be functionally equivalent. If there is a change in electricity consumption as a result of the project, then baseline and project electricity consumption should be included in the “Electricity Usage” SS.

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
B20 Passive Anaerobic Wastewater Treatment	Controlled	Controlled	Included	Included in baseline condition.
P20 Anaerobic Wastewater Treatment	Controlled	Controlled	Excluded	Carbon dioxide and methane produced from anaerobic wastewater treatment in the Project is collected and accounted for in other SSs (combustion, venting or flaring). Emissions resulting from the combustion of biogas and fossil fuels or electricity are included under SSs P26, P27, P28 and P34.
P21 Biogas Flaring	N/A	Controlled	Included	Included in project condition.
P22 Pricing Fossil Fuel Flaring	N/A	Controlled	Included	Included in project condition.
P23 Biogenic CO_2 Flaring	N/A	Controlled	Included	Included in project condition.
P24 Biogas Venting	N/A	Controlled	Included	Included in project condition.
P25 Biogas Conditioning	N/A	Controlled	Excluded	Emissions resulting from the combustion of biogas and fossil fuels or electricity are included under SSs P26, P27, P28 and P34. There are no process related emissions from this SS.
P26 Combustion of Biogas	N/A	Controlled	Included	Included in project condition.
P27 Combustion of Pricing Fossil Fuels	N/A	Controlled	Included	Included in project condition.

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
P28 On-site Biogenic CO_2 Emissions	N/A	Controlled	Included	Included in project condition.
B29 Solid-Liquid Separation P29 Solid-Liquid Separation	Controlled Controlled	Controlled Controlled	Excluded Excluded	Excluded as in the majority of project configurations the solid-liquid separation unit operation downstream of the anaerobic treatment unit will not be impacted by the project activity and, therefore, will be functionally equivalent in the baseline and project conditions. If there is a change in electricity consumption as a result of the project, then baseline and project electricity consumption should be included in the "Electricity Usage" SS.
B30 Wastewater Polishing P30 Wastewater Polishing	Controlled Controlled	Controlled Controlled	Excluded Excluded	Excluded as in the majority of project configurations the polishing treatment downstream of the anaerobic treatment unit will not be impacted by the project activity and, therefore, will be functionally equivalent in the baseline and project conditions. If there is a change in electricity consumption as a result of the project, then baseline and project electricity consumption should be included in the "Electricity Usage" SS.
P31 On-site organic Waste Handling	N/A	Controlled	Excluded	Emissions resulting from the combustion of biogas and fossil fuels or electricity are included under SSs P26, P27, P28 and P34. There are no process related emissions associated with this SS.

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
P32 Anaerobic Organic Waste Treatment	N/A	Controlled	Excluded	Carbon dioxide and methane produced from anaerobic treatment of solid waste in the Project is collected and accounted for in other SSs (combustion, venting or flaring). Emissions resulting from the combustion of biogas and fossil fuels or electricity are included under SSs P26, P27, P28 and P34.
B33 Solid Waste Temporary Storage	Controlled	Controlled	Excluded	Emissions from temporary storage in the baseline condition are likely minimal as the time in temporary storage following collection is likely minimal. Further, excluding this baseline emission source is conservative.
P33 Digestate/Sludge Temporary Storage	Controlled	Controlled	Included	Emissions from temporary storage of sludge from anaerobic wastewater treatment or digestate from anaerobic organic waste treatment must be included if the temporary storage is longer than 24 hours in duration. See Flexibility Mechanism 3 for further information.
P34 Electricity Usage	N/A	Controlled	Included	Included in project condition.
B35 Fugitive Emission Leaks	Controlled	Controlled	Excluded	Excluded as projects applying this protocol must meet the requirement to establish and maintain a leak detection and repair program. Emissions from these sources should therefore be negligible. See Protocol Applicability for further information.
P35 Fugitive Emission Leaks	Controlled	Controlled	Excluded	

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
Downstream Sources and Sinks				
B36 Wastewater Discharge	Controlled	Controlled	Excluded	Excluded as in the majority of project configurations, the wastewater discharge systems downstream of the anaerobic treatment unit will not be impacted by the project activity and, therefore, will be functionally equivalent in the baseline and project conditions. If there is a change in electricity consumption as a result of the project, then baseline and project electricity consumption should be included in the "Electricity Usage" SS.
P36 Wastewater Discharge	Controlled	Controlled	Excluded	
B37 Solid Waste Transportation	Controlled	Controlled	Excluded	Excluded as quantity of waste and related emissions from its transport are negligible.
P37 Digestate/Sludge Transportation	Controlled	Controlled	Excluded	
B38 Solid Waste Landfill Disposal	Related	Related	Excluded	Excluded as the emissions associated with landfill operations would be difficult to track and are not the focus of this Protocol. It is conservative to exclude this baseline emission source. Project condition can be assumed to be functionally equivalent to the baseline condition and excluded.
P38 Digestate/Sludge Landfill Disposal	Related	Related	Excluded	
B39 Landfill Decomposition	Related	Related	Included	Included in both baseline and project condition.
P39 Landfill Decomposition	Related	Related	Included	

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
B40 Solid Waste Incineration	Related	Related	Included	Included in both baseline and project condition.
P40 Digestate/Sludge Incineration	Related	Related	Included	
B41 Solid Waste Land Application	Related	Related	Excluded	Greater carbon sequestration will occur in the baseline condition than in the project condition because a significant amount of carbon in the raw organic waste is removed in the digester in the form of biogas. The nitrogen in digestate is more stable than the nitrogen in raw organic waste and therefore, less nitrous oxide will be produced from land applied digestate (project condition) than from land applied raw organic waste (baseline condition). The reduction of nitrous oxide emissions between the baseline and project conditions has been shown to be significantly greater than the reduced sequestration of carbon between the baseline and project conditions (on a carbon dioxide equivalent basis). Further, the quantification of these differences involves complex data capture, management and calculation, with considerable inherent uncertainty. Additionally, the emission reduction described here is not the focus of this protocol. Therefore, this emission source is excluded as it is conservative.
P41 Land Application	Related	Related	Excluded	

Identified Sources and Sinks	Baseline	Project	Include or Exclude from Quantification	Justification
B42 Fertilizer Production P42 Fertilizer Production	Related Related	Related Related	Excluded Excluded	Excluded as the emission reduction that is achieved by using organic fertilizer produced as a co-product of biogas production is not the focus of this protocol. It is conservative to exclude this emission source.
B43 Fertilizer Transportation P43 Fertilizer Transportation	Related Related	Related Related	Excluded Excluded	Excluded as the emission reduction that is achieved by using organic fertilizer that is likely transported a shorter distance than conventional fertilizer in most project configurations is not the focus of this protocol. It is conservative to exclude this emission source.
B44 Site Decommissioning P44 Site Decommissioning	Related Related	Related Related	Excluded Excluded	Emissions from decommissioning are not material for the baseline condition given the minimal decommissioning typically required.
P45 End-use Combustion of Biogas	N/A	Related	Included	Included in project condition.
P46 End-use Biogenic CO_2 Emissions	N/A	Related	Included	Included in project condition.

4.1 Quantification Methodology

Emissions 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, as referenced in ISO 14064-2[1].

However, only some reductions may be eligible for emission offsets. Eligible reductions are listed in 4.1.2.

4.1.1 Net Emissions Reductions

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

Where:

$\text{Emissions}_{\text{Baseline}}$ = $\text{Emissions}_{\text{Organic Waste Storage and Handling}} + \text{Emissions}_{\text{Fuel Extraction and Processing}} + \text{Emissions}_{\text{Grid Electricity Generation Displaced in Project}} + \text{Emissions}_{\text{Pipeline Natural Gas Displaced in Project}} + \text{Emissions}_{\text{On-site Heat Generation Displaced in Project}} + \text{Emission}_{\text{On-site Electricity Generation Displaced in Project}} + \text{Emissions}_{\text{Passive Anaerobic Wastewater Treatment}} + \text{Emissions}_{\text{Landfill Decomposition}} + \text{Emissions}_{\text{Solid Waste Incineration}}$

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

= Emissions under B3 Organic Waste Storage and Handling

+ Emissions under B5 Fuel Extraction and Processing

+ Emissions under B7 Grid Electricity Generation Displaced in Project

+ Emissions under B8 Pipeline Natural Gas Displaced in Project

+ Emissions under B16 On-site Heat Generation Displaced in Project

+ Emissions under B17 On-site Electricity Generation Displaced in Project

+ Emissions under B20 Passive Anaerobic Wastewater Treatment

+ Emissions under B39 Landfill Decomposition

+ Emissions under B40 Solid Waste Incineration

and

$\text{Emissions}_{\text{Project}}$ = $\text{Emissions}_{\text{Fuel Extraction and Processing}} + \text{Emissions}_{\text{Biogas Flaring}} + \text{Emissions}_{\text{Priced Fossil Fuel Flaring}} + \text{Emissions}_{\text{Biogenic CO2 Flaring}} + \text{Emissions}_{\text{Biogas Venting}} +$

[1] International Standards Organization. (2006). Greenhouse gases — Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements. In ISO 14064-2:2006 (en). Retrieved February 10, 2015, from https://www.iso.org/obp/ui/#iso:std:iso:14064:-2:ed-1:v1:en

Emissions Combustion of Biogas + Emissions Combustion of Priced Fossil Fuels + Emissions On-site Biogenic CO2 Emissions + Emissions Solid Waste Temporary Storage + Emissions Electricity Usage + Emissions Landfill Decomposition + Emissions Solid Waste Incineration + Emissions End-use Combustion of Biogas + Emissions End-use Biogenic CO2 Emissions

Emissions Project = Sum of the emissions under the project condition.

= Emissions under P5 Fuel Extraction and Processing

+ Emissions under P21 Biogas Flaring

+ Emissions under P22 Priced Fossil Fuel Flaring

+ Emissions under P23 Biogenic CO_2 Flaring

+ Emissions under P24 Biogas Venting

+ Emissions under P26 Combustion of Biogas

+ Emissions under P27 Combustion of Priced Fossil Fuels

+ Emissions under P28 On-site Biogenic CO_2 Emissions

+ Emissions under P33 Digestate/Sludge Temporary Storage

+ Emissions under P34 Electricity Usage

+ Emissions under P39 Landfill Decomposition

+ Emissions under P40 Digestate/Sludge Incineration

+ Emissions under P45 End-use Combustion of Biogas

+ Emissions under P46 End-use Biogenic CO_2 Emissions

4.1.2 Offset-eligible reductions (non-priced emissions):

Offset Eligible Emissions Reductions = **Emissions Non-Priced Baseline** – **Emissions Non-Priced Project**

Where:

Emissions Non-Priced Baseline = Emissions Organic Waste Storage and Handling + Emissions Fuel Extraction and Processing + Emission Grid Electricity Generation Displaced in Project + Emission On-site Electricity Generation Displaced in Project + Emissions Passive Anaerobic Wastewater Treatment+ Emissions Landfill Decomposition

Emissions Non-Priced Baseline = Sum of the emissions under the baseline condition that are not subject to the carbon price.

= Emissions under B3 Organic Waste Storage and Handling

+ Emissions under B5 Fuel Extraction and Processing

+ Emissions under B7 Grid Electricity Generation Displaced in Project

+ Emissions under B17 On-site Electricity Generation Displaced in Project

+ Emissions under B20 Passive Anaerobic Wastewater Treatment

+ Emissions under B39 Landfill Decomposition and

Emissions $_{\textbf{Non-Priced Project}}$	=	Emissions $_{\text{Fuel Extraction and Processing}}$ + Emissions $_{\text{Biogas Flaring}}$ + Emissions $_{\text{Biogas Venting}}$ + Emissions $_{\text{Combustion of Biogas}}$ + Emissions $_{\text{Solid Waste Temporary Storage}}$ + Emissions $_{\text{Electricity Usage}}$ + Emissions $_{\text{Landfill Decomposition}}$ + Emissions $_{\text{End-use Combustion of Biogas}}$
Emissions $_{\textbf{Non-Priced Project}}$	=	Sum of the emissions under the project condition that are not subject to the carbon price. = Emissions under P5 Fuel Extraction and Processing + Emissions under P21 Biogas Flaring + Emissions under P24 Biogas Venting + Emissions under P26 Combustion of Biogas + Emissions under P33 Digestate/Sludge Temporary Storage + Emissions under P34 Electricity Usage + Emissions under P39 Landfill Decomposition + Emissions under P45 End-use Combustion of Biogas

4.1.3 Priced reductions (reported but not included in emission offset calculation):

Priced Emissions Reductions = **Emissions** $_{\textbf{Priced Baseline}}$ – **Emissions** $_{\textbf{Priced Project}}$

Where:

Emissions $_{\textbf{Priced Baseline}}$	=	Emissions $_{\text{Pipeline Natural Gas Displaced in Project}}$ + Emissions $_{\text{On-Site Heat Generation Displaced in Project}}$ + Emissions $_{\text{Solid Waste Incineration}}$
Emissions $_{\textbf{Priced Baseline}}$	=	Sum of the emissions under the baseline condition that are subject to the carbon price. = Emissions under B8 Pipeline Natural Gas Displaced in Project + Emissions under B16 On-site Heat Generation Displaced in Project + Emissions under B40 Solid Waste Incineration

and

Emissions $_{\textbf{Priced Project}}$	=	Emissions $_{\text{Priced Fossil Fuel Flaring}}$ + Emissions $_{\text{Combustion of Priced Fossil Fuels}}$ + Emissions $_{\text{Solid Waste Incineration}}$
Emissions $_{\textbf{Priced Project}}$	=	Sum of the emissions under the project condition that are subject to the carbon price. = Emissions under P22 Priced Fossil Fuel Flaring + Emissions under P27 Combustion of Priced Fossil Fuels

+ Emissions under P40 Digestate/Sludge Incineration

4.1.4 Biogenic CO_2 reductions (reported but not included in emission offset calculation):

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

Where:

Emissions $_{\textbf{Biogenic Baseline}}$	=	0

and

Emissions $_{\textbf{Biogenic Project}}$	=	Emissions $_{\text{Biogenic CO2 Flaring}}$ +Emissions $_{\text{On-site Biogenic CO2 Emissions}}$ + Emissions $_{\text{End-use Biogenic CO2 Emissions}}$
Emissions $_{\textbf{Biogenic Project}}$	=	Sum of the biogenic CO_2 emissions under the project condition. = Emissions under P23 Biogenic CO_2 Flaring + Emissions under P28 On-site Biogenic CO_2 Emissions + Emissions under P46 End-use Biogenic CO_2 Emissions

The quantification equations provided in Table 5 on the following pages calculate total emissions in carbon dioxide equivalent (tonnes CO_2e). The project developer is 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). The total emission reduction for each greenhouse gas as well as the total emission reduction in carbon dioxide equivalent is reported in each GHG Assertion.

Table 5: Quantification Methodology

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
Baseline Condition						
B3 Organic Waste Storage and Handling	$Emissions_{Organic\ Waste\ Storage\ and\ Handling} = M_{manure\ processed} * VS_{in} * B_o * MCF * \rho_{CH4} * Emptying_{frequency} * GWP_{CH4} / 1000$ or $Emissions_{Organic\ Waste\ Storage\ and\ Handling} = V_{manure\ processed} * \rho_{manure} * VS_{in} * B_o * MCF * \rho_{CH4} * Emptying_{frequency} * GWP_{CH4} / 1000$					
	$Emissions_{Organic\ Waste\ Storage\ and\ Handling}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$M_{manure\ processed}$ Mass of manure processed	$tonnes_{manure\ processed}$	Measured	Mass of truckload of manure shipped for processing or mass of manure in digester	Each truckload	Frequency of measurement is highest level possible.
	$V_{manure\ processed}$ Volume of manure processed	$m^3_{manure\ processed}$	Measured	Volume of truckload of manure shipped	Each truckload	Frequency of measurement is highest level possible.
	ρ_{manure} Density of manure	tonnes / m^3	Estimated	1.0	N/A	Dairy and hog liquid slurry consists mainly of water, so the use of the density of water to convert volume to mass is appropriate.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	VS_{in} Proportion Volatile Solids in Manure Processed	kg VS / $tonne_{manure\ processed}$	Measured	Laboratory analysis of sample taken at source.	Monthly composite sample or upon change in source of manure.	Proper sampling and lab analysis provide reliable, source specific estimates. Change in source of manure necessitates sampling, which provides highest level of detail possible. For a monthly composite sample, samples taken daily or weekly should be frozen until the need to be put into a composite sample (See Appendix A).
	B_o Maximum CH_4 Producing Potential for Manure	m^3 $CH_{4\ max}$ / kg VS	Estimated	0.24 for dairy cattle; 0.48 for swine	N/A	Value from IPCC Tables 10A-4 and 10A-7, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 10 – Emissions from Livestock and Manure Management.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	MCF Methane Conversion Factor	(m^3 CH_4 / year) / m^3 CH_4 max	Estimate	0.13 or 0.14	N/A	MCF estimate extrapolated from values provided in Table 10.17 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 10 – Emissions from Livestock and Manure Management. Use 0.13 where annual normal temperature for nearest weather station is less than 5.0 degrees Celsius. Use 0.14 where annual normal temperature for nearest weather station is 5.0 degrees Celsius or greater. MCF estimate extrapolated using weather normal data from Government of Canada – Canadian Climate Normals: 1981 – 2010, available at www.gc.ca
	ρ_{CH4} Density of Methane	kg per m^3	Constant	0.67847 at standard temperature and pressure.	Actual value	Constant value at STP (15 degrees Celsius; 1 atm.)

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$Emptying_{frequency}$	%	Estimated	50% conservative default value; 100% by a deviation approval	N/A	The default value is 50% unless evidence is available to substantiate once per year emptying. Emptying of manure storage twice annually is the most common practice in Alberta.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
B5 Fuel Extraction and Processing	$Emissions_{Fuel\ Extraction\ and\ Processing} = [\sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CO2}) + \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CH4} * GWP_{CH4}) + \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ N2O} * GWP_{N2O})] / 1000$					
	$Emissions_{Fuel\ Extraction\ and\ Processing}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Vol.\ Fuel_i$ Volume of Fuel Consumed	L / m^3 / 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 (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$EF\ Fuel_{i\ CO2}$ CO_2 Emissions Factor for Each Type of Fuel	kg CO_2 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	$EF\ Fuel_{i\ CH4}$ CH_4 Emissions Factor for Each Type of Fuel	kg CH_4 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	$EF\ Fuel_{i\ N2O}$ N_2O Emissions Factor for Each Type of Fuel	kg N_2O per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	Annual	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{N2O} Global Warming Potential for N_2O	kg CO_2e / kg N_2O	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
B7 Grid Electricity Generation Displaced in Project	$Emissions_{Grid\ Electricity\ Generation\ Displaced\ in\ Project} = Electricity_{Grid} * EF_{EG}$					
	$Emissions_{Grid\ Electricity\ Generation\ Displaced\ in\ Project}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Electricity_{Grid}$ Electricity delivered to the Alberta Interconnected Electricity Grid	MWh	Measured	Direct metering of quantity of renewable electricity delivered to the Alberta Interconnected Electricity Grid.	Continuous metering	Continuous direct metering represents the industry practice and the highest level of detail. This quantity of electricity generated in the project condition displaces an equivalent quantity of electricity that would have been produced by other grid connected facilities had the project activity not been implemented.
	EF_{EG} Emissions Factor for Electricity	tonnes CO_2e per MWh	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
B8 Pipeline Natural Gas Displaced in Project	$Emissions_{Pipeline\ Natural\ Gas\ Displaced\ in\ Project} = [\sum (Vol.\ Natural\ Gas * EF\ Fuel_{i\ CO2}) + \sum (Vol.\ Natural\ Gas * EF\ Fuel_{i\ CH4} * GWP_{CH4}) + \sum (Vol.\ Natural\ Gas * EF\ Fuel_{i\ N2O} * GWP_{N2O})] / 1000$					
	$Emissions_{Pipeline\ Natural\ Gas\ Displaced\ in\ Project}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Vol.\ Natural\ Gas = Vol.\ Biogas\ Injected * ((F_{CH4} * HHV_{Methane}) / HHV_{Natural\ Gas})$					
	Vol. Natural Gas Volume of Natural Gas Displaced in Project	m^3	Calculated	N/A	N/A	Interim calculation.
	Vol. Biogas Injected Volume of Biogas Injected into Pipeline	m^3	Measured	Direct metering of volume.	Continuous metering	Frequency of metering is highest level possible.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	F_{CH4} Fraction of methane in biogas	m^3 CH_4 per m^3 biogas	Measured	Gas composition analysis. Proportion of methane may be measured and assume remaining volume is carbon dioxide or vice versa.	Daily	Biogas composition changes regularly. Frequency of metering provides for reasonable diligence.
	$HHV_{Methane}$ Higher Heating Value of Methane	GJ / m^3	Constant	37.3	N/A	Physical constant at STP. CRC Handbook of Chemistry and Physics, 98th edition.
	$HHV_{Natural\ Gas}$ Higher Heating Value of Pipeline Quality Natural Gas	GJ / m^3	Estimated	Reference value for pipeline quality natural gas from Environment Canada National GHG Inventory.	N/A	Reference value. Use of the higher heating value is consistent with Environment Canada's National GHG Inventory.
	$EF\ Fuel_{i\ CO2}$ CO_2 Emissions Factor for Combustion of Each Type of Fuel	kg CO_2 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF Fuel $_{i\ CH_4}$ CH_4 Emissions Factor for Combustion of Each Type of Fuel	kg CH_4 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{i\ N_2O}$ N_2O Emissions Factor for Fuel Including Production and Processing	kg N_2O per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{CH_4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{N_2O} Global Warming Potential for N_2O	kg CO_2e / kg N_2O	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

$$\text{Emissions}_{\text{On-site Heat Generation Displaced in Project}} = [\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\ CO_2}) + \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\ CH_4} * GWP_{CH_4})$$

$$+ \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\ N_2O} * GWP_{N_2O})] / 1000$$

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
B16 On-site Heat Generation Displaced in Project	Emissions $_{\text{On-site Heat Generation Displaced in Project}}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Vol.\ Fuel_i = Vol.\ Biogas\ Combusted * ((F_{CH4} * HHV_{Methane}) / HHV_{Fuel\ i})$					
	Vol Fuel $_i$ Volume of Fossil Fuel Displaced in the Project	L / m^3 / other	Calculated	N/A	N/A	Interim calculation.
	Vol. Biogas Injected Volume of Biogas Combusted for On-site Heat Generation	m^3	Measured	Direct metering of volume.	Continuous metering	Frequency of metering is highest level possible.
	F_{CH4} Fraction of methane in biogas	m^3 CH_4 per m^3 biogas	Measured	Gas composition analysis. Proportion of methane may be measured and assume remaining volume is carbon dioxide or vice versa.	Daily	Biogas composition changes regularly. Frequency of metering provides for reasonable diligence.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$HHV_{Methane}$ Higher Heating Value of Produced Biogas	GJ / m^3	Constant	37.3	N/A	Physical constant at STP. CRC Handbook of Chemistry and Physics, 98th edition.
	$HHV_{Fuel\ i}$ Higher Heating Value of Fossil Fuel Displaced in the Project	GJ / m^3	Estimated	Reference value for each fossil fuel from Environment Canada National GHG Inventory.	N/A	Reference value. Use of the higher heating value is consistent with Environment Canada's National GHG Inventory.
	$EF\ Fuel_{i\ CO2}$ CO_2 Emissions Factor for Each Type of Fuel	kg CO_2 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	$EF\ Fuel_{i\ CH4}$ CH_4 Emissions Factor for Each Type of Fuel	kg CH_4 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$EF\ Fuel_{i\ N2O}$ N_2O Emissions Factor for Each Type of Fuel	kg N_2O per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{N2O} Global Warming Potential for N_2O	kg CO_2e / kg N_2O	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
B17 On-site Electricity Generation Displaced in Project	$Emissions_{\text{On-site Electricity Generation Displaced in Project}} = Electricity_{\text{On-site}} * EF_{EG}$					
	$Emissions_{\text{On-site Electricity Generation Displaced in Project}}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$Electricity_{On\text{-}site}$ Electricity Sent to Directly Connected Facilities	MWh	Measured	Direct metering of quantity of renewable electricity delivered to directly connected users net of parasitic loads attributable to the project activity.	Continuous metering	Continuous direct metering represents the industry practice and the highest level of detail. This quantity of electricity generated in the project condition displaces an equivalent quantity of electricity that would have been produced by other grid connected facilities had the project activity not been implemented.
	EF_{EG} Emissions Factor for Electricity	tonnes CO_2e per MWh	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	Annual	Reference values in Carbon Offset Emission Factors Handbook.
B20 Passive Anaerobic Wastewater Treatment	$Emissions_{Passive\ Anaerobic\ Wastewater\ Treatment} = [\sum [(Flow_{IN} * COD_{IN}) - (Flow_{OUT} * COD_{OUT}) - (Q_{Sediment} * COD_{Sediment})] * MCF * B_o * GWP_{CH4}] / 1000$					
	$Emissions_{Passive\ Anaerobic\ Wastewater\ Treatment}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$Flow_{IN}$ Flow Rate of Wastewater into the Anaerobic Treatment Unit in the Project Condition	m^3 of wastewater	Measured	Direct measurement of volumetric flow rate of wastewater into the anaerobic treatment unit in the project condition.	Daily	Frequency of metering provides for reasonable diligence as wastewater volumes will be fairly consistent over the course of a year.
	COD_{IN} Concentration of Chemical Oxygen Demand in the Inlet Wastewater Stream Entering the Anaerobic Treatment Unit in the Project Condition	kg COD per m^3 of wastewater	Measured	Direct measurement of chemical oxygen demand of inlet wastewater to the anaerobic treatment unit in the project activity. Measurement may be performed on site by trained technicians or tested by an external third-party laboratory.	Weekly	Frequency of metering provides for reasonable diligence.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$Flow_{OUT}$ Flow Rate of Wastewater exiting the Anaerobic Treatment Unit in the Project Condition	m^3 of wastewater	Measured	Direct measurement of volumetric flow rates of wastewater exiting the anaerobic treatment unit in the project condition.	Daily	Frequency of metering provides for reasonable diligence as wastewater volumes will be fairly consistent over the course of a year.
	COD_{OUT} Concentration of Chemical Oxygen Demand in the Wastewater Stream Exiting the Anaerobic Treatment Unit in the Project Condition	kg COD per m^3 of wastewater	Measured	Direct measurement of chemical oxygen demand of wastewater exiting the anaerobic treatment unit in the project activity. Measurement may be performed on site by trained technicians or tested by an external third-party laboratory.	Weekly	Frequency of metering provides for reasonable diligence.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$Q_{Sediment}$ Quantity of Sediments Removed from the Anaerobic Digester in the Project Condition	m^3 of wastewater	Measured	Direct measurement or reconciliation from disposal or haulage fees.	Each time sediments are removed from the anaerobic digester	Frequency of metering represents the highest level of assurance.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$COD_{Sediment}$ Concentration of Chemical Oxygen Demand in Sediments Removed from the Anaerobic Treatment Unit in the Project Condition	kg COD per m^3 of wastewater	Measured	Direct measurement of chemical oxygen demand of wastewater and sediments removed from the anaerobic treatment unit in the project activity (e.g. due to decreased volume in the anaerobic treatment unit because of sediment build up or due to upset conditions). Measurement may be performed on site by trained technicians or tested by an external third-party laboratory.	Each time sediments are removed from the anaerobic digester	Frequency of metering represents the highest level of assurance.
	MCF Methane Conversion Factor	%	Calculated	Calculated based on IPCC guidelines as per CDM Methodology ACM0014, Version 7.	Monthly	Values calculated by applying methodology published by the CDM.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$MCF = f_d * f_T * 0.89$					
	f_d Depth Factor When D < 1 m $f_d = 0$ When 1 m ≤ D < 2 m $f_d = 0.5$ When D ≥ 2 m $f_d = 0.7$	%	Measured and Estimated	Reconciliation of the dimensions of the anaerobic treatment unit from system designs or depth measurements under normal operating conditions.	Annual	Values calculated based on values published by CDM methodology ACM0014, Version 7. Depth (D) of the lagoon or sludge pit is used to calculate the depth factor following CDM guidelines.
	f_T Temperature Factor	%	Calculated	Calculated monthly following CDM methodology ACM0014, Version 7.	Monthly	Values calculated by applying methodology published by the CDM.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	When $T_{Effluent} > 302.5$ K: $f_T = 0.95$ When $T_{Effluent} \geq 283$ K and ≤ 302.5 K: $f_T = \frac{\exp[(15,175 * (T_{Effluent} - 303.16))}{(1.987 * (303.16 * T_{Effluent}))]}$ When $T_{Effluent} < 283$ K: $f_T = 0$					
	Conservativeness Factor	%	Estimated	Value of 0.89 from CDM methodology ACM0014.	-	The use of a conservative factor from CDM methodology ACM0014 (Version 7) is consistent with best practice guidance.
	$T_{Effluent}$ Temperature of the Wastewater Effluent from the Anaerobic Treatment Unit in the Baseline	Degrees Kelvin	Modeled	Heat transfer model developed and signed by a Professional Engineer.	Monthly	A monthly heat transfer model that accounts for local conditions is required to accurately model the baseline effluent temperature.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	B_o Maximum Methane Producing Capacity	kg CH_4 per kg COD	Estimated	Default value from ACM0014 = 0.21	N/A	IPCC default value from 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 6 – Table 6.2 The IPCC default value is discounted in ACM0014 (Version 7) to account for uncertainty in this value. If wastewater does not contain materials akin to simple sugars, a different methane production capacity factor must be obtained from published literature and applied.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
B39 Landfill Decomposition	$Emissions_{Landfill\ Decomposition} = Q \times GWP_{CH4}$					

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$Emissions_{Landfill\ Decomposition}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$M_{organic\ waste}$	tonnes	Measured	Measurement of each truck load diverted from landfill and delivered to digester.	Periodic	Measurement is most accurate practice. $M_{organic\ waste}$ is applied in the Carbon Offset Emission Factors Handbook Quantification of Avoided Landfill and Stockpile Methane Emissions as the variable 'W_c'.
	Q Quantity of Methane Emitted from Landfill	tonnes CH_4 / time	Calculated	Provided in Carbon Offset Emission Factors Handbook (uses $M_{organic\ waste}$ as an input)	N/A	Must use most recent methodology published by Alberta Environment and Parks.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
B40 Solid Waste Incineration	$Emissions_{Solid\ Waste\ Incineration} = [\sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CO2}) + \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CH4} * GWP_{CH4}) + \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ N2O} * GWP_{N2O})] / 1000$					
	$Emissions_{Solid\ Waste\ Incineration}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Vol\ Fuel_i$ Volume of Each Type of Fuel used for incineration	L / m^3 / 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.
	$EF\ Fuel_{i\ CO2}$ CO_2 Emissions Factor for Each Type of Fuel	kg CO_2 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF Fuel $_{i\ CH_4}$ CH_4 Emissions Factor for Each Type of Fuel	kg CH_4 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{i\ N_2O}$ N_2O Emissions Factor for Each Type of Fuel	kg N_2O per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{CH_4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{N_2O} Global Warming Potential for N_2O	kg CO_2e / kg N_2O	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
Project Condition						
P5 Fuel Extraction and Processing	Emissions $_{\text{Fuel Extraction and Processing}}$ = [∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO_2}$) + ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH_4}$ * GWP_{CH_4}) +∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ N_2O}$ * GWP_{N_2O})] / 1000					

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Emissions $_{Fuel\ Extraction\ and\ Processing}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol. Fuel $_i$ Volume of Fuel Consumed	L / m^3 / 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.
	EF Fuel $_{i\ CO2}$ CO_2 Emissions Factor for Each Type of Fuel	kg CO_2 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{i\ CH4}$ CH_4 Emissions Factor for Each Type of Fuel	kg CH_4 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{i\ N2O}$ N_2O Emissions Factor for Each Type of Fuel	kg N_2O per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{N2O} Global Warming Potential for N_2O	kg CO_2e / kg N_2O	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
P21 Biogas Flaring	$Emissions_{Biogas\ Flaring} = [Vol.\ Biogas_{Flared} * F_{CH4} * \rho_{CH4} * (1 - D_{CH4}) * GWP_{CH4}] / 1000$					
	$Emissions_{Biogas\ Flaring}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Vol.\ Biogas_{combusted}$ Volume of Biogas Flared	m^3	Measured	Direct metering of volume of biogas being combusted in the flare.	Continuous metering	Direct metering is standard practice. Frequency of metering is highest level possible.
	F_{CH4} Fraction of methane in biogas	m^3 CH_4 per m^3 biogas	Measured	Gas composition analysis. Proportion of methane may be measured and assume remaining volume is carbon dioxide or vice versa.	Daily	Biogas composition changes regularly. Frequency of metering provides for reasonable diligence.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	ρ_{CH4} Density of Methane	kg per m^3	Constant	0.67847 kg/m^3 at standard temperature and pressure.	Actual value	Constant value at STP (15 degrees Celsius; 1 atm.)
	D_{CH4} Destruction Efficiency of Combustion Device	%	Estimated	Methane destruction efficiency obtained from manufacturer or vendor.	Actual value	The manufacturer or vendor's specifications represent the industry practice and the highest level of detail.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
P22 Priced Fossil Fuel Flaring	$Emissions_{Priced\ Fossil\ Fuel\ Flaring} = [Vol.\ Fossil\ Fuel_{Flared} * F_{CH4} * \rho_{CH4} * D_{CH4} * Molar\ Ratio_{CO2\text{-}CH4} + Vol.\ Fossil\ Fuel_{Flared} * F_{CH4} * \rho_{CH4} * (1 - D_{CH4}) * GWP_{CH4}] / 1000$					
	$Emissions_{Priced\ Fossil\ Fuel\ Flaring}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Vol.\ Fossil\ Fuel_{Flared}$ Volume of Fossil Fuel Flared	m^3	Measured	Direct metering of volume of fossil fuel being combusted in the flare.	Continuous metering	Direct metering is standard practice. Frequency of metering is highest level possible.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	D_{CH4} Flare Destruction Efficiency	%	Estimated	Methane destruction efficiency obtained from manufacturer or vendor.	Actual value	The manufacturer or vendor's specifications represent the industry practice and the highest level of detail.
	Molar Ratio $_{CO2\text{-}CH4}$	Unitless	Constant	44.01 / 16.04	Actual value	Physical constant
	F_{CH4} Fraction of methane in fossil fuel	m^3 CH_4 per m^3 fossil fuel	Measured or Estimated at 100%	Measured on-site, provided by fossil fuel supplier, or estimated at 100% methane	Monthly	Measurement on-site or value provided by fossil fuel supplier is the standard practice. The assumption of 100% methane is the most conservative estimate.
	ρ_{CH4} Density of Methane	kg CH_4 / m^3 CH_4	Constant	0.67847 at standard temperature and pressure	Actual value	Constant value at STP (15 degrees Celsius; 1 atm.)
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
P23 Biogenic CO_2 Flaring	$\text{Emissions}_{\text{Biogenic CO2 Flaring}} = [\text{Vol. Biogas}_{\text{Flared}} * F_{CH4} * \rho_{CH4} * D_{CH4} * \text{Molar Ratio}_{CO2\text{-}CH4}] / 1000$					
	$\text{Emissions}_{\text{Biogenic CO2 Flaring}}$	tonnes CO_2	N/A	N/A	N/A	Quantity being calculated.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Vol. Biogas $_{Flared}$	m^3	Measured	Direct metering of volume of biogas being combusted in the flare.	Continuous metering	Direct metering is standard practice. Frequency of metering is highest level possible.
	F_{CH4} Fraction of methane in biogas	m^3 CH_4 per m^3 biogas	Measured	Gas composition analysis.	Daily	Biogas composition changes regularly. Frequency of metering provides for reasonable diligence.
	ρ_{CH4} Density of Methane	kg CH_4 / m^3 CH_4	Constant	0.67847 at standard temperature and pressure	Actual value	Constant value at STP (15 degrees Celsius; 1 atm.)
	D_{CH4} Flare Destruction Efficiency	%	Estimated	Methane destruction efficiency obtained from manufacturer or vendor.	Actual value	The manufacturer or vendor's specifications represent the industry practice and the highest level of detail.
	Molar Ratio $_{CO2-CH4}$	(g/mol CO_2) / (g/mol CH_4)	Constant	44.01 / 16.04	Actual value	Physical constant
P24 Biogas Venting	Emissions $_{Biogas\ Venting}$ = (Emissions $_{Catastrophic\ Venting}$ + Emissions $_{Cover\ Venting}$) * GWP_{CH4} / 1000					
	Emissions $_{Biogas\ Venting}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	$Emissions_{Catastrophic\ Venting} = (Max.\ Storage\ Vol._{Vessel} + Flow\ Biogas_{Vessel} * Time_{Venting}) * F_{CH4} * \rho\ CH_4$					
	$Emissions_{Catastrophic\ Venting}$ Venting emissions during a catastrophic biogas containment failure	kg CH_4	Calculated	N/A	N/A	Interim value being calculated.
	Max. Storage $Vol._{Vessel}$ Maximum volume of biogas stored in Vessel at Steady State	m^3	Estimated	From facility engineering specifications or engineering estimate based on dimensions.	Annual	Reference value will remain consistent unless system is re-engineered (i.e. change to maximum storage volume from change in cap). This may represent only the segment of the digester the leak occurred in if the digester is compartmentalized (e.g. covered lagoon)

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Flow Biogas $_{Vessel}$ Flow Rate of Biogas at Steady State	m^3 / hour	Measured	Average flow rate of biogas from the digester at steady state for the preceding period.	Weekly	Biogas flow rates are steady state for the previous week should provide a reasonable approximation of the biogas flow rate at time of venting.
	Time $_{venting}$ Time that vessel is venting	hours	Measured	Duration recorded with reduced or zero biogas production on biogas production meter.	Continuous metering	Change in biogas production will indicate venting time. Frequency of metering is highest level possible.
	F $_{CH4}$ Fraction of methane in biogas	m^3 CH_4 per m^3 biogas	Measured	Gas composition analysis. Proportion of methane may be measured and assume remaining volume is carbon dioxide.	Daily	Biogas composition changes regularly. Frequency of metering provides for reasonable diligence.
	ρ CH_4 Density of Methane	kg per m^3	Constant	0.67847 at standard temperature and pressure.	Actual value	Constant value at STP (15 degrees Celsius; 1 atm.)
	Emissions $_{Cover\ Venting}$ = Vol. Biogas * ((1 - CE) / CE) * F_{CH4} * ρ CH_4)					

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$Emissions_{Cover\ Venting}$ Venting emissions from incomplete biogas collection due to cover design. This equation does not apply if negative pressure is maintained on cover.	kg CH_4	Calculated	N/A	N/A	Interim value being calculated.
	Vol. Biogas Total Volume of Biogas Captured from Anaerobic Treatment System	m^3	Measured	Direct metering of volume of biogas being combusted.	Continuous Metering	Direct metering is standard practice. Frequency of metering is highest level possible.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	CE Collection Efficiency for Anaerobic Digester	%	Estimated	Value of 95% collection efficiency for bank-to-bank covered lagoon systems and 98% for enclosed vessel systems (complete mix or fixed film digesters). Alternatively, the project proponent may utilize engineering designs for the anaerobic digester and methane capture systems if available.	Annual	Values obtained from *US Environmental Protection Agency (EPA) Climate Leaders Draft Offset Protocol for Managing Manure with Biogas Recovery Systems* (October 2006) Table II.f. Digester Collection Efficiencies. Represents best practice guidance and a conservative approach to quantification. Venting emissions are not normally practical to measure, therefore estimation is reasonable.
	F_{CH4} Fraction of methane in biogas	m^3 CH_4 per m^3 biogas	Measured	Gas composition analysis. Proportion of methane may be measured and assume remaining volume is carbon dioxide.	Daily	Biogas composition changes regularly. Frequency of metering provides for reasonable diligence.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	ρ CH_4 Density of Methane	kg per m^3	Constant	0.67847 at standard temperature and pressure.	Actual value	Constant value at STP (15 degrees Celsius; 1 atm.)
P26 Combustion of Biogas	$Emissions_{Combustion\ of\ Biogas}$ = [Vol. $Biogas_{Combusted}$ * EF $Biogas_{CH4}$ * GWP_{CH4} + Vol. $Biogas_{Combusted}$ * EF $Biogas_{N2O}$ * GWP_{N2O}] / 1000					
	$Emissions_{Combustion\ of\ Biogas}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol. $Biogas_{combusted}$ Volume of Biogas Combusted On-site	m^3	Measured	Direct metering of volume of biogas consumed on site.	Continuous metering	Direct metering is standard practice. Frequency of metering is highest level possible.
	EF $Biogas_{CH4}$ CH_4 Emissions Factor for Natural Gas	kg CH_4 per m^3	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook. Natural Gas emission factor is appropriate for combustion of biogas.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF Biogas $_{N2O}$ N_2O Emission Factor for Natural Gas	kg N_2O per m^3	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook. Natural Gas emission factor is appropriate for combustion of biogas.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{N2O} Global Warming Potential for N_2O	kg CO_2e / kg N_2O	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
P27 Combustion of Priced Fossil Fuels	$Emissions_{\text{Combustion of Priced Fossil Fuels}} = [\sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CO2}) + \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CH4} * GWP_{CH4}) + \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ N2O} * GWP_{N2O})] / 1000$					
	Emissions $_{\text{Combustion of Priced Fossil Fuels}}$	tonnes CO_2e	N/A	N/A	N/A	Value being calculated.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Vol. Fuel $_i$ Volume of Fuel Consumed	L / m^3 / 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.
	EF Fuel $_{i\ CO2}$ CO_2 Emissions Factor for Each Type of Fuel	kg CO_2 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{i\ CH4}$ CH_4 Emissions Factor for Each Type of Fuel	kg CH_4 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{i\ N2O}$ N_2O Emissions Factor for Each Type of Fuel	kg N_2O per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	GWP_{N2O} Global Warming Potential for N_2O	kg CO_2e / kg N_2O	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
P28 On-site Biogenic CO_2 Emissions	$Emissions_{On\text{-}site\ Biogenic\ CO2\ Emissions} = [Vol.\ Biogas_{Combusted} * F_{CH4} * \rho_{CH4} * Molar\ Ratio_{CO2\text{-}CH4}] / 1000$					
	$Emissions_{On\text{-}site\ Biogenic\ CO2\ Emissions}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	$Vol.\ Biogas_{Combusted}$ Volume of Biogas Combusted On-site	m^3	Measured	Direct metering of volume of biogas being consumed on site.	Continuous metering	Direct metering is standard practice. Frequency of metering is highest level possible.
	F_{CH4} Fraction of methane in biogas	m^3 CH_4 per m^3 biogas	Measured	Gas composition analysis. Proportion of methane may be measured and assume remaining volume is carbon dioxide.	Daily	Biogas composition changes regularly. Frequency of metering provides for reasonable diligence.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	ρ_{CH4} Density of Methane	kg CH_4 / m^3 CH_4	Constant	0.67847 at standard temperature and pressure	Actual value	Constant value at STP (15 degrees Celsius; 1 atm.)
	Molar Ratio $_{CO2-CH4}$	(g/mol CO_2) / (g/mol CH_4)	Constant	44.01 / 16.04	Actual value	Physical constant
P33 Digestate/Sludge Temporary Storage	: $Emissions_{Digestate/sludge\ Temporary\ Storage} = V_{digestate} * \rho_{digestate} * VS_{in} * B_o * MCF * \rho_{CH4} * Emptying_{frequency} * GWP_{CH4} / 1000$					
	$Emissions_{Digestate\ Temporary\ Storage}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated following UNFCCC CDM (Tool 14 Version 02.0, 2017) when digestate or sludge storage depth is greater than one meter. Digestate or sludge storage depth of up to one meter assumed to be aerobic and excluded.
	$V_{digestate}$ Volume of digestate	m^3	Measured	Measured volume of waste from digester	Each batch in the digester	Frequency of measurement is highest level possible.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$\rho_{digestate}$ Density of digestate	tonnes / m^3	Estimated	Default of 1.0 or use measured density of waste from digester	If not using default, each batch in the digester	Density of dairy and hog slurry is the conservative default. Dairy and hog liquid slurry consists mainly of water, so use of density of water to convert volume to mass is appropriate. Density must be directly measured if not using default density of 1.0 tonnes/m^3.
	VS_{in} Proportion Volatile Solids in digestate Processed	kg VS / $tonne_{digestate}$	Measured	Laboratory analysis of well mixed sample from digester.	Monthly or upon change in source of feedstock.	Proper sampling and lab analysis provide reliable, source specific estimates. Change in source of feedstock necessitates sampling, which provides highest level of detail possible.
	B_o Maximum CH_4 Producing Potential for Manure	m^3 $CH_{4\ max}$ / kg VS	Estimated	0.24 for dairy cattle; 0.48 for swine	N/A	Value from IPCC Tables 10A-4 and 10A-7, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 10 – Emissions from Livestock and Manure Management.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	MCF Methane Conversion Factor	(m^3 CH_4 / year) / m^3 CH_4 max	Estimated	0.13	N/A	MCF estimate extrapolated from values provided in Table 10.17 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 10 – Emissions from Livestock and Manure Management.
	ρ_{CH4} Density of Methane	kg per m^3	Constant	0.678477157 kg/m^3 at standard temperature and pressure.	Actual value	Constant value at STP (15 degrees Celsius; 1 atm.)
	$Emptying_{frequency}$	%	Measured	The frequency of emptying is calculated as the average number of days the digestate is in storage divided by the number of days in the year.	N/A	. The average number of days in storage must be tracked to determine the frequency of emptying.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
P34 Electricity Usage	$Emissions_{Electricity\ Usage} = Electricity * EF_{Elec}$					
	$Emissions_{Electricity\ Usage}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Electricity Electricity consumed	MWh	Measured	Direct metering of quantity of electricity consumed.	Continuous metering	Continuous direct metering represents the industry practice and the highest level of detail.
	EF_{Elec} Emissions Factor for Electricity	tonnes CO_2e per MWh	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
P39 Landfill Decomposition	$Emissions_{Landfill\ Decomposition} = Q \times GWP_{CH4}$					
	$Emissions_{Landfill\ Decomposition}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	$M_{organic\ waste}$	tonnes	Measured	Measurement of the quantity of digestate or sludge disposed of in landfill.	Periodic	Measurement is most accurate practice. $M_{organic\ waste}$ is applied in the Carbon Offset Emission Factors Handbook Quantification of Avoided Landfill and Stockpile Methane Emissions as the variable ‘W_c’.
	Q Quantity of Methane Emitted from Landfill	tonnes CH_4 / time	Calculated	Provided in Carbon Offset Emission Factors Handbook (uses $M_{organic\ waste}$ as an input)	N/A	Must use most recent methodology published by Alberta Environment and Parks.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
P40 Digestate/Sludge Incineration	$Emissions_{digestate\ Incineration} = [\sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CO2}) + \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CH4} * GWP_{CH4}) + \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ N2O} * GWP_{N2O})] / 1000$					
	$Emissions_{digestate\ Incineration}$	tonne CO_2e	N/A	N/A	N/A	Value being calculated.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Vol. Fuel $_i$ Volume of Fuel Consumed	L / m^3 / 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.
	EF Fuel $_{i\ CO2}$ CO_2 Emissions Factor for Each Type of Fuel	kg CO_2 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{i\ CH4}$ CH_4 Emissions Factor for Each Type of Fuel	kg CH_4 per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	EF Fuel $_{i\ N2O}$ N_2O Emissions Factor for Each Type of Fuel	kg N_2O per L / m^3 / other	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	GWP_{N2O} Global Warming Potential for N_2O	kg CO_2e / kg N_2O	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook.
P45 End-use Combustion of Biogas	Emissions $_{End\text{-}use\ Combustion\ of\ Biogas}$ = [Vol. Biogas $_{Combusted}$ * EF Biogas $_{CH4}$ * GWP $_{CH4}$ + Vol. Biogas $_{Combusted}$ * EF Biogas $_{N2O}$ * GWP $_{N2O}$] / 1000					
	Emissions $_{End\text{-}use\ Combustion\ of\ Biogas}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Vol. Biogas $_{Combusted}$ Volume of Biogas Combusted for End-use Applications	m^3	Measured	Direct metering of volume of biogas being injected into pipeline.	Continuous metering	Direct metering is standard practice. Frequency of metering is highest level possible.
	EF Natural Gas $_{CH4}$ CH_4 Emissions Factor for Natural Gas	kg CH_4 per m^3	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook. Natural Gas emission factor is appropriate for combustion of biogas.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF Biogas $_{N2O}$ N_2O Emission Factor for Natural Gas	kg N_2O per m^3	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook. Natural Gas emission factor is appropriate for combustion of biogas.
	GWP_{CH4} Global Warming Potential for CH_4	kg CO_2e / kg CH_4	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook. Natural Gas emission factor is appropriate for combustion of biogas.
	GWP_{N2O} Global Warming Potential for N_2O	kg CO_2e / kg N_2O	Estimated	See emission factor in Carbon Offset Emission Factors Handbook.	N/A	Reference values in Carbon Offset Emission Factors Handbook. Natural Gas emission factor is appropriate for combustion of biogas.
P46 End-use Biogenic CO_2 Emissions	$Emissions_{End\text{-}use\ Biogenic\ CO2\ Emissions} = Vol.\ Biogas_{Combusted} * F_{CH4} * \rho_{CH4} * Molar\ Ratio_{CO2\text{-}CH4} / 1000$					
	Emissions $_{End\text{-}use\ Biogenic\ CO2\ Emissions}$	tonnes CO_2e	N/A	N/A	N/A	Quantity being calculated.

Source/Sink (SS)	Parameter/ Variable	Unit	Measured/ Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Vol. Biogas $_{Combusted}$ Volume of Biogas Combusted for End-use Applications	m^3	Measured	Direct metering of volume of biogas injected into pipeline for downstream end-use.	Continuous metering	Direct metering is standard practice. Frequency of metering is highest level possible.
	F_{CH4} Fraction of methane in biogas	m^3 CH_4 per m^3 biogas	Measured	Gas composition analysis. Proportion of methane may be measured and assume remaining volume is carbon dioxide.	Daily	Biogas composition changes regularly. Frequency of metering provides for reasonable diligence.
	ρ_{CH4} Density of Methane	kg CH_4 / m^3 CH_4	Constant	0.67847 at standard temperature and pressure	Actual value	Constant value at STP (15 degrees Celsius; 1 atm.)
	Molar Ratio $_{CO2-CH4}$	(g/mol CO_2) / (g/mol CH_4)	Constant	44.01 / 16.04	Actual value	Physical constant

5.0 Management of Data Quality

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

The verification process relies heavily on the quality and availability of documentation to support each GHG assertion. Projects are verified to a reasonable level of assurance. Objective evidence of project implementation is required. 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 31(6) of the Technology Innovation and Emissions Reduction Regulation, and
- Prevented from loss

In the case of aggregated projects the project developer 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 all GHG reductions. 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 can be conducted for the project.

5.1 Project Documentation

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

Documents are 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 and protocol 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 31(6) of the Technology Innovation and Emissions Reduction Regulation.

In addition to the criteria outlined in this protocol, the 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 Criteria	Examples of Records
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	Documented regulatory review that was conducted to ensure that there are no regulatory requirements associated with the reduction activity. Should also include an analysis and justification for why the project is beyond business as usual (BAU).
No leakage	Written explanation of how the project ensures there is no carbon leakage.
Permanence	Not applicable to this protocol.
Project eligibility	Written explanation of how the project is eligible for offset criteria including credit ownership and project location within Alberta.
Baseline condition	Methodology used to demonstrate that waste was being sent to a landfill for three years previous project if claiming emissions under B39 Landfill Decomposition.
Project quantification	Methodology used to measure the project condition over the project period. This should address the level of service, frequency and duration of measurement, units, emissions factors, and default values for quantifying baseline emissions.

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 records that must be collected and disclosed to the third party verifier and/or government auditor upon request. Note that certain records are specifically related to certain emission sources and therefore, certain records will not be required for every project.

Table 7: Record Requirements

Record Requirement	Examples of Records
Protocol Applicability	
Project in Alberta	• Evidence that the project has occurred in Alberta.
Project began after 2002	• Evidence that the project started after January 1, 2002, such as a commissioning document.
Ownership	• Evidence that the emission offsets are clearly owned or allowed to be collected by the project developer, which may include agreements, contracts, etc.
Fugitive emissions management program	• An inventory of joints, seals and equipment prone to fugitive emissions; • A monitoring and maintenance procedure for each item in the fugitive emissions inventory; • Leak detection report from plant commissioning; and • Annual leak detection and repair report.
Depth of passive anaerobic wastewater systems	• Engineering design document; or • As-built documents. Note: this information is also required to calculate the "depth factor" in SS B20.
Evidence that digestate/sludge doesn't undergo windrow composting or go to landfill	• Custom hauling receipts; or • Log book indicating specific land locations where digestate/sludge is spread including application date and number of loads; and • Photograph of stored digestate/sludge, empty storage pit/tank, hauling trucks, and land application. The photographs must contain electronic date, time and location information.
Protocol Flexibility	

Record Requirement	Examples of Records
Less than 24-hour duration of temporary storage of solid waste	• Digester log book with recording of date of each digester batch; and • A photograph taken within one day of the end of the digester cycle showing the empty secondary storage. The photograph must contain electronic time and location information.
Activity Data	
Mass or volume of manure processed	• Truck tickets indicating mass or volume; or • Operations log book with recording of date of each digester batch, source of feedstock, and mass or volume of each batch.
Proportion of volatile solids (VS) in manure (if applicable)	• Documented standard operating procedure for collecting a representative sample of manure and shipping it to a laboratory for testing; • Documented standard operating procedure for collecting a composite sample, if applicable; • Shipping records indicating the date of shipment of manure samples; and • Laboratory reports with clearly indicated sample date and sample location
Time manure is in upstream storage in baseline (applied only if SS B3 is quantified)	If default value provided in Table 5 is not used, • Custom hauling invoices showing invoice of manure removed, which substantiates number of times storage is emptied per year
Electricity delivered to the Alberta Interconnected Electricity Grid	• Sales invoices; • AESO settlement statements; or • AESO metered volumes report
Electricity delivered to directly connected facilities	• Metered quantity with meter calibration report indicating calibration was conducted during the reporting period or at a frequency that meets manufacturer specifications

Record Requirement	Examples of Records
Volume of biogas injected into pipeline	• Natural gas pipeline sales invoice; or • Metered quantity with meter calibration report indicating calibration was conducted during the reporting period or at a frequency that meets manufacturer specifications
Volume of biogas combusted on-site	• Metered quantity with meter calibration report indicating calibration was conducted during the reporting period or at a frequency that meets manufacturer specifications
Volume of biogas flared	• Metered quantity with meter calibration report indicating calibration was conducted during the reporting period or at a frequency that meets manufacturer specifications
Higher heating value of produced biogas	• Natural gas pipeline sales invoice; or • Daily gas composition analysis
Fraction of methane in biogas	• Daily gas composition analysis
Passive anaerobic wastewater treatment – flow rate of wastewater entering and exiting the treatment unit	• Metered quantity; the flow meters used for this type of measurement are typically not calibrated. However, a preventative maintenance routine should be in place and documented.
Passive anaerobic wastewater treatment – chemical oxygen demand in the wastewater inlet and effluent	• Laboratory reports with clearly indicated sample date and sample location
Passive anaerobic wastewater treatment – depth factor	• Engineering design document; or • As-built documents
Passive anaerobic wastewater treatment – temperature of effluent	• Metered quantity with meter calibration report indicating calibration was conducted during the reporting period or at a frequency that meets manufacturer specifications

Record Requirement	Examples of Records
Volume of fossil fuels consumed	• Metered quantities with meter calibration or preventative maintenance reports that meet manufacturer specifications; or • Purchase invoices that indicate volume of fuel purchased during the reporting period along with reconciliation of volume in storage, if applicable
Flow rate of biogas at steady state	• Metered quantity with meter calibration report indicating calibration was conducted during the reporting period or at a frequency that meets manufacturer specifications
Time that biogas vessel is venting	• Biogas production meter data; biogas meter should be calibrated and calibration report filed indicating calibration was conducted during the reporting period or at a frequency that meets manufacturer specifications
Diversion of organic waste from landfill	• Demonstrate that waste was being sent to a landfill for three years previous project if claiming emissions under B39 Landfill Decomposition
Heat transfer model for passive anaerobic systems	• Monthly heat transfer model developed and stamped by a Professional Engineer
Quantity of sediments removed from anaerobic digester in project condition	• Direct measurement or reconciliation from disposal or haulage fees
Direct measurement of COD of wastewater and sediments removed from anaerobic treatment unit in the project activity	• Measurement performed on-site by trained techs or • tested by an external third-party laboratory
Volume of fossil fuel flared	• Metered quantities with meter calibration or preventative maintenance reports that meet manufacturer specifications; or • Purchase invoices that indicate volume of fuel purchased during the reporting period along with reconciliation of volume in storage, if applicable

Record Requirement	Examples of Records
Fraction of methane in flared fossil fuel – measured on site, provided by fossil fuel supplier, or estimated at 100% methane	• Supplier invoices; or • On-site gas composition analysis
Maximum storage volume for calculation of catastrophic venting	• Engineering design document; or • As-built documents
Cover venting – total volume of biogas captured from anaerobic treatment system	• Engineering design document; or • As-built documents
Volume of waste from digester	• Operations log book of volume of each batch; and • Engineering design document; or • As-built documents
VS in digestate processed (digestate downstream)	• Documented standard operating procedure for collecting a representative sample for digestate; and • Laboratory reports with clearly indicated sample date and sample location
Time that digestate is in temporary storage	• Digester log book with recording of date of each digester batch; and • Custom hauling receipts or a photograph showing the empty secondary storage. The photograph must contain electronic date, time and location information

Records must form a complete, auditable data trail from source through final application to the project quantification. For example, fuel records must start with a purchase invoice or statement and be linked to use through a dispensing record and on-board computer data or hour meter/odometer data. This data trail should be emulated a hierarchical series of records from point of purchase and individual unit of consumption to the project level and thence to individual quantifications.

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:

- Protecting monitoring equipment (sealed meters and data loggers);
- 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

Alberta emission offset projects must be implemented according to the standard, approved protocol and in accordance with government regulations. Alberta Environment and Parks reserves the right to reverify emission offset projects and associated project reports submitted to Alberta Environment and Parks for compliance under the Technology Innovation and Emissions Reduction Regulation and may require corrections based on findings.

6.0 References

Intergovernmental Panel on Climate Change. (2006). Guidelines for National Greenhouse Gas Inventories. Volume 4, Chapter 10 – Emissions from Livestock and Manure Management.

Intergovernmental Panel on Climate Change. (2006). Guidelines for National Greenhouse Gas Inventories. Volume 5, Chapter 6 – Wastewater Treatment and Discharge.

United Nations Framework Convention on Climate Change (2017). Clean Development Mechanism, Methodological tool 14 version 02.0. Project and leakage emissions from anaerobic digesters.

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

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Original signed by: ______________________ **Date:** ______________________

Name of Approver

Executive Director

Alberta Environment and Parks,
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APPENDIX A:
Sampling requirements for VS measurement

A sample drawn from a composite at source or digester content in a month is acceptable, provided the following conditions are met:

- Approximately the same volume from each individual sample or digester content is added to the composite sample;
- The samples are frozen during the month before the composite sample is drawn;
- The samples may be stored separately or combined in a plastic pail during the month. Do not use a metal pail;
- The composite sample is drawn from a well-mixed collection of the samples;
- The composite sample should be shipped within a day or may be frozen until shipped; and
- The composite sample should spend no more than two days in transit.