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BRITISH COLUMBIA
Biogas & Composting Facility Greenhouse Gas Tool:

METHODOLOGY OVERVIEW

BRITISH COLUMBIA

Canada

ACKNOWLEDGEMENTS

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DISCLAIMERS AND USAGE TERMS

To minimize uncertainty in estimated GHG reductions, the GHG emission reductions are calculated over a maximum 20 year time period for the project and baseline scenarios, and cannot be used to calculate emission reductions for a period longer than 20 years.

The GHG accounting is completed using a rigorous approach that is intended to give a realistic GHG emission reduction scenario resulting from the project implementation, however, this tool is not designed for estimating GHG emission reductions for 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 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 calculator.

The Tool is not designed for estimating GHG emission reductions from biogas facilities at wastewater treatment facilities or for landfill gas capture projects.

The Tool can calculate GHG emission reductions from projects that process food waste, yard waste, dairy manure, hog manure, and poultry manure. It cannot calculate GHG emission reductions from other organic feedstocks, including, but not limited to, biosolids and municipal sewage sludge.

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

CO_2 emissions sources are excluded if they are deemed to be biogenic.

The B.C. Biogas & Composting Facility Greenhouse Gas Calculation Tool was published in 2018.

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

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INTRODUCTION

The B.C. Biogas and Composting Facility Greenhouse Gas (GHG) Tool enables users to assess the greenhouse gas 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 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 20 year period. Users may also use the tool to track GHG reduction performance and outcomes.

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

Some key definitions used in this document are:

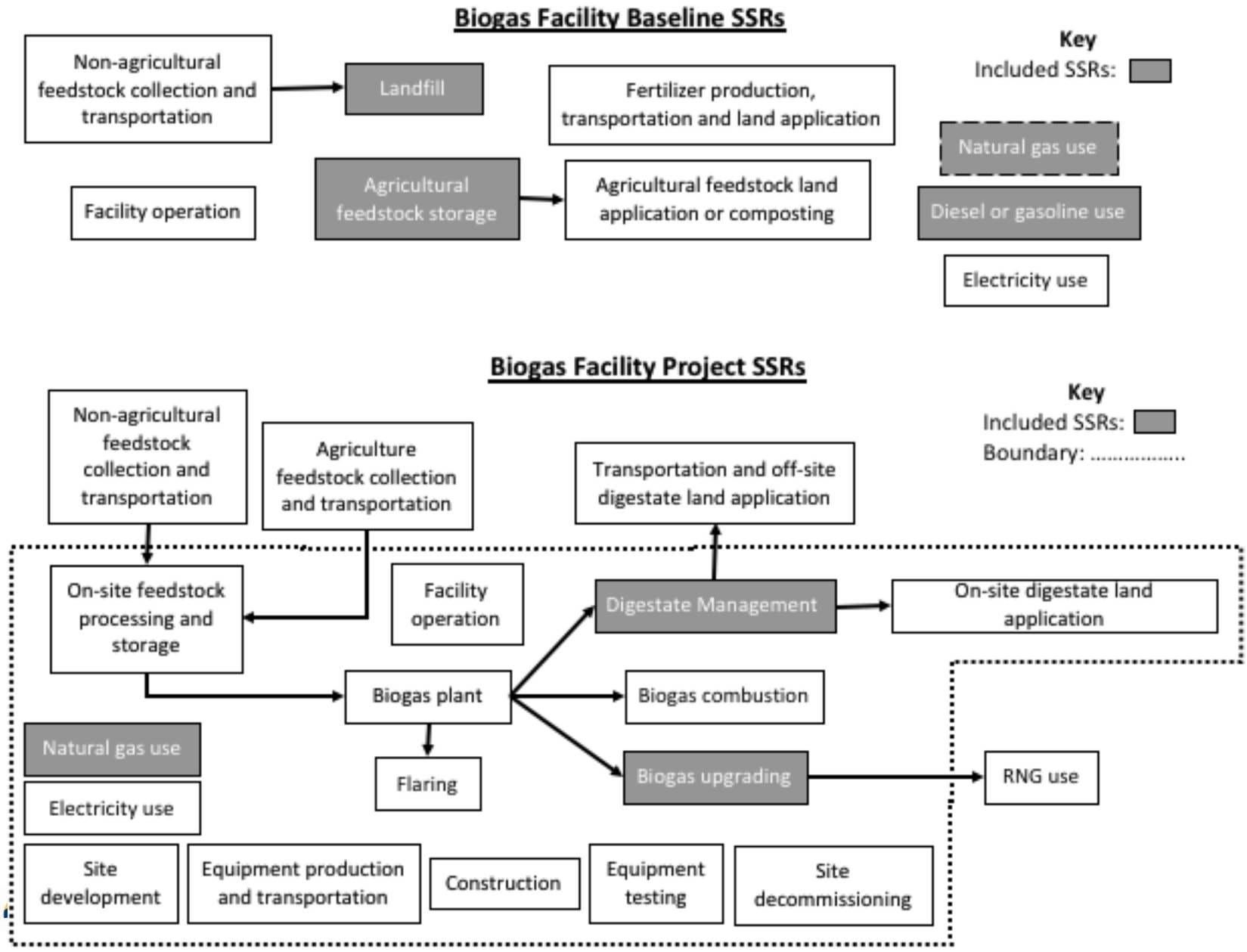
Agricultural feedstock	organic material produced on-farm. The most common types are dairy, hog and poultry manure, spoiled silage and crops, and crop residues;
Baseline scenario	practice before implementation of the biogas or compost facility;
Biogas	methane-rich gas produced by biogas facility, typically 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;
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.

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
Non-agricultural feedstock collection and transportation
Landfill
Fertilizer production, transportation and land application
Facility operation
Agricultural feedstock storage
Agricultural feedstock land application or composting
Key
Included SSRs:
Natural gas use
Diesel or gasoline use
Electricity use
Biogas Facility Project SSRs
Non-agricultural feedstock collection and transportation
Agriculture feedstock collection and transportation
Transportation and off-site digestate land application
Key
Included SSRs:
Boundary: .....
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 B.C. 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 B.C. 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			
Fertilizer production,	Emissions from fossil fuel	CO_2	Excluded	Excluded as configuration of	Minor

Sink, Source & Reservoirs	Description	GHG	In B.C. Tool	Justification	GHG Effect*
transportation and application	consumed in production, transportation and land application of synthetic fertilizer	CH_4		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 B.C. 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	Emissions due to physical	CO_2	Excluded	Excluded as most biogas facilities	Minor

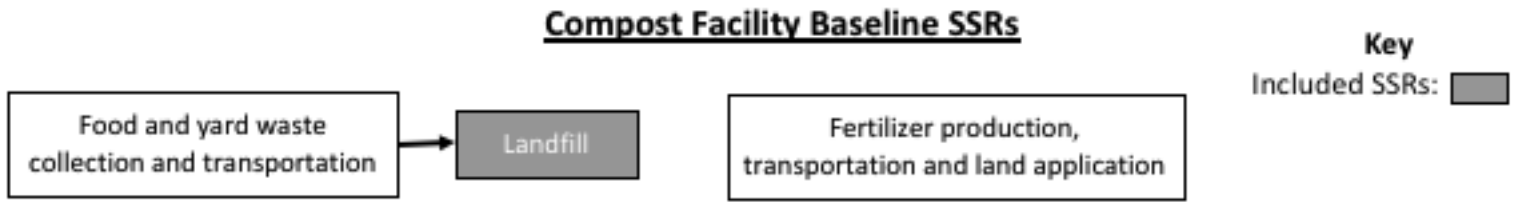
Sink Source & Reservoirs	Description	Gas	In B.C. Tool	Justification	GHG Effect*
	leakages from biogas facility	CH_4		will establish and maintain a leak detection and repair program. Emissions should therefore be minor	
		N_2O			
Electricity use	Emissions from electricity to operate biogas facility, for 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			

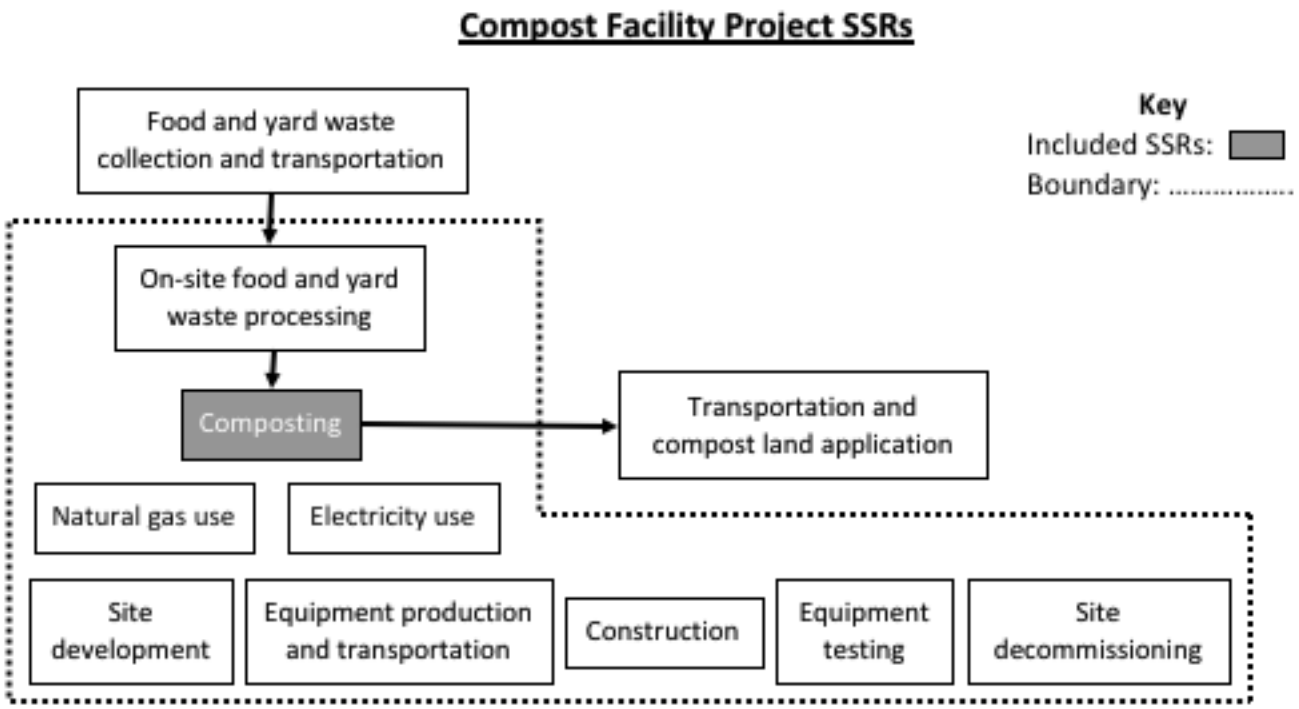
Sink Source & Reservoirs	Description	Gas	In B.C. Tool	Justification	GHG Effect*
Flaring	Emissions from flaring biogas of RNG during times of maintenance or during times of equipment failure	CO_2	Excluded	Excluded as emissions deemed to be minor	Minor
		CH_4			
		N_2O			
Digestate management	Emissions 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		Excluded because project condition	

Sink Source & Reservoirs	Description	Gas	In B.C. Tool	Justification	GHG Effect*
		N_2O		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	Emissions from combustion of fossil fuel during equipment	CO_2	Excluded	Emissions minor due to short duration of testing required	Minor
		CH_4			

Sink Source & Reservoirs	Description	Gas	In B.C. Tool	Justification	GHG Effect*
	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
Key
Included SSRs:
Food and yard waste collection and transportation
Landfill
Fertilizer production, transportation and land application


Compost Facility Project SSRs
Key
Included SSRs:
Boundary: .....
Food and yard waste collection and transportation
On-site food and yard waste processing
Composting
Transportation and compost land application
Natural gas use
Electricity use
Site development
Equipment production and transportation
Construction
Equipment testing
Site decommissioning

JUSTIFICATION FOR BASELINE SSRS INCLUSION/EXCLUSION: COMPOST FACILITY

Sink, Source & Reservoirs	Description	GHG	In B.C. Tool	Justification	GHG Effect*
Food and yard waste collection and transportation	Emissions from fossil fuel consumed to collect and transport 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 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 B.C. Tool	Justification	GHG Effect*
Food and yard waste collection and transportation	Emissions from fossil fuel consumed to collect and transport 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 food and yard waste processing	Emissions from energy consumed to process food and/or 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 food and/or 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 B.C. 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	Emissions from combustion of fossil fuel during equipment	CO_2	Excluded	Emissions minor due to short duration of testing required	Minor
		CH_4			

Sink Source & Reservoirs	Description	Gas	In B.C. Tool	Justification	GHG Effect*
	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 at least 20 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 twenty 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. Twenty 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 Tool if required.

BASELINE EMISSION CALCULATIONS

B1: Agricultural Feedstock (biogas facilities only)

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

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

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%

Variable	Description	Value
MPP	Methane production potential	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
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: Farm Biogas Facility

For Farm A, which has 250 dairy cows and 150 heifers, and supplies manure to a biogas facility in Fraser Valley, emissions from manure storage are:

$$(250 * 38.3 + 150 * 10.4) * 8\% * 82\% * 240 * 19\% * 0.0006557 * 25 * 0.9 = 491 \text{ tCO}_2\text{e/year}$$

$$T_{Manure} \quad DM \quad VS \quad MPP \quad MCF \quad \rho_{CH4} \quad GWP \quad CF$$

B2: Landfill Gas (biogas and compost facilities)

Emissions from anaerobic decomposition of food or yard waste disposed of in landfills in year y in tCO_2e/year are calculated as follows:

$$Landfill\ gas = k\ x\ (T_{Food}\ x\ MPP_F + T_{Yard}\ x\ MPP_Y)\ x\ \rho_{CH_4}\ x\ (1 - CAP)\ x\ GWP\ x\ CF\ x \sum_{X=T_{lag}}^{n-1} e^{-k(X - T_{Lag})}$$

Variable	Description	Value
k	Decay rate of food and yard waste	Use default value in Appendix B
T_{Food}	Tonnes of food waste sent to landfill in year T	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 T	Enter tonnes of yard waste
MPP_Y	Yard waste methane production potential	Use default value of 140 m^3 CH_4/tonne[2]
n	Number of years modeled	Use default value of 20 years
X	Years since food waste deposited	
T_{Lag}	Lag time between deposition of food waste and generation of landfill gas	Use 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[3]
GWP_{CH4}	Global warming potential of methane	25
CF	Correction factor to account for uncertainties	0.9

[1] Estimate based on industry experience.

[2] Yard waste landfill gas emissions should only be included for dry batch biogas facilities (not complete mix biogas facilities).

[3] The design recommendation for landfill gas capture systems in B.C. is 75% collection efficiency. If food and/or yard waste are landfilled at multiple landfills, use the appropriate tonnage and landfill gas capture efficiency for each landfill.

Example Farm and Municipal Biogas and Compost Facilities

For Farm A that co-digests 10,698 tonnes/year of food waste (which would otherwise have been landfilled in the Vancouver Landfill), avoided landfill gas emissions for food waste digested in the first year of the biogas facility, over the biogas facility's twenty year lifetime, are:

0.11 * 10,698 * 160 * 0.0006557 * (1 - 0.75) * 25 * 0.9 * 8.413 = 5,842 tCO_2e

$$k \quad T_{Food} \quad MPP_F \quad \rho_{CH_4} \quad CAP \quad GWP \quad CF \quad \sum_{T=1}^{19}$$

Avoided landfill gas emissions for food waste digested in subsequent years are lower because this food waste would have produced landfill gas for fewer years of the biogas facility's lifetime. For example, for food waste digested in year two, the sum for the last term in the above equation is 8.27, as this food waste would have only produced landfill gas for 18 years (food waste digested in the first year would have produced landfill gas for 19 years). Total avoided emissions for food waste digested during the biogas facility's lifetime are 76,426 tCO2e.

For Municipality A that composts 40,000 tonnes/year of food waste (which would otherwise have been landfilled in the Salmon Arm Landfill), avoided landfill gas emissions for food waste composted in the first year of the compost facility, over the compost facility's twenty year lifetime, are:

0.09 * 40,000 * 160 * 0.0006557 * (1 - 0.25) * 25 * 0.9 * 9.517 = 20,219 tCO_2e

$$k \quad T_{Food} \quad MPP_F \quad \rho_{CH_4} \quad CAP \quad GWP \quad CF \quad \sum_{T=1}^{19}$$

Total avoided emissions for all food composted during the project's lifetime are 254,286 tCO_2e.

B3: Fossil Fuel & Electricity Use *(biogas facilities only)*

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:

$$Complete\ mix\ fossil\ fuel\ use = (T_{Manure}\ x\ MPP_{CM} + T_{Food}\ x\ MPP_{CM})\ x\ M_{GJ}\ x\ CF\ \ \{A, B, C\ and/or\ D\}$$

$$\boldsymbol{A} = x\ NG_{EF}\ x\ P \qquad \boldsymbol{B} =/\ LD\ x\ D_{EF}\ x\ P \qquad \boldsymbol{C} =/\ LG\ x\ G_{EF}\ x\ P \qquad \boldsymbol{D} = x\ EL_{EF}\ x\ P$$

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:

$$Dry\ batch\ fossil\ fuel\ use = \ (T_{Food}\ x\ MPP_{DB} + T_{Yard}\ x\ MPP_{DB})\ x\ M_{GJ}\ x\ CF\ \ \{A, B, C\ and/or\ D\}$$

$$\boldsymbol{A} = x\ NG_{EF}\ x\ P \qquad \boldsymbol{B} =/\ LD\ x\ D_{EF}\ x\ P \qquad \boldsymbol{C} =/\ LG\ x\ G_{EF}\ x\ P \qquad \boldsymbol{D} = x\ EL_{EF}\ x\ P$$

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

Variable	Description	Value
CF	Correction factor to account for uncertainties	0.9
NG_{EF}	Natural gas emission factor	Use default value of 0.04987 tonnes/GJ[2]
LD	GJ per litre of diesel	Use default value of 0.0383 GJ/litre[2]
LG	GJ per litre of gasoline	Use default value of 0.035 GJ/litre[2]
D_{EF}	Diesel emission factor	Use default value of 0.00263 tonnes/litre[3]
G_{EF}	Gasoline emission factor	Use the following default values:[3] 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[5]
P	Percentage of fossil fuel or electricity displaced by biogas or RNG	Enter percentage

[1] Estimate based on industry experience.

[2] 2016 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions, Page 12, Table 1.

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

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

[5] 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 Farm and Municipal Biogas Facilities

For Farm A that replaces only natural gas with RNG, emissions from fossil fuel use are:

(11,135 * 20 + 10,698 * 160) * 0.0373 * 0.9 * 0.04987 * 1 = 3,238 tCO_2e/year

$$T_{Manure}\ MPP_{CM}\ T_{Food}\ \ MPP_{CM}\ \ M_{GJ}\ \ \ CF\ \ \ NG_{EF}\ \ \ P$$

For Municipality A that replaces only diesel with RNG, emissions from fossil fuel use are:

(40,000 * 80 + 20,000 * 50) * 0.0373 * 0.9 / 0.0383 * 0.002649 * 1 = 9,752 tCO_2e/year

$$T_{Food}\ \ MPP_{DB}\ T_{Yard}\ \ MPP_{DB}\ \ M_{GJ}\ \ \ CF\ \ \ LD\ \ \ \ \ D_{EF}\ \ \ P$$

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, and based on 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:

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

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

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

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

Variable	Description	Value
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[2]
NG_{Use}	Natural gas use	Use default value of 10%[1]

[1] Estimate based on industry experience.

[2] 2016 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions, Page 12, Table 1.

Example Farm and Municipal Biogas Facilities

For Farm A, emissions from natural gas use are:

(11,135 * 20 + 10,698 * 160) * 0.0373 * 0.04987 * 10% = 360 tCO_2e/year

T_{Manure} MPP_{CM} T_{Food} MPP_{CM} M_{GJ} NG_{EF} NG_{Use}

For Municipality A, emissions from natural gas use are:

(40,000 * 80 + 20,000 * 50) * 0.0373 * 0.04987 * 10% = 781 tCO_2e/year

T_{Food} MPP_{DB} T_{Yard} MPP_{DB} 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:

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

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:

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

Variable	**Description**	**Value**
T_{Manure}	Tonnes of manure/year sent to biogas facility	Enter tonnes of manure
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 facilities	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
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

Variable	Description	Value
M_{Slip}	Methane slip	Use the default value of 2%[1]

[1] Estimate based on industry experience.

Example Farm and Municipal Biogas Facilities

For Farm A, emissions from upgrading biogas to RNG are:

(11,135 * 20 + 10,698 * 160) * 0.0006557 * 25 * 2% = 634 tCO_2e/year

T_{Manure} MPP_{CM} T_{Food} MPP_{CM} ρ_{CH4} GWP M_{Slip}

For Municipality A, emissions from upgrading biogas to RNG are:

(40,000 * 80 + 20,000 * 50) * 0.0006557 * 25 * 2% = 1,377 tCO_2e/year

T_{Food} MPP_{DB} T_{Yard} MPP_{DB} ρ_{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:

$$Liquid\ digestate\ storage = (T_{Manure}\ x\ MPP_{CM} + T_{Food}\ x\ MPP_{CM})\ x\ RVS\ x\ DM\ x\ MCF\ x\ \rho_{CH4}\ x\ GWP$$

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

Variable	Description	Value
MPP_{CM}	Methane production potential	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
RVS	Remaining volatile solids	Use default value of 10% (all other volatile solids converted to biogas during digestion)[2]
DM	Dry matter	Use the following default values:[3] 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[4]
ρ_{CH4}	Density of methane	Use 0.0006557 tonnes/m^3
GWP	Global warming potential of methane	25

[1] Same MPP as used for biogas production inside a digester.

[2] Estimate based on industry experience.

[3] 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.

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

Example Farm Biogas Facility

For Farm A that uses simple solid-liquid separation equipment (e.g., slope screen), emissions from liquid digestate storage are:

(11,135 * 20 + 10,698 * 160) * 10% * 60% * 19% * 0.0006557 * 25 = 361 tCO_2e/year

$$T_{Manure} \quad MPP_{CM} \quad T_{Food} \quad MPP_{CM} \quad RVS \quad DM \quad \text{MCF} \quad \rho_{CH4} \quad GWP$$

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:

$$Complete\ mix\ composting = T_{Digestate}\ x\ (RVS_{CM}\ x\ DM\ x\ EF_{CH4} + RVS_{CM}\ x\ DM\ x\ EF_{N2O})$$

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

$$Dry\ batch\ composting\ = T_{Digestate}\ x\ (RVS_{DB}\ x\ EF_{CH4} + RVS_{DB}\ x\ EF_{N2O})$$

If food and/or yard waste diverted from a landfill is composted (without being in a biogas facility), emissions in tCO_2e/year are calculated as follows:

$$Composting\ = T_{Food}\ x\ (EF_{CH4} + EF_{N2O}) + T_{Yard}\ x\ (EF_{CH4} + EF_{N2O})$$

Variable	Description	Value
$T_{Digestate}$	Tonnes of manure/year sent to biogas facility	Enter tonnes of manure
T_{Food}	Tonnes of food waste/year sent to biogas or compost facility	Enter tonnes of food waste

Variable	Description	Value
T_{Yard}	Tonnes of yard waste/year sent to biogas or compost facility	Enter tonnes of yard waste
RVS_{CM}	Remaining volatile solids	Use default value of 10% (all other volatile solids converted to biogas during digestion)[1]
RVS_{DB}	Volatile solids	Use default value of 50% (all other of volatile solids converted to biogas during digestion)[1]
DM	Dry matter	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 Farm and Municipal Biogas and Compost Facilities

For Farm A, which uses advanced solid-liquid separation and composts the dry digestate using a turned system (non-forced aeration turned windrows or piles) with no process controls, emissions from composting are:

(11,135 + 10,698) * (10% * 80% * 0.09 + 10% * 80% * 0.09) = 314 tCO_2e/year

$$T_{Digestate} \quad VS_{CM} \quad DM \quad EF_{CH4} \quad RVS_{CM} \quad DM \quad EF_{N2O}$$

For Municipality A, which composts the digestate using a turned system (non-forced aeration turned windrows or piles) with no process controls, emissions from solid digestate are:

(40,000 + 20,000) * (50% * 0.09 + 50% * 0.09) = 5,400 tCO_2e/year

$T_{Digestate}$ VS_{DB} EF_{CH4} RVS_{DB} EF_{N2O}

For Municipality A that composts 20,000 tonnes/year of food waste and 40,000 tonnes/year of yard waste in an optimized forced aeration compost system, emissions from food and yard waste are:

20,000 * (0.03 + 0.06) + 60,000 * (0.03 + 0.06) = 7,200 tCO_2e/year

T_{Food} EF_{CH4} EF_{N2O} 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:

$$Reduction = Baseline - Project$$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