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BRITISH COLUMBIA
Biogas & Composting Facility Greenhouse Gas Tool:

METHODOLOGY OVERVIEW (VERSION 2.2)

BRITISH COLUMBIA

Canada

ACKNOWLEDGEMENTS

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DISCLAIMERS AND USAGE TERMS

Operational greenhouse gas (GHG) emissions are calculated over a maximum 30-year period for the project scenario. Avoided landfill emissions in the baseline scenario are calculated over a maximum 100-year period which is based on the start year of the project.

The GHG accounting is completed using an approach that is intended to provide a high-level estimate of GHG emission reductions resulting from the implementation of a waste diversion and utilization project, however, this tool has not been designed for estimating GHG emission reductions for federal life cycle climate lens assessments, carbon offsets or any other monetizable or transferable environmental attribute, and is not intended to take the place of GHG reduction verification.

The Project Proponent is responsible for the justifications, assumptions and estimates that they input into the tool.

This B.C. Biogas & Composting Facility Greenhouse Gas Calculation Tool (the GHG Tool) is intended to be used by project proponents when assessing their potential GHG emission reductions associated with implementing a project. Actual GHG emission reductions achieved through a project may differ from that reported in the GHG Tool.

The GHG Tool can calculate GHG emission reductions from projects that process sewage sludge, biosolids, food waste, yard waste, dairy manure, hog manure, and/or poultry manure.

When quantifying change in GHG emissions reductions a system boundary is used to define the Sources, Sinks and Reservoirs (SSRs) that will be included or excluded in the calculations. GHG emissions are excluded from the methodology if they fall into the following justification:

Emissions estimated to be minor are not included. Minor emissions are defined as those that account for < 2% of total project emission reductions (i.e., baseline minus project GHG emissions); and

Emissions sources are excluded if the emission sources under the project condition is equivalent to baseline scenario; and

Carbon dioxide (CO_2) emissions sources are excluded if they are deemed to be biogenic.

Version 2.1 of the B.C. Biogas & Composting Facility Greenhouse Gas Calculation Tool was published in October 2020. Version 2.2 and updates to the methodology guide were published March 2022.

This B.C. Biogas & Composting Facility Greenhouse Gas Calculation Tool and methodology overview was prepared by Hallbar Consulting Inc. in consultation with the B.C. Ministry of Agriculture and the B.C. Ministry of Environment and Climate Change Strategy. Stantec Consulting Ltd. was engaged to update the B.C. Biogas & Composting Facility Greenhouse Gas Calculation Tool to estimate GHG emissions from biosolids (version 2.1). Further updates to differentiate between sewage sludge and biosolids were subsequently undertaken by B.C. Ministry of Environment and Climate Change Strategy (version 2.2).

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INTRODUCTION

The B.C. Biogas and Composting Facility Greenhouse Gas Tool (the GHG Tool) enables users to assess the greenhouse gas (GHG) emission reductions from implementing projects for biogas facilities, and/or for compost facilities in B.C. The GHG Tool can be used to determine the quantifiable GHG reductions from diverting sewage sludge, biosolids, food waste, yard waste, and/ or agricultural organic waste from landfills to an organics processing facility, including on-farm or off-farm biogas facilities, or compost facilities in B.C.

GHG emissions are calculated for baseline and project scenarios. The GHG emissions reductions calculated are the difference between the baseline and project scenarios. The baseline scenario is based on the user's current practices before the project is implemented. The project scenario is the future scenario, and is that where a composting facility or biogas facility has been built in B.C.

This GHG Tool allows users to evaluate the GHG benefits from their projects over a 30-year period.

This document provides an overview of the methodology used to create the B.C. Biogas & Composting Facilities Greenhouse Gas Calculation Tool. All reference to tonnes in the GHG Tool are wet, metric tonnes.

Some key definitions used in this document are:

Agricultural feedstock organic material produced on-farm. The most common types are dairy, hog and poultry manure, spoiled silage and crops, and crop residues;

Baseline scenario practice before implementation of the biogas or compost facility;

Biogas methane-rich gas produced by biogas facility, typically 55% – 65% methane and 35% – 45% carbon dioxide.

Biogenic emissions related to the natural carbon cycle that do not result in a net increase in atmospheric CO_2 emissions over the baseline scenario;

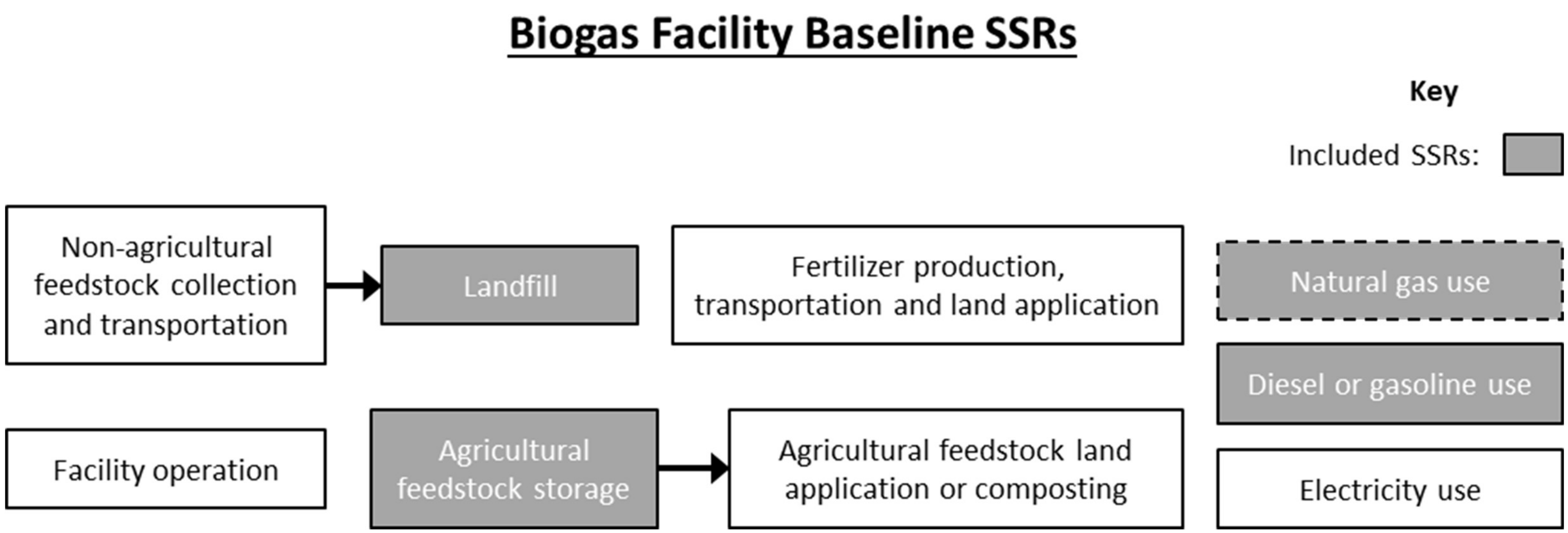
Biosolids municipal sewage sludge resulting from a municipal wastewater treatment process or septage treatment process which has been sufficiently treated to reduce pathogen densities and vector attraction to allow the sludge to be beneficially recycled in accordance with

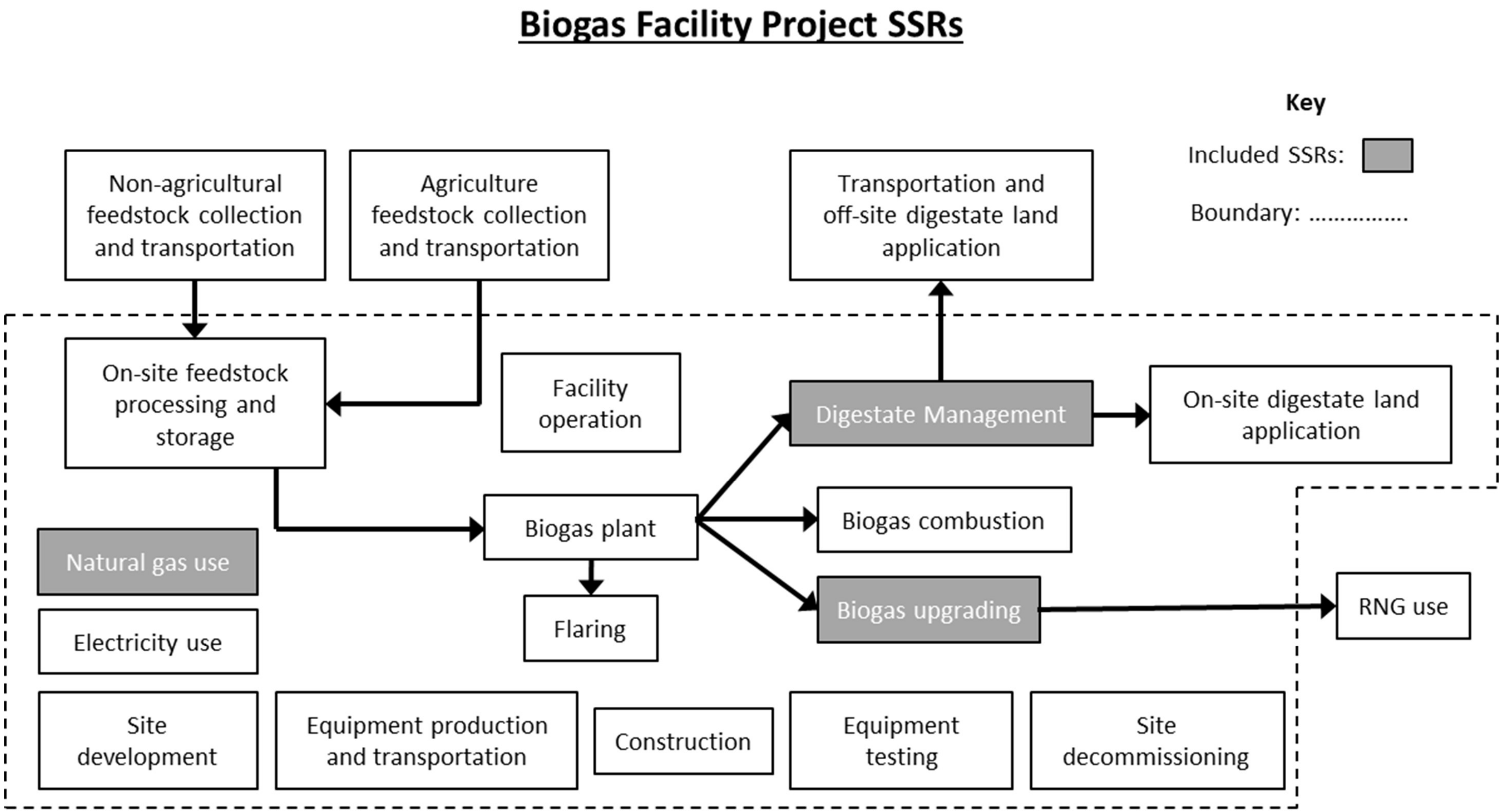
	the requirements of the Organic Matter Recycling Regulation (OMRR).
Boundary	project activities that are within the control of the biogas or compost facility;
Non-agricultural feedstock	organic material produced by non-farm sources. The most common types are food and beverage waste, from processing, grocery stores, restaurants, hotels and abattoirs, food waste collected from homes (often called green bin waste), and yard waste;
Project condition	the biogas or compost facility; and
Renewable Natural Gas (RNG)	renewable substitute to natural gas that is produced by removing the carbon dioxide from biogas using upgrading technology.
Sewage Sludge	settled solids from treatment of raw sewage at a wastewater treatment plant which may not have been sufficiently treated to reduce pathogen densities and vector attraction to allow the sludge to be beneficially recycled in accordance with the requirements of the OMRR.

Sources, Sinks & Reservoirs

GHG emissions from an on-farm or municipal biogas facilities, and compost facilities can be categorized as emission sources, sinks and reservoirs (SSRs). The project boundary delineates the SSRs that should be included or excluded when quantifying net change in GHG emissions associated with a biogas or compost facility. The following diagrams illustrate all potential baseline and project SSRs for municipal and on-farm biogas facility, and for compost facilities in B.C. For these SSRs, only those highlighted in grey are have been included in the B.C. Biogas & Composting Greenhouse Gas Calculation Tool. Justification for excluding all other SSRs include:

- Emissions are estimated to be minor. Minor emissions are defined as those that account for < 2% of total project emission reductions (i.e., baseline minus project GHG emissions); and
- Project condition is equivalent to baseline scenario.


Biogas Facility Baseline SSRs
Key
Included SSRs:
Non-agricultural feedstock collection and transportation
Landfill
Fertilizer production, transportation and land application
Natural gas use
Diesel or gasoline use
Facility operation
Agricultural feedstock storage
Agricultural feedstock land application or composting
Electricity use


Biogas Facility Project SSRs
Key
Included SSRs:
Boundary: ....
Non-agricultural feedstock collection and transportation
Agriculture feedstock collection and transportation
Transportation and off-site digestate land application
On-site feedstock processing and storage
Facility operation
Digestate Management
On-site digestate land application
Biogas plant
Biogas combustion
Natural gas use
Flaring
Biogas upgrading
RNG use
Electricity use
Site development
Equipment production and transportation
Construction
Equipment testing
Site decommissioning

Justification for Baseline SSRs Inclusion/Exclusion: Biogas Facility

Sink, Source & Reservoirs	Description	GHG	In GHG Tool	Justification	GHG Effect*
Non-agricultural feedstock collection and transportation	Emissions from fossil fuel consumed to collect and transport non-agricultural feedstock to a landfill	CO_2	Excluded	Excluded as configuration of biogas facility expected to be equivalent to the baseline scenario	Minor
		CH_4			
		N_2O			
Landfill	Emissions from anaerobic decomposition of non-agricultural feedstock disposed of in a landfill	CO_2	Excluded	Excluded as emissions deemed to be biogenic	Minor
		CH_4	Included		Major
		N_2O	Excluded	Excluded as emissions deemed to be minor	Minor
Facility operation	Emissions from consumption of electricity and fossil fuel in day-to-day operations	CO_2	Excluded	Excluded because in majority of configurations facility operations will not be impacted by project activity and, therefore, will be functionally equivalent in baseline and project conditions	Minor
		CH_4			
		N_2O			
Agricultural feedstock storage	Emissions from decomposition of agricultural feedstock stored in anaerobic conditions	CO_2	Excluded	Excluded as emissions deemed to be biogenic	Minor
		CH_4	Included	For liquid dairy and hog manure only, as emissions from storage of all other feedstock deemed to be minor	Moderate

Sink, Source & Reservoirs	**Description**	**GHG**	**In GHG Tool**	**Justification**	**GHG Effect***
		N_2O	Excluded	Excluded as configuration of biogas facility expected to be equivalent to the baseline scenario	Minor
Agricultural feedstock land application or composting	Emissions from fossil fuel consumed to land apply or compost agricultural feedstock, and emissions from agricultural feedstock or compost land application	CO_2	Excluded	Excluded as configuration of biogas facility expected to be equivalent to the baseline scenario	Minor
		CH_4			
		N_2O			
Natural gas use	Emissions from consumption of natural gas in the absence of a biogas facility	CO_2	Included		Major
		CH_4	Excluded	Excluded as emissions deemed to be minor	Minor
		N_2O			
Diesel or gasoline use	Emissions from consumption of diesel or gasoline in the absence of a biogas facility	CO_2	Included		Major
		CH_4	Excluded	Excluded as emissions deemed to be minor	Minor
		N_2O			
Electricity use	Emissions from consumption of electricity in the absence of a biogas facility	CO_2	Excluded	Excluded as emissions deemed to be minor (due to B.C.'s electricity having an emissions factor of 0.00001067 tonnes CO_2e/kWh)	Minor
		CH_4			
		N_2O			
		CO_2	Excluded		Minor

Sink, Source & Reservoirs	Description	GHG	In GHG Tool	Justification	GHG Effect*
Fertilizer production, transportation and application	Emissions from fossil fuel consumed in production, transportation and land application of synthetic fertilizer	CH_4		Excluded as configuration of biogas facility expected to be equivalent to the baseline scenario	
		N_2O			

** GHG effect estimates the magnitude of each SSRs as a % of total project emission reductions (i.e., baseline GHG emissions minus project GHG emissions). Minor is < 2%, moderate is 2% - 20%, and major is > 20%.*

Justification for Project SSRs Inclusion/Exclusion: Biogas Facility

Sink Source & Reservoirs	**Description**	**Gas**	**In GHG Tool**	**Justification**	**GHG Effect***
Non-agricultural feedstock collection and transportation	Emissions from fossil fuel consumed to collect and transport non-agricultural feedstock to biogas facility	CO_2	Excluded	Excluded because in majority of configurations project condition is equivalent to baseline scenario. Where project condition is greater than baseline scenario, emissions are deemed to be minor	Minor
		CH_4			
		N_2O			
Agricultural feedstock collection and transportation	Emissions from fossil fuel consumed to collect and transport agricultural feedstock to biogas facility	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			
On-site feedstock processing and storage	Emissions from energy consumed to process non-agricultural feedstock (e.g., clean, de-pack, grind) and from decomposition of feedstock stored in anaerobic conditions	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			
Facility operation	Emissions from consumption of electricity and fossil fuel in day-to-day operations	CO_2	Excluded	Excluded because in majority of configurations facility operations will not be impacted by project activity and, therefore, will be equivalent to baseline conditions	Minor
		CH_4			
		N_2O			
Biogas facility		CO_2	Excluded		Minor

Sink Source & Reservoirs	**Description**	**Gas**	**In GHG Tool**	**Justification**	**GHG Effect***
	Emissions due to physical leakages from biogas facility	CH_4		Excluded as most biogas facilities will establish and maintain a leak detection and repair program. Emissions should therefore be minor	
		N_2O			
Electricity use	Emissions from electricity to operate biogas facility, for biogas upgrading equipment and/or digestate management	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			
Natural gas use	Emissions from natural gas to heat biogas facility, for biogas upgrading equipment and/or digestate management	CO_2	Included		Moderate
		CH_4	Excluded	Excluded as emissions deemed to be minor	Minor
		N_2O			
Biogas upgrading	Emissions in biogas upgrader exhaust gas (i.e., methane slip)	CO_2	Excluded	Excluded as emissions deemed to be biogenic	Minor
		CH_4	Included		Moderate
		N_2O	Excluded	Excluded as emissions deemed to be minor	Minor
Biogas combustion	Emissions from incomplete combustion of biogas in combined heat and power engine or boiler	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			

Sink Source & Reservoirs	Description	Gas	In GHG Tool	Justification	GHG Effect*
Flaring	Emissions from flaring biogas of RNG during times of maintenance or during times of equipment failure	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			
Digestate management	Emissions from liquid digestate storage and or solid digestate composting	CO_2	Excluded	Excluded as emissions deemed to be biogenic	Minor
		CH_4	Included		Moderate
		N_2O	Excluded	Excluded for liquid digestate storage because in majority of configurations project condition is equivalent to or less than baseline scenario due to the nitrogen in digestate being more stable than in manure	
On-site digestate land application	Emissions from fossil fuel consumed to land apply digestate, and emissions from digestate land application	CO_2	Excluded	Excluded because in majority of configurations project condition is equivalent to or less than baseline scenario (due to the nitrogen in digestate being more stable than in manure)	Minor
		CH_4			
		N_2O			
RNG use	Emissions from combustion of RNG by end user	CO_2	Excluded	Excluded as emissions deemed to be biogenic	Minor
		CH_4			

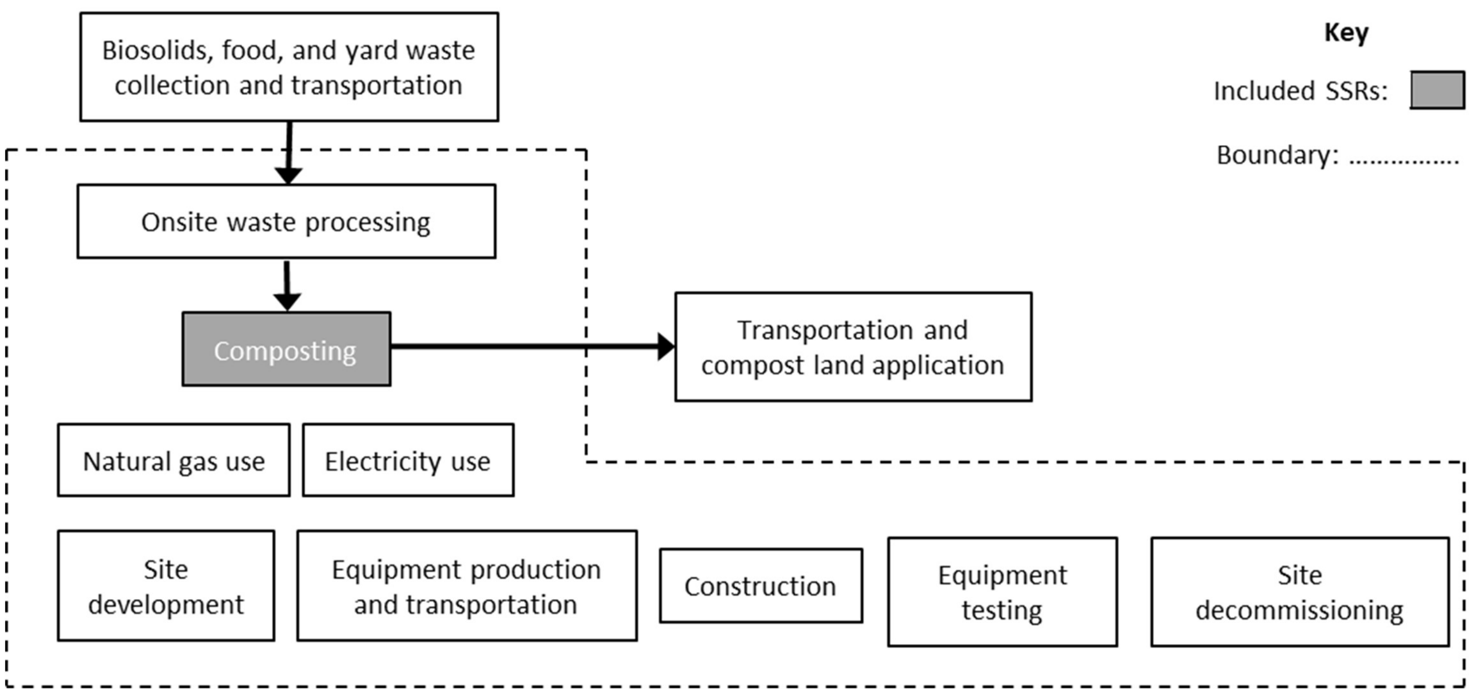
Sink Source & Reservoirs	**Description**	**Gas**	**In GHG Tool**	**Justification**	**GHG Effect***
		N_2O		Excluded because project condition is equivalent to baseline scenario	
Transportation and off-site digestate land application	Emissions from fossil fuel consumed to transport and land apply digestate off-site, and emissions from off-site digestate land application	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			
Site preparation	Emissions from fossil fuel consumed by site preparation equipment	CO_2	Excluded	Emissions minor due to short duration and minimal site preparation typically required	Minor
		CH_4			
		N_2O			
Equipment production and transportation	Emissions from fossil fuel consumed for equipment manufacturing and transportation to site	CO_2	Excluded	Emissions minor given amount of equipment typically required	Minor
		CH_4			
		N_2O			
Construction	Emissions from fossil fuel consumed to build biogas facility	CO_2	Excluded	Emissions minor given minimal construction typically required	Minor
		CH_4			
		N_2O			
Equipment testing		CO_2	Excluded	Emissions minor due to short duration of testing required	Minor
		CH_4			

Sink Source & Reservoirs	Description	Gas	In GHG Tool	Justification	GHG Effect*
	Emissions from combustion of fossil fuel during equipment testing	N_2O			
Site decommissioning	Emissions from use of fossil fuel to decommission biogas facility	CO_2	Excluded	Emissions minor due to short duration and minimal decommissioning typically required	Minor
		CH_4			
		N_2O			

** GHG effect estimates the magnitude of each SSRs as a % of total project emission reductions (i.e., baseline GHG emissions minus project GHG emissions). Minor is < 2%, moderate is 2% - 20%, and major is > 20%.*

Compost Facility Baseline SSRs

Compost Facility Project SSRs



Justification for Baseline SSRs Inclusion/Exclusion: Compost Facility

Sink, Source & Reservoirs	**Description**	**GHG**	**In GHG Tool**	**Justification**	**GHG Effect***
Biosolids, food and yard waste collection and transportation	Emissions from fossil fuel consumed to collect and transport biosolids, food and/or yard waste to a landfill	CO_2	Excluded	Excluded as configuration of compost facility expected to be equivalent to the baseline scenario	Minor
		CH_4			
		N_2O			
Landfill	Emissions from anaerobic decomposition of biosolids, food and/or yard waste disposed of in a landfill	CO_2	Excluded	Excluded as emissions deemed to be biogenic	Minor
		CH_4	Included		Major
		N_2O	Excluded	Excluded as emissions deemed to be minor	Minor
Fertilizer production, transportation and application	Emissions from fossil fuel consumed in production, transportation and land application of synthetic fertilizer	CO_2	Excluded	Excluded as configuration of compost facility expected to be equivalent to the baseline scenario	Minor
		CH_4			
		N_2O			

** GHG effect estimates the magnitude of each SSRs as a % of total project emission reductions (i.e., baseline GHG emissions minus project GHG emissions). Minor is < 2%, moderate is 2% - 20%, and major is > 20%.*

Justification for Project SSRs Inclusion/Exclusion: Compost Facility

Sink Source & Reservoirs	Description	Gas	In GHG Tool	Justification	GHG Effect*
Biosolids, food and yard waste collection and transportation	Emissions from fossil fuel consumed to collect and transport biosolids, food and/or yard waste to compost facility	CO_2	Excluded	Excluded because in majority of configurations project condition is equivalent to baseline scenario. Where project condition is greater than baseline scenario, emissions are deemed to be minor	Minor
		CH_4			
		N_2O			
On-site biosolids, food and yard waste processing	Emissions from energy consumed to process biosolids, food and yard waste (e.g., clean, de-pack, grind)	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			
Composting	Emissions from composting biosolids, food and yard waste	CO_2	Excluded	Excluded as emissions deemed to be biogenic	Minor
		CH_4	Included		Moderate - Major
		N_2O			
Electricity use	Emissions from electricity to operate compost facility	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			
Natural gas use	Emissions from natural gas to heat compost facility	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			

Sink Source & Reservoirs	Description	Gas	In GHG Tool	Justification	GHG Effect*
		N_2O			
Compost transportation and land application	Emissions from fossil fuel consumed to transport and land apply compost, and emissions from compost land application	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			
Site preparation	Emissions from fossil fuel consumed by site preparation equipment	CO_2	Excluded	Emissions minor due to short duration and minimal site preparation typically required	Minor
		CH_4			
		N_2O			
Equipment production and transportation	Emissions from fossil fuel consumed for equipment manufacturing and transportation to site	CO_2	Excluded	Emissions minor given amount of equipment typically required	Minor
		CH_4			
		N_2O			
Construction	Emissions from fossil fuel consumed to build compost facility	CO_2	Excluded	Emissions minor given minimal construction typically required	Minor
		CH_4			
		N_2O			
Equipment testing		CO_2	Excluded	Emissions minor due to short duration of testing required	Minor
		CH_4			

Sink Source & Reservoirs	**Description**	**Gas**	**In GHG Tool**	**Justification**	**GHG Effect***
	Emissions from combustion of fossil fuel during equipment testing	N_2O			
Site decommissioning	Emissions from use of fossil fuel to decommission compost facility	CO_2	Excluded	Emissions minor due to short duration and minimal decommissioning typically required	Minor
		CH_4			
		N_2O			

** GHG effect estimates the magnitude of each SSRs as a % of total project emission reductions (i.e., baseline GHG emissions minus project GHG emissions). Minor is < 2%, moderate is 2% - 20%, and major is > 20%.*

SSR Calculations

Typically, biogas and compost facilities operate for up to 30 years. During this time, facility operations are not expected to change significantly. To minimize uncertainty, GHG emission reductions from both biogas and compost facilities are calculated for a maximum of thirty years. Uncertainty with a longer timeframe stems from complexities in projecting food waste decomposition, unknown technology innovations, changes in the regulatory environment, and changes to business as usual. Thirty years therefore acts as credible time span to make projections under a project scenario, recognizing that any significant changes to the aforementioned criteria could be integrated into the GHG Tool if required.

BASELINE EMISSION CALCULATIONS

B1: Agricultural Feedstock Storage Emissions

This baseline calculation is used in scenarios where there is a Complete Mix biogas facility.

Emissions from off-site and on-site agriculture feedstock storage (liquid dairy and hog manure) in tCO_2e/year are calculated as follows:

$$Agricultural\ feedstock\ storage = T_{Manure} * DM * VS * MPP * MCF * \rho_{CH4} * GWP * CF$$

Variable	Description	Value
T_{Manure}	Tonnes of manure/year	Use the following default values:(1) Dairy cow = 38.3 tonnes/year/head Heifers = 10.4 tonnes/year/head Hog = 3.7 tonnes/year/head
DM	Average dry matter	Use the following default values: (2) Dairy manure = 8% Hog manure = 6%
VS	Volatile solids	Use the following default values: (2) Dairy manure (dairy cows and heifers) = 82% Hog manure = 82%
MPP	Methane production potential during storage	Use the following default values: (3) Dairy manure = 240 m^3 CH_4/tonne VS Hog manure = 480 m^3 CH_4/tonne VS
MCF	Methane conversion factor	Use default value in Appendix A (4)
ρ_{CH4}	Density of methane	Use 0.0006557 tonnes/m^3
GWP	Global warming potential of methane	25

Variable	Description	Value
CF	Correction factor to account for uncertainties	0.9

[1] The Canada – British Columbia Environmental Farm Plan Program Reference Guide, Page 3-31, Table 3.4 (dairy cow manure includes milk center waste). For conversion, 1,000 litres of manure = 1 tonne.

[2] Estimate based on industry experience.

[3] 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4, Chapter 10, Pages 10.77 – 8, Tables 10A-4 – 7.

[4] Percentage of gross energy in manure converted to methane at different annual average temperatures.

Example A:

A farm suppling 17,400 tonnes of dairy manure to a biogas facility in Metro Vancouver is estimated to release 768 tonnes of emissions annually as a result of manure storage.

$$17{,}400 * 8\% * 82\% * 240 * 19\% * 0.0006557 * 25 * 0.9$$

$$= 768\ tCO_2e / year$$

$$\frac{\text{Emissions}}{\text{year}} = T_{Manure} * DM * VS * MPP * MCF * \rho_{CH} * GWP * CF$$

B2: Landfill Emissions

This baseline calculation is used in both compost facility and biogas facility scenarios.

Emissions from anaerobic decomposition of sewage sludge, biosolids, food and/ or yard waste disposed of in landfills in tCO_2e over n years are calculated as follows:

$$Landfill\ gas = k * (1 - o) * (T_{Food} * MPP_F + T_{Yard} * MPP_Y + \left(T_{Sludge} * DM_{Sludge} * VS_{Sludge} * MPP_{Sludg}\right) + (T_{Bio} * DM_{Bio} * VS_{Bio} * MPP_B)) * \rho_{CH_4} * (1 - CAP) * GWP * \sum_{X=T_{lag}}^{n-1} e^{-k(X - T_{Lag})}$$

Variable	Description	Value
k	Decay rate of sewage sludge, biosolids, food and yard waste	Use default value in Appendix B
o	Landfill gas oxidization factor	Use default value of 0.10 (unitless)
T_{Food}	Tonnes of food waste sent to landfill in year X	Enter tonnes of food waste
MPP_F	Food waste methane production potential	Use default value of 160 m^3 CH_4/tonne (1)
T_{Yard}	Tonnes of yard waste sent to landfill in year X	Enter tonnes of yard waste (2)
MPP_Y	Yard waste methane production potential	Use default value of 140 m^3 CH_4/tonne (2)
T_{Bio}	Tonnes of biosolids sent to landfill in year X	Enter tonnes of biosolids
MPP_B	Biosolids methane production potential	Use default value of 208 m^3 CH_4/tonne of volatile solids (VS) (3)
DM_{Bio}	Average dry matter of biosolids	Use default value: 23% (4)
VS_{Bio}	Volatile solids in biosolids	Use default value: 32% (5)
T_{Sludge}	Tonnes of sewage sludge sent to landfill in year X	Enter tonnes of sewage sludge

MPP_{Sludge}	Sewage sludge methane production potential	Use default value of 480 m^3 CH_4/tonne of VS (6)
DM_{Sludge}	Average dry matter of sewage sludge	Use default value: 9% (7)
VS_{Sludge}	Volatile solids in sewage sludge	Use default value: 70% (7)
n	Number of years modeled	Use default value of 100 years
X	Years since organic waste deposited	Enter years since start of organic waste deposition
T_{Lag}	Lag time between deposition of organic waste and generation of landfill gas	User default value of 1 year
ρ_{CH4}	Density of methane	Use 0.0006557 tonnes/m^3
CAP	Landfill gas capture efficiency	Enter percentage of landfill gas captured by the landfill's gas capture system (8)
GWP_{CH4}	Global warming potential of methane	25

[1] Estimate based on industry experience.

[2] Estimate based on industry experience. Yard waste landfill gas emissions should only be considered for dry batch biogas facilities or compost facilities (not complete mix biogas facilities).

[3] Average of values for secondary sewage sludge, excluding lowest outlier, from: Filer, Jameson; Ding, H.H.; Chang, Sheng. Biochemical Methane Potential (BMP) Assay Method for Anaerobic Digestion Research. *Water*. 2019, *11(5)*, 921.

[4] Assume 23% for average dry matter of biosolids. This is the average for Class A and B biosolids from wastewater treatment plants in B.C. from 2016.

[5] Assume the minimum vector attraction reduction of 38% required by the Organic Matter and Recycling Regulation (OMRR) has occurred, and the starting volatile solids was 70% prior to this reduction. Therefore assume 32% for the volatile solids of biosolids in the absence of better data.

[6] Average of values for primary sewage sludge: Filer, Jameson; Ding, H.H.; Chang, Sheng. Biochemical Methane Potential (BMP) Assay Method for Anaerobic Digestion Research. *Water*. 2019, *11(5)*, 921.

[7] Typical solids concentrations in raw primary sludge from settling municipal wastewater are 6%-8%. The portion of volatile solids varies from 60% to 80%. (https://www3.epa.gov/npdes/pubs/mstr-ch4.pdf)

[8] The design standard for landfill gas capture systems in B.C. is 75% collection efficiency, (Landfill Gas Management Facilities Design Guidelines, March 2010, https://www2.gov.bc.ca/assets/gov/environment/waste-management/garbage/designguidelinesfinal.pdf). If food and/or yard waste are landfilled at multiple landfills, use the appropriate tonnage and landfill gas capture efficiency for each landfill.

Example A:

A project that co-digests 30,000 tonnes/year of food waste (which would otherwise have been landfilled in the Vancouver Landfill) is estimated to avoid the release of 18,695 tCO_2e per year.

$$0.11 * (1 – 0.1) * 30{,}000 * 160 * 0.0006557 * (1 - 0.75) * 25 * 9.6 = 18{,}695\ tCO_2e\ /year$$

$$\text{Emissions} = k * (1 - o) * T_{Food} * MPP_F * \rho_{CH_4} \quad (1 - CAP) * GWP * \sum_{X=TLag}^{n-1} e^{-k(X - T_{Lag})}$$

Over the 20-year life of the project, the avoided emissions are estimated to amount to 373,888 tCO_2e.

Example B:

A project that co-digests 50,000 tonnes/year of sewage sludge (which would otherwise have been landfilled in the Vancouver Landfill) with 9% solids content and 70% volatile solids content is estimated to avoid the release of 5,889 tCO_2e per year.

0.11 * (1 – 0.1) * 50,000 * 480 * 0.09 * 0.70* 0.0006557 * (1 - 0.75) * 25 * (9.6)= 5,889 tCO_2e

$$k * (1 - o) * T_{Sludge} * MPP_{Sludge} * DM * VS * \rho_{CH_4} * (1 - CAP) * GWP * \sum_{T=TLag}^{n-1} e^{-k(X - T_{Lag})}$$

Over the 20-year life of the project, the avoided emissions are estimated to amount to 117,775 tCO_2e.

Example C:

A project that that composts 40,000 tonnes/year of yard waste (which would otherwise have been landfilled in the Vancouver Landfill) is estimated to avoid the release of 21,811 tonnes of emissions per year.

0.11 * (1 – 0.1) * 40,000 * 140 * 0.0006557 * (1 - 0.75) * 25 * 9.6 = 21,811 tCO_2e

$$k * (1 - o) * T_{Yard} * MPP_{Y} * \rho_{CH_4} * (1 - CAP) * GWP * \sum_{T=TLag}^{n-1} e^{-k(X - T_{Lag})}$$

Total avoided emissions for all yard waste composted during the project's 20-year lifetime are 436,202 tCO_2e.

B3: Fossil Fuel & Electricity Emissions

This baseline calculation is used in scenarios where there is a biogas facility, (not for compost facility calculations).

The GHG Tool offers two biogas technology choices: complete mix or dry batch. The technology selection will limit the feedstock types that may be entered into the GHG Tool. This is reflected in the equations below, as selecting complete mix will allow for the user to enter manure, food waste and/or sewage sludge feedstocks, while selecting dry batch will limit feedstock options to yard waste and/or food waste.

Emissions from the consumption of fossil fuel (natural gas, diesel or gasoline) or electricity in the absence of a complete mix biogas facility in tCO_2e/year are calculated as follows:

$$Complete\ mix\ fossil\ fuel\ use =$$

$$\left(T_{Manure} * MPP_{CM} + T_{Food} * MPP_{CM} + T_{Sludge} * VS * DM * MPP_{CM}\right) * M_{GJ} * CF\ \{A, B, C\ and/or\ D\}$$

$$\boldsymbol{A} = NG_{EF} * P \qquad \boldsymbol{B} = \frac{1}{LD} * D_{EF} * P \qquad \boldsymbol{C} = \frac{1}{LG} * G_{EF} * P \qquad \boldsymbol{D} = EL_{EF} * P$$

The choice of factor A, B, C and/or D depends on which fuel or fuels are being displaced. A is for displacement of natural gas, B for displacement of diesel, C for displacement of gasoline, and D for displacement of electricity.

Emissions from the consumption of fossil fuel (natural gas, diesel or gasoline) or electricity in the absence of a dry batch biogas facility in tCO_2e/year are calculated as follows:

$$Dry\ batch\ fossil\ fuel\ use =$$

$$(T_{Food} * MPP_{DB} + T_{Yard} * MPP_{DB}) * M_{GJ} * CF\ \{A, B, C\ and/or\ D\}$$

$$\boldsymbol{A} = NG_{EF} * P \qquad \boldsymbol{B} = \frac{1}{LD} * D_{EF} * P \qquad \boldsymbol{C} = \frac{1}{LG} * G_{EF} * P \qquad \boldsymbol{D} = EL_{EF} * P$$

Variable	Description	Value
T_{Manure}	Tonnes of manure/year sent to biogas facility	Enter tonnes of manure
T_{Sludge}	Tonnes of sewage sludge/year sent to biogas facility	Enter tonnes of sewage sludge

Variable	Description	Value
T_{Food}	Tonnes of food waste/year sent to biogas facility	Enter tonnes of food waste
T_{Yard}	Tonnes of yard waste/year sent to biogas facility	Enter tonnes of yard waste
MPP_{CM}	Methane production potential for complete mix biogas facility	Use the following default values:(1) Dairy manure = 20 m^3 CH_4/tonne Hog manure = 22 m^3 CH_4/tonne Poultry manure = 100 m^3 CH_4/tonne Food waste = 160 m^3 CH_4/tonne Sewage sludge = 480 m^3 CH_4/tonne VS (2)
DM	Average dry matter of sewage sludge	Use default value: 9% (3)
VS	Volatile solids in sewage sludge	Use default value: 70% (3)
MPP_{DB}	Methane production potential for dry batch biogas facility	Use the following default values: (1) Food waste = 80 m^3 CH_4/tonne Yard waste = 50 m^3 CH_4/tonne
M_{GJ}	GJ per m^3 of methane	Use default value of 0.0373 GJ/m^3
CF	Correction factor to account for uncertainties	0.9
NG_{EF}	Natural gas emission factor	Use default value of 0.04987 tonnes/GJ (4)
LD	GJ per litre of diesel	Use default value of 0.0383 GJ/litre (4)
LG	GJ per litre of gasoline	Use default value of 0.035 GJ/litre (4)
D_{EF}	Diesel emission factor	Use default value of 0.00263 tonnes/litre (5)

Variable	Description	Value
G_{EF}	Gasoline emission factor	Use the following default values: [6] Light-duty vehicle = 0.002346 tonnes/litre Heavy-duty vehicle = 0.002262 tonnes/litre
EL_{EF}	Electricity emission factor	Use default value of 0 tonnes/GJ [7]
P	Percentage of fossil fuel or electricity displaced by biogas or RNG	Enter percentage

[1] Estimate based on industry experience.

[2] Average of values for primary sewage sludge: Filer, Jameson; Ding, H.H.; Chang, Sheng. Biochemical Methane Potential (BMP) Assay Method for Anaerobic Digestion Research. *Water*. 2019, *11(5)*, 921.

[3] Typical solids concentrations in raw primary sludge from settling municipal wastewater are 6%-8%. The portion of volatile solids varies from 60% to 80%. (https://www3.epa.gov/npdes/pubs/mstr-ch4.pdf)

[4] 2016 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions, Page 12, Table 1.

[5] *Ibid.* Page 22, Table 7.

[6] Light-duty vehicles = Gross Vehicle Weight Rating (GVWR) ≤ 3,900 kg. Heavy duty vehicles = GVWR > 3,900 kg.

[7] Electricity use emissions estimated as zero because B.C.'s electricity emissions are minor due to an emission factor of 0.00001067 tonnes CO_2e/kWh.

Example A:

For the co-digestion project that converts the 17,400 tonnes of dairy manure and 30,000 food waste into RNG to displace natural gas, the avoided emissions from fossil fuel use are estimated to be 8,618 tCO_2e per year.

$$(17{,}400 * 20 + 30{,}000 * 160) * 0.0373 * 0.9 * (0.04987*1) = 8{,}618\ tCO_2e/year$$

$$(T_{Manure} * MPP_{CM} + T_{Food} * MPP_{CM}) * M_{GJ} * CF * (NG_{EF} * P)$$

Example B:

For the co-digestion project that converts the co-digests 50,000 tonnes/year of sewage sludge into RNG to displace natural gas, the avoided emissions from fossil fuel use are estimated to be 2,531 tCO_2e per year.

$$(50,000 * 480 * 0.09 * 0.70) * 0.0373 * 0.9 * (0.04987 * 1) = 2,531\ tCO_2e/year$$

$$\left(T_{Sludge} * MPP_{CM} * DM * VS\right) * M_{GJ} * CF * (NG_{EF} * P)$$

PROJECT EMISSION CALCULATIONS

P1: Natural Gas Use *(biogas facilities only)*

Until a biogas facility has been designed, estimating natural gas use to heat the biogas facility, for biogas upgrading equipment and/or digestate management is challenging. Therefore, an industry average natural gas use of 10% of total biogas facility methane production is assumed.

Emissions from natural gas use for a complete mix biogas facility in tCO_2e/year are calculated as follows:

$$Complete\ mix\ natural\ gas\ use = (T_{Manure} * MPP_{CM} + T_{Food} * MPP_{CM} + T_{Sludge} * VS * DM * MPP_{CM}) * M_{GJ} * NG_{EF} * NG_{Use}$$

Emissions from natural gas use for a dry batch biogas facility in tCO_2e/year are calculated as follows:

$$Dry\ batch\ natural\ gas\ use = (T_{Food} * MPP_{DB} + T_{Yard} * MPP_{DB}) * M_{GJ} * NG_{EF} * NG_{Use}$$

Variable	Description	Value
T_{Manure}	Tonnes of manure/year sent to biogas facility	Enter tonnes of manure
T_{Sludge}	Tonnes of sewage sludge/year sent to biogas facility	Enter tonnes of sewage sludge
T_{Food}	Tonnes of food waste/year sent to biogas facility	Enter tonnes of food waste
T_{Yard}	Tonnes of yard waste/year sent to biogas facility	Enter tonnes of yard waste

Variable	Description	Value
MPP_{CM}	Methane production potential for complete mix biogas facility	Use the following default values:(1) Dairy manure = 20 m^3 CH_4/tonne Hog manure = 22 m^3 CH_4/tonne Poultry manure = 100 m^3 CH_4/tonne Food waste = 160 m^3 CH_4/tonne Sewage sludge = 480 m^3 CH_4/tonne VS (2)
DM	Average dry matter of sewage sludge	Use default value: 9% (3)
VS	Volatile solids in sewage sludge	Use default value: 70% (3)
MPP_{DB}	Methane production potential for dry batch biogas facility	Use the following default values:(1) Food waste = 80 m^3 CH_4/tonne Yard waste = 50 m^3 CH_4/tonne
M_{GJ}	GJ per m^3 of methane	Use default value of 0.0373 GJ/m^3
NG_{EF}	Natural gas emission factor	Use default value of 0.04987 tonnes/GJ (4)
NG_{Use}	Natural gas use	Use default value of 10% (1)

[1] Estimate based on industry experience.

[2] Average of values for primary sewage sludge: Filer, Jameson; Ding, H.H.; Chang, Sheng. Biochemical Methane Potential (BMP) Assay Method for Anaerobic Digestion Research. *Water*. 2019, *11(5)*, 921.

[3] Typical solids concentrations in raw primary sludge from settling municipal wastewater are 6%-8%. The portion of volatile solids varies from 60% to 80%. (https://www3.epa.gov/npdes/pubs/mstr-ch4.pdf)

[4] 2016 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions, Page 12, Table 1.

Example A:

For the co-digestion project that converts the 17,400 tonnes/year of dairy manure and 30,000 tonnes/year of food waste, the project released emissions from natural gas consumption are estimated to be 958 tCO_2e per year.

$$(17{,}400 * 20 + 30{,}000 * 160) * 0.0373 * 0.04987 * 10\% = 958\ tCO_2e/year$$

$$(T_{Manure} * MPP_{CM} + T_{Food} * MPP_{CM}) * M_{GJ} * NG_{EF} * NG_{Use}$$

Example B:

For the co-digestion project that converts the co-digests 50,000 tonnes/year of sewage sludge, the project released emissions from natural gas consumption are estimated to be 281 tCO_2e per year.

$$(50{,}000 * 480 * 0.09 * 0.70) * 0.0373 * 0.04987 * 10\% = 281\ tCO_2e/year$$

$$(T_{Sludge} * MPP_{CM} * DM * VS) * M_{GJ} * NG_{EF} * NG_{Use}$$

P2: Biogas Upgrading *(biogas facility only)*

Until type of biogas upgrading equipment is known, calculating methane emissions from upgrading biogas to RNG (i.e., the amount of methane present in the biogas upgrader's exhaust gas) is challenging. This is because these methane emissions, often referred to as 'methane slip', vary between technologies. While some biogas to RNG upgrading technologies, such as three-phase membrane, typically have a methane slip of ≤ 1%, other technologies, such as water wash, pressure swing and two-phase membrane, typically have a methane slip of 2% or 3%. Therefore, based on industry average, a methane slip of 2% is assumed during upgrading of biogas to RNG.

Emissions from upgrading of biogas to RNG (i.e., methane slip) for a complete mix biogas facility in tCO_2e/year are calculated as follows:

$$Complete\ mix\ biogas\ upgrading$$
$$= (T_{Manure} * MPP_{CM} + T_{Food} * MPP_{CM} + T_{Sludge} * VS * DM * MPP_{CM}) * \rho_{CH4} * GWP * M_{Slip}$$

Emissions from upgrading of biogas to RNG (i.e., methane slip) for a dry batch biogas facility in tCO_2e/year are calculated as follows:

$$Dry\ batch\ biogas\ upgrading$$
$$= (T_{Food} * MPP_{DB} + T_{Yard} * MPP_{DB}) * \rho_{CH4} * GWP * M_{Slip}$$

Variable	Description	Value
T_{Manure}	Tonnes of manure/year sent to biogas facility	Enter tonnes of manure
T_{Sludge}	Tonnes of sewage sludge/year sent to biogas facility	Enter tonnes of sewage sludge
T_{Food}	Tonnes of food waste/year sent to biogas facility	Enter tonnes of food waste
T_{Yard}	Tonnes of yard waste/year sent to biogas facility	Enter tonnes of yard waste
MPP_{CM}	Methane production potential for complete mix biogas facility	Use the following default values: (1) Dairy manure = 20 m^3 CH_4/tonne Hog manure = 22 m^3 CH_4/tonne Poultry manure = 100 m^3 CH_4/tonne

Variable	Description	Value
		Food waste = 160 m^3 CH_4/tonne Sewage sludge = 480 m^3 CH_4/tonne VS (2)
DM	Average dry matter of sewage sludge	Use default value: 9% (3)
VS	Volatile solids in sewage sludge	Use default value: 70% (3)
MPP_{DB}	Methane production potential for dry batch biogas facility	Use the following default values: (1) Food waste = 80 m^3 CH_4/tonne Yard waste = 50 m^3 CH_4/tonne
ρ_{CH4}	Density of methane	Use 0.0006557 tonnes/m^3
GWP	Global warming potential of methane	25
M_{Slip}	Methane slip	Use the default value of 2% (1)

[1] Estimate based on industry experience.

[2] Average of values for primary sewage sludge: Filer, Jameson; Ding, H.H.; Chang, Sheng. Biochemical Methane Potential (BMP) Assay Method for Anaerobic Digestion Research. *Water*. 2019, *11(5)*, 921.

[3] Typical solids concentrations in raw primary sludge from settling municipal wastewater are 6%-8%. The portion of volatile solids varies from 60% to 80%. (https://www3.epa.gov/npdes/pubs/mstr-ch4.pdf)

Example A:

For the co-digestion project that converts the 17,400 tonnes/year of dairy manure and 30,000 tonnes/year of food waste, the emissions related to the upgrading of RNG are estimated to be 1,688 tCO_2e per year.

$$(17{,}400 * 20 + 30{,}000 * 160) * 0.0006557 * 25 * 2\% = 1{,}688\ tCO_2e/year$$

$$(T_{Manure} * MPP_{CM} + T_{Food} * MPP_{CM}) * \rho_{CH} * GWP * M_{Slip}$$

Example B:

For the co-digestion project that converts the co-digests 50,000 tonnes/year of sewage sludge, the emissions related to the upgrading of RNG are estimated to be 496 tCO_2e per year.

$$(50,000 * 480 * 0.09 * 0.70) * 0.0006557 * 25 * 2\% = 496\ tCO_2e/year$$

$$(T_{Bio} * MPP_{CM} * DM * VS) * \rho_{CH4} * GWP * M_{Slip}$$

P3: Liquid Digestate Storage *(biogas facilities only)*

If liquid digestate from a complete mix biogas facility is stored in closed pits, tanks, etc. (i.e., gas tight) and gas from this storage is collected for combustion or conversion to RNG, emissions from digestate storage are zero. If liquid digestate from a complete mix biogas facility is stored in open pits, tanks, etc., emissions from liquid digestate stored in tCO_2e/year are calculated as follows:

$$Liquid\ digestate\ storage =$$

$$(T_{Manure} * MPP_{CM} + T_{Food} * MPP_{CM} + T_{Sludge} * VS * DM * MPP_{CM}) * RVS * DM * MCF * \rho_{CH} * GWP$$

Variable	Description	Value
T_{Manure}	Tonnes of manure/year sent to biogas facility	Enter tonnes of manure
T_{Sludge}	Tonnes of sewage sludge /year sent to biogas facility	Enter tonnes of sewage sludge
T_{Food}	Tonnes of food waste/year sent to biogas facility	Enter tonnes of food waste
MPP_{CM}	Methane production potential for complete mix biogas facility	Use the following default values: (1) Dairy manure = 20 m^3 CH_4/tonne Hog manure = 22 m^3 CH_4/tonne Poultry manure = 100 m^3 CH_4/tonne Food waste = 160 m^3 CH_4/tonne Sewage Sludge = 480 m^3 CH_4/tonne VS (2)
DM	Average dry matter of sewage sludge	Use default value: 9% (3)
VS	Volatile solids in sewage sludge	Use default value: 70% (3)
RVS	Remaining volatile solids	Use default value of 10% (all other volatile solids converted to biogas during digestion) (4)

Variable	Description	Value
DM	Dry matter in liquid phase	Use the following default values: (5) Without solid-liquid separation = 100% With simple solid-liquid separation = 60% With advanced solid-liquid separation = 20%
MCF	Methane conversion factor	Use default value in Appendix A(6)
ρ_{CH4}	Density of methane	Use 0.0006557 tonnes/m^3
GWP	Global warming potential of methane	25

[1] Estimate based on industry experience.

[2] Average of values for primary sewage sludge: Filer, Jameson; Ding, H.H.; Chang, Sheng. Biochemical Methane Potential (BMP) Assay Method for Anaerobic Digestion Research. *Water*. 2019, *11(5)*, 921.

[3] Typical solids concentrations in raw primary sludge from settling municipal wastewater are 6%-8%. The portion of volatile solids varies from 60% to 80%. (https://www3.epa.gov/npdes/pubs/mstr-ch4.pdf)

[4] Estimate based on industry experience.

[5] Estimate based on industry experience. Simple solid-liquid separation equipment is a slope screen, roller press, etc., advanced solid-liquid separation equipment is a centrifuge, dissolved air floatation, etc.

[6] Percentage of gross energy in digestate converted to methane at different annual average temperatures.

Example A:

For the co-digestion project that converts the 17,400 tonnes of manure and 30,000 food waste that uses advanced solid-liquid separation equipment (e.g., centrifuge), the emissions from liquid digestate storage are estimated to be 321 tCO_2e per year:

(17,400 * 20 + 30,000 * 160) * 10% * 20% * 19% * 0.0006557 * 25 = 321 tCO_2e/year

$$(T_{Manure} * MPP_{CM} + T_{Food} * MPP_{CM}) * RVS * DM * \text{MCF} * \rho_{CH4} * GWP$$

Example B:

For the co-digestion project that converts the 50,000 tonnes/year of sewage sludge that uses advanced solid-liquid separation equipment (e.g., centrifuge), the emissions from liquid digestate storage are estimated to be 94 tCO_2e per year:

(50,000 * 480 * 0.09 * 0.70) * 10% * 20% * 19% * 0.0006557 * 25 = 94 tCO_2e/year

$$(T_{Sludge} * MPP_{CM} * VS * DM) * RVS * DM * \text{MCF} * \rho_{CH} * GWP$$

P4: Composting *(biogas and compost facilities)*

If the fibre captured by solid-liquid separation equipment from a complete mix biogas facility or if digestate from a dry batch biogas facility is only stored temporarily (i.e., a week) before being land applied, emissions from decomposition are minor. If the fibre captured by solid-liquid separation equipment from a complete mix biogas facility is composted, emissions in tCO_2e/year are calculated as follows:

$$Composting\ following\ Complete\ mix\ digestion = T_{Digestate} * RVS_{CM} * DM * (* EF_{CH} + EF_{N2O})$$

If digestate from a dry batch biogas facility is composted, emissions in tCO_2e/year are calculated as follows:

$$Composting\ following\ Dry\ batch\ digestion = T_{Digestate} * RVS_{DB} * (EF_{CH} + EF_{N2O})$$

If biosolids, food and/or yard wastes diverted from a landfill are composted at a compost facility, emissions in tCO_2e/year are calculated as follows:

$$Composting = (T_{Food} + T_{Yard} + T_{Bio}) * (EF_{CH4} + EF_{N2O})$$

Variable	Description	Value
$T_{Digestate}$	Tonnes of feedstock/year sent to biogas facility	Enter tonnes of feedstock
T_{Bio}	Tonnes of biosolids/year sent to compost facility	Enter tonnes of biosolids
T_{Food}	Tonnes of food waste/year sent to biogas or compost facility	Enter tonnes of food waste
T_{Yard}	Tonnes of yard waste/year sent to biogas or compost facility	Enter tonnes of yard waste
RVS_{CM}	Remaining volatile solids after complete mix digestion.	Use default value of 10% (all other volatile solids converted to biogas during digestion) (1)
RVS_{DB}	Remaining volatile solids after dry batch digestion.	Use default value of 50% (all other of volatile solids converted to biogas during digestion) (1)

Variable	Description	Value
DM	Dry matter in solid phase	Use the following default capture values: (2) With simple solid-liquid separation = 40% With advanced solid-liquid separation = 80%
EF_{CH4}	Methane emission factor	Use default value in Appendix C
EF_{N2O}	Nitrous oxide emission factor	Use default value in Appendix C

[1] Estimated based on industry experience.

[2] Estimate based on industry experience. Simple solid-liquid separation is a slope screen, roller press, etc., advanced solid-liquid separation is a centrifuge, dissolved air floatation, etc.

Example A:

For the co-digestion project that converts the 17,400 tonnes/year of dairy manure and 30,000 tonnes/year food waste that uses advanced solid-liquid separation and composts the dry digestate using a basic turned system (non-forced aeration turned windrows or piles) with no process controls, emissions from composting are estimated to be 683 tCO_2e per year.

$$(17{,}400 + 30{,}000) * 10\% * 80\% * (0.09 + 0.09) = 683\ tCO_2e/year$$

$$T_{Digestate} * RVS_{CM} * DM * (EF_{CH4} + EF_{N2O})$$

Example B:

For the co-digestion project that converts the 50,000 tonnes/year of sewage sludge that uses advanced solid-liquid separation and composts the dry digestate using a basic turned system (non-forced aeration turned windrows or piles) with no process controls, emissions from composting are estimated to be 720 tCO_2e per year.

$$50{,}000 * 10\% * 80\% * (0.09 + 0.09) = 720\ tCO_2e/year$$

$$T_{Digestate} * RVS_{CM} * DM * (EF_{CH} + EF_{N2O})$$

Example C:

A project that that composts 40,000 tonnes/year of yard waste in an optimized forced aeration compost system, emissions from the yard waste are estimated to be 3,600 tCO_2e per year.

$$40{,}000 * (0.03 + 0.06) = 3{,}600\ tCO_2e/year$$

$$T_{Yard} * (EF_{CH4} + EF_{N2O})$$

SUMMARY

Baseline emissions, GHG emissions before implementing a biogas or compost facility, are calculated as follows:

$$Baseline = B1 + B2 + B3$$

Project emissions, GHG emissions from a biogas or compost facility, are calculated as follows:

$$Project \ = P1 + P2 + P3 + P4$$

GHG emission reductions from a biogas or compost facility are calculated as follows:

$$Reduction = Baseline - Project$$

Appendix A: Methane Conversion Factors

Regional District	Methane Conversion Factor	Regional District	Methane Conversion Factor
Alberni-Clayoquot	17%	Kitimat-Stikine	17%
Bulkley-Nechako	17%	Kootenay Boundary	17%
Capital	17%	Metro Vancouver	19%
Cariboo	17%	Mount Waddington	17%
Central Coast	17%	Nanaimo	17%
Central Kootenay	17%	North Coast	17%
Central Okanagan	17%	North Okanagan	17%
Columbia Shuswap	17%	Okanagan-Similkameen	17%
Comox Valley	17%	Peace River	17%
Cowichan Valley	17%	Powell River	17%
East Kootenay	17%	Squamish-Lillooet	17%
Fraser Valley	19%	Strathcona	17%
Fraser-Fort George	17%	Sunshine Coast	17%
Islands Trust	17%	Thompson-Nicola	17%

Note: Methane conversion factors are taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4, Chapter 10, Page 10.44, Table 10.17 and are based on average annual temperature of each regional district. Aside from the Fraser Valley and Metro Vancouver, all regional districts in B.C. have average annual temperatures <10^{o}C. For these regional districts, and because the 2006 IPCC Guidelines don't provide methane conversion factors for temperatures <10^{o}C, the methane conversion factor for 10^{o}C has been used. The methane conversion factor for liquid/slurry without natural crust cover has been used as all dairy and hog farms in B.C. have manure pit agitators to prevent the formation of a crust cover during storage.

Appendix B: Decay Rate of Food Waste & Yard Waste

Landfill Name	Decay Rate	Landfill Name	Decay Rate
Alberni Valley	0.11	Heffley Creek	0.05
Armstrong	0.05	Knockholt	0.05
Bailey	0.11	Lower Nicola	0.05
Bessborough	0.05	McKelvey Creek	0.09
Cache Creek	0.05	Mini's Pit	0.11
Campbell Mtn	0.05	Mission Flats	0.05
Campbell River	0.11	Nanaimo	0.11
Central	0.09	Ootischenia	0.09
Central Subregion	0.05	Prince Rupert	0.12
Columbia Regional	0.05	Roosevelt	0.03
Comox Valley	0.11	Salmon Arm	0.09
Ecowaste	0.11	Sechelt	0.11
Foothills	0.09	Squamish	0.12
Ft. Nelson	0.05	Terrace	0.11
Ft. St. John	0.05	Thornhill	0.11
Gibraltar	0.09	Vancouver	0.11
Glenmore	0.05	Vernon	0.05
Hartland	0.09	Westside	0.05

Note: This table was produced using 2009 Landfill Gas Generation Assessment Procedure Guidelines, Page 14, Table 5.2 and annual average precipitation values from Environment Canada, National Climate Data and Information Archive (Canadian Climate Normals or Averages 1971-2000).

Appendix C: Composting Methane & Nitrous Oxide Emission Factors

<table>
<tr><th rowspan="2">Composting Category</th><th rowspan="2">Description</th><th>CH_4 Emission Factor</th><th>N_2O Emission Factor</th></tr>
<tr><th colspan="2">(TCO_2e/T Digestate)</th></tr>
<tr><td>Turned compost (basic)</td><td>Non-forced aeration, turned windrows or piles</td><td>0.09</td><td rowspan="2">0.09</td></tr>
<tr><td>Turned compost (optimized)</td><td>Non-forced aeration, windrows covered with 15 cm or more of finished compost for first 3 weeks of composting cycle</td><td>0.06</td></tr>
<tr><td>Forced aeration compost (basic)</td><td>Aerated static pile (ASP) or other forced aeration system</td><td>0.06</td><td rowspan="2">0.06</td></tr>
<tr><td>Forced aeration compost (optimized)</td><td>- ASP systems using synthetic covers; or
- Positive aeration – piles covered with 15 cm or more of finished compost for first 2 weeks of composting cycle; or
- Negative aeration - exhaust gas directed through a control system consisting of wood chips or other biofilter</td><td>0.03</td></tr>
</table>

Source: Climate Action Reserve (2010, updated 2012) "Organic Waste Composting Project Protocol" - Table 5.2