# Operating Criteria and Quantification Methodology for Displacement of Natural Gas with Green Natural Gas

## May 2020

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# Protocol Overview

ICF has been retained by Bullfrog Power to identify the standards that an emission reduction project based on the displacement of conventional natural gas with Green Natural Gas should meet. This document describes how a *Green Natural Gas Project* results in reduced emissions of greenhouse gases (GHGs) through the displacement of fossil-derived natural gas. In this Protocol, Green Natural Gas may be derived from one or both of two processes: Landfill Operations or Anaerobic Waste Water Treatment.

Green Natural Gas from Landfill Operations is defined as any form of naturally occurring gas captured from the decay and putrefaction of organic material contained in a landfill site that is utilized for the production of heat and/or electricity resulting in the displacement of fossil-derived natural gas. Landfill gas that has large particulate matter and water removed but is still comprised of approximately 40-60% $CH_4$ and 40-60% $CO_2$, as well as some trace elements, would be referred to as biogas.

Green Natural Gas from Anaerobic Waste Water Treatment is defined as any form of naturally occurring gas produced and captured from waste water treatment systems that employ anaerobic microbes to consume organic matter contained in the wastewater. The captured biogas must be utilized for the production of heat and/or electricity resulting in the displacement of fossil-derived natural gas. The biogas produced from anaerobic waste water treatment is typically 70-75% methane.

Biogas that is processed further to remove the $CO_2$ and other smaller particulates resulting in approximately 95-97% $CH_4$, similar to the quality of fossil-derived natural gas, would be referred to as biomethane.

This document has three parts and an Appendix:

- **Part 1: Overview of the carbon cycle and Green Natural Gas projects.** The document first explains why Green Natural Gas is considered biogenic and should be treated as a net zero carbon dioxide emission fuel because it does not result in an increase of carbon dioxide emissions in the atmosphere.
- **Part 2: Quantification of Emission Reductions.** A significant reduction in carbon dioxide emissions results when fossil-derived natural gas is substituted with Green Natural Gas. This part of the document establishes a methodology for quantifying carbon dioxide emission reductions, which can be applied to any natural gas displacement by Green Natural Gas project to quantify the associated emission reductions.
- **Part 3: Project and annual audit standards as well as Methodology Applicability.** The document then identifies the operating and quality standards that a Green Natural Gas project should meet and that a regular verification should review. The applicability criteria for applying this methodology to Green Natural Gas projects are also outlined.
- **Appendix A: GHG emission factors and glossary of terms and acronyms.**

The calculation methodologies provided in this document serve as guideline for project specific applications and, therefore, this document must be uniquely adapted for individual projects.

Emissions sources relevant for each specific project are identified within a separate site specific Project Document.

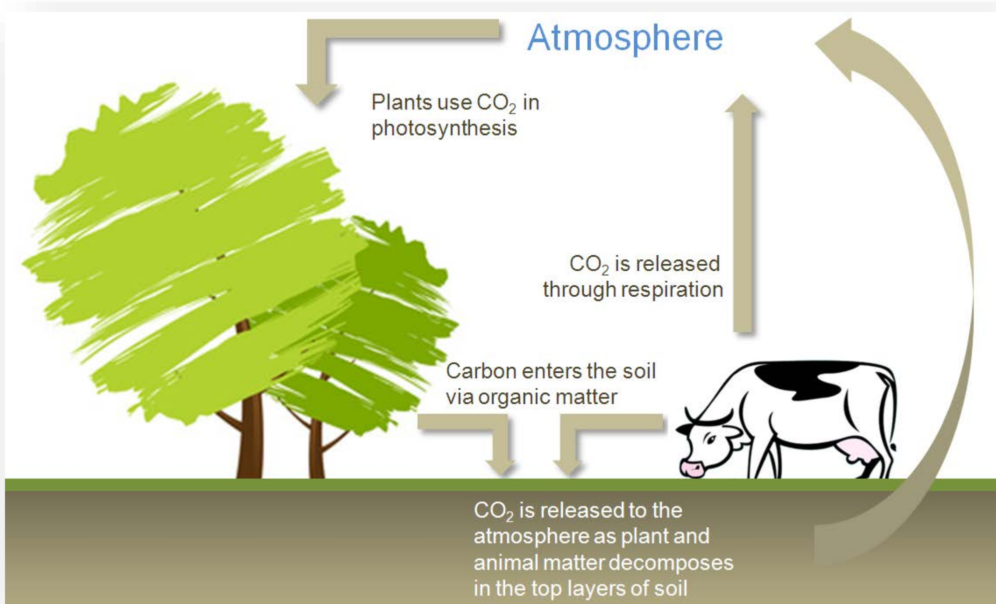
# Part I: The Carbon Cycle and Natural Gas Displacement by Green Natural Gas Projects

## 1. The Carbon Cycle and Human Activity

Carbon is the foundation of all living organisms and is naturally exchanged between living and decaying organisms, the soil and the atmosphere in the form of carbon dioxide ($CO_2$) and other carbon based compounds through a continuous cycle known as the carbon cycle that has been in operation since the beginning of life on earth. When plant and animal matter decomposes, some carbon is emitted to the atmosphere as $CO_2$, while the remaining carbon is stored in the soil. $CO_2$ that occurs naturally within the carbon cycle as a result of biological processes is known as *biogenic* $CO_2$. As a result of this natural process, carbon dioxide from the decay of organic matter is recycled through the carbon cycle, and does not increase the amount of carbon in the atmosphere.

Carbon dioxide, as well as other gases including methane ($CH_4$) and nitrous oxide ($N_2O$) are GHGs that contribute to global warming. Since the industrial revolution, human activity has dramatically increased the concentration of GHGs in the atmosphere (above the naturally occurring level present in the carbon cycle) through the combustion of fossil fuels, land-use changes, and the development of new industrial processes. The combustion of natural gas, for instance, releases carbon that had been stored below the earth's surface for thousands of years, into the atmosphere.

Figure 1: The Carbon Cycle



## 2. Waste Management in a Landfill

The disposal of waste in a landfill is a conventional method of waste management that is very common around the world. Waste is collected at its various sources and transported to landfills where it is spread and covered with alternating layers of waste and cover material, such as soil and sand. As organic material in the waste decomposes in a landfill, landfill gas forms below the surface. Landfill gas naturally migrates towards the surface of the landfill and eventually escapes into the atmosphere.

Landfill gas typically contains approximately 40-60% methane, 40-60% carbon dioxide, water vapor and small quantities of other gases and contaminants. The carbon dioxide component of landfill gas is biogenic because it is formed through the natural decomposition of organic material as part of the carbon cycle.

In an oxygen depleted environment, which exists within a landfill, methane is produced as organic material decomposes. The methane contained in landfill gas is not considered to be biogenic. Methane would not form during the natural decomposition of organic material in an oxygen rich environment. However, if landfill gas is collected and the methane is converted to carbon dioxide[1], the resulting quantity of carbon dioxide is considered biogenic. The volume of carbon dioxide converted from methane is approximately equivalent to the quantity of carbon dioxide that would have been formed through the natural decomposition of the organic material.

## 3. Anaerobic Waste Water Treatment

Anaerobic waste water treatment is a common practice in industrial settings to purify waste water streams containing high concentrations of biodegradable organic matter prior to discharge to a municipal waste water plant or additional aerobic polishing processes. Anaerobic processes typically use substantially less energy, require less chemicals, and incur lower sludge handling costs compared to aerobic treatment options. In addition, the biogas produced in the anaerobic process is a source of renewable energy that can be used to displace fossil fuels or to generate electricity.

Biogas from anaerobic waste water treatment typically contains 70-75% methane, 25-30% $CO_2$ as well as water vapor. The carbon dioxide component of landfill gas is biogenic because it is formed through the natural decomposition of organic material as part of the carbon cycle.

In an oxygen depleted environment methane is produced as microbes consume the organic matter in the waste water. The methane contained in biogas gas is not considered to be biogenic. Methane would not form during the natural decomposition of organic material in an oxygen rich environment. However, if biogas is collected and the methane is converted to carbon dioxide[2], the resulting quantity of carbon dioxide is considered biogenic. The volume of

[1] One of the most effective and productive methods for converting methane to carbon dioxide is through combustion (burning).
[2] One of the most effective and productive methods for converting methane to carbon dioxide is through combustion (burning).

carbon dioxide converted from methane is approximately equivalent to the quantity of carbon dioxide that would have been formed through the natural decomposition of the organic material.

# 4. Green Natural Gas Opportunity

Many landfill operators either do not collect landfill gas, allowing it to be released into the atmosphere, or collect landfill gas and use a simple combustion device, such as a vertical flare stack, to combust the methane and convert it into carbon dioxide. Similarly, many anaerobic waste water treatment facilities allow the biogas to simply vent to atmosphere.

Currently, Ontario has regulations requiring new, expanding and operating landfills larger than 1.5 million cubic meters (volume) to collect and flare or *use* landfill gas[3]. In addition, a number of other provinces have similar regulations in place to manage methane emissions. While flaring successfully reduces the amount of methane emitted into the atmosphere, it does not utilize the significant energy contained within biogas, which is simply lost.

The equipment required to process biogas and produce Green Natural Gas is more extensive and capital intensive than flaring. Currently, there are no Canadian jurisdictions that require landfill operators or anaerobic waste water treatment facilities to incur the additional expense of building a Green Natural Gas facility.

# 5. Operation of a Green Natural Gas Facility

In both conventional (fossil-derived) natural gas processing and Green Natural Gas processing, the removal of non-combustible gases and other contaminants produces a high quality gas that is safe for injection into a natural gas pipeline. Typically, biogas is dehydrated to remove water vapour and compressed to increase the pressure of the gas. The resulting biogas can be used onsite or safely injected into direct-use natural gas pipelines to displace conventional natural gas. Further treatment processes can be used to remove trace contaminants such as $H_2S$ and ammonia ($NH_3$). Volatile Organic Compounds (VOCs) and particulate matter (PM, which is essentially very fine dust). Finally, the methane is separated from the carbon dioxide (which is biogenic and released) and other trace gases (such as small amounts of oxygen and nitrogen). The resulting biomethane is of sufficient quality to be safely injected into the natural gas distribution system to displace conventional natural gas.

# 6. Carbon Dioxide Emissions from Green Natural Gas

As previously discussed, carbon dioxide resulting from the combustion of Green Natural Gas is considered to be biogenic. Consequently, burning Green Natural Gas does not add incremental carbon dioxide to the atmosphere.

Companies and individuals purchasing Green Natural Gas, whether as a bundled product (the environmental attributes bundled with the gas commodity) or as an unbundled product (the

[3] *O. Reg. 232/98* and *Regulation 347* under the *Environmental Protection Act,* amended June 2008 https://www.ontario.ca/page/landfill-gas-capture-guideline-regulatory-and-approval-requirements-landfill-gas

environmental attributes unbundled from the commodity) may treat Green Natural Gas as having net zero direct carbon dioxide emissions in the quantification of Scope 1 emissions. For instance, many companies use the World Resources Institute's *Greenhouse Gas Protocol*[4] to calculate their corporate GHG inventory. Under the rules of the Greenhouse Gas Protocol, emissions associated with consumption of natural gas in a building that the company owns or controls is considered as part of that company's Scope 1 (direct) emissions. If a company purchases Green Natural Gas, whether bundled with the commodity or unbundled through certificates, the company would report the biogenic $CO_2$ emissions associated with natural gas consumption separately from the scopes[5], and as zero within the Scope 1 quantification. Green Natural Gas effectively displaces the carbon dioxide emissions associated with burning conventional (fossil-derived) natural gas.

# Part II – Quantifying Emission Reductions from Natural Gas Displacement by Green Natural Gas

From a consumer's perspective, replacing conventional natural gas with Green Natural Gas (either bundled or unbundled) results in a carbon dioxide emission reduction (Scope 1). Processing biogas to produce Green Natural Gas to displace fossil-derived natural gas also results in a fuel that is less energy intensive than extracting, processing and transporting conventional natural gas, which results in an indirect reduction of GHGs (Scope 3 emissions). In addition, processing biogas to meet transmission/distribution pipeline quality standards prevents or removes pollutants that would otherwise have been flared, resulting in the reduction of other emissions (e.g. NOx, $SO_2$, VOCs and particulates).

This Protocol provides a framework for calculating direct and indirect emissions in two scenarios: the business as usual or Baseline scenario, without the Green Natural Gas project (in which the biogas is not collected and/or flared while end use consumers are burning conventional natural gas), and the Project scenario (in which Green Natural Gas, is combusted by end use consumers thereby displacing the consumption of fossil-derived natural gas).

The direct GHG emission reduction is calculated by multiplying the amount of conventional natural gas that is displaced by Green Natural Gas (the end user's consumption) and the fossil-derived natural gas emission factor for carbon dioxide (see Table A1 in Appendix). The emission factor is a standard intensity factor, which provides the carbon dioxide emissions per energy unit of fossil-derived natural gas burned.

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[4] World Resources Institute, *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard*. Revised Edition. http://www.ghgprotocol.org. 2010.
[5] World Resources Institute, *GHG Protocol Scope 2 Guidance, An Amendment to the GHG Protocol Corporate Standard*. http://www.ghgprotocol.org. 2015.

# 1. Identification of Baseline and Project Conditions

The intent of this document is to serve as a template for project specific applications and therefore, it must be uniquely adapted for individual projects. Emissions sources relevant for each specific project should be identified within a separate site specific project document.

The framework analyzes processes upstream and downstream of the project scope, as well as activities within the project scope. Emissions sources that are present in both scenarios are ignored; the focus of this Protocol is on the *difference* between the two scenarios identified[6].

This analysis demonstrates that a Green Natural Gas project may result in a reduction in GHG emissions through each stage of the lifecycle (production through consumption). The protocol utilizes the same framework to evaluate net emission reductions associated with use of Green Natural Gas whether it is processed to meet transmission/distribution pipeline quality standards or not. The quantification of an emission reduction is accomplished by comparing the emissions in the Baseline scenario to the Project scenario.

The two scenarios are graphically depicted in the figures that follow. Figure 1 illustrates the process flow of a typical Baseline configuration with a collection and flare system in place. Figure 2 illustrates the process flow in a typical Project scenario in which the landfill continues to operate as it did in the Baseline scenario. The change is that the landfill gas, instead of being flared, is sent via a dedicated pipeline to a facility where it displaces combustion of conventional natural gas or sent to a facility where it is processed further to meet pipeline quality specifications and injected into a transmission/distribution pipeline.

Figure 3 illustrates the process flow of a typical Baseline configuration for an anaerobic waste water treatment plant. Figure 4 illustrates the process flow for a typical Project scenario for anaerobic waste water treatment plant where the biogas is collected. The change is that the biogas, instead of being vented or flared, is sent via a dedicated pipeline to a facility where it displaces combustion of conventional natural gas.

The emission reductions resulting from Green Natural Gas are equal to the difference between the emissions from all sources in the Baseline scenario and the emissions from all sources in the Project scenario. It is not necessary to quantify the emissions source if emissions are equivalent in both scenarios for a particular emissions source (for example, garbage trucks collecting waste occurs in both scenarios).

Table 1 provides a description of each emissions source shown in the process flow diagrams and explains whether each emissions source will result in any difference between the Baseline and the Project scenarios. If the emissions source is not different or material, it is not given further consideration. Table 2 provides basic guidelines for monitoring emissions sources in a Green Natural Gas project.

[6] In order to yield a net reduction of emissions, the project activity must be additional to federal, provincial and/or regional regulations or binding mandates. Only reductions beyond current regulated levels may be counted as real reductions.

Figure 1: Baseline Process Flow Diagram – Landfill Gas Collection and Flare System

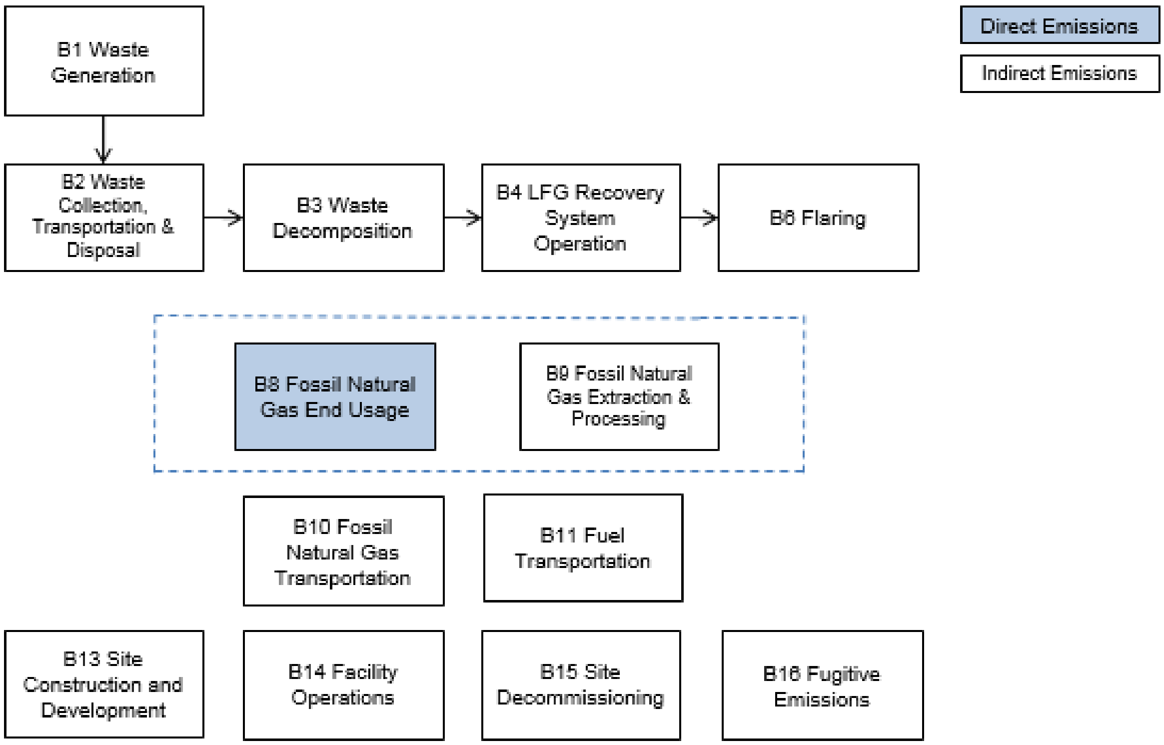


Figure 2: Project Process Flows – Landfill Gas Collection and Processing to Displacement of Natural Gas System

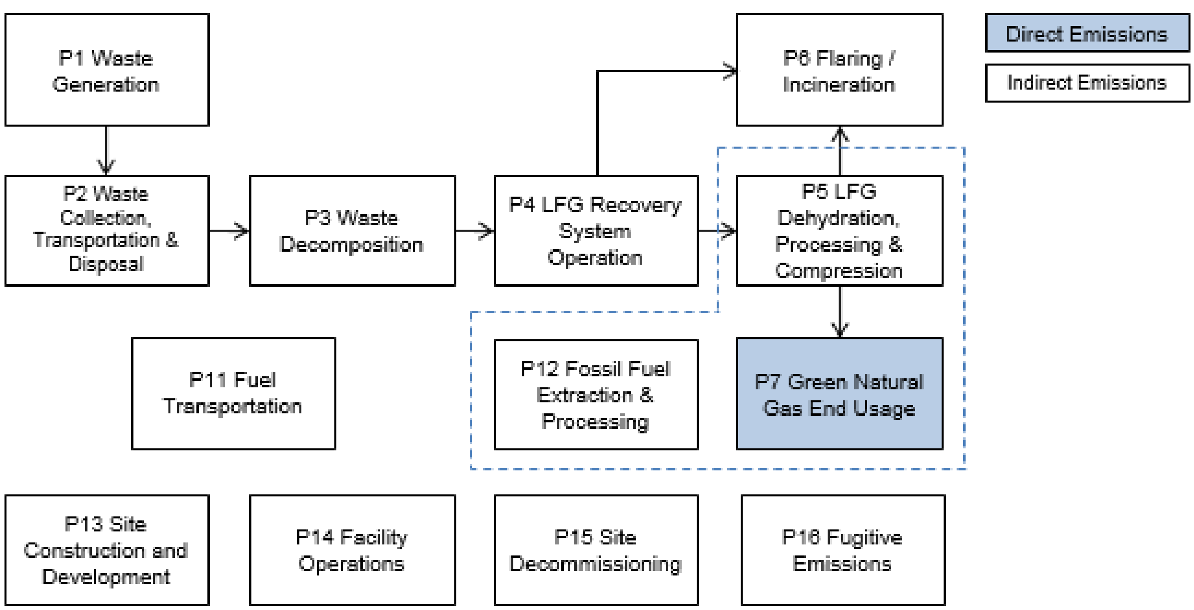

Figure 3: Baseline Process Flow Diagram – Anaerobic Waste Water Treatment

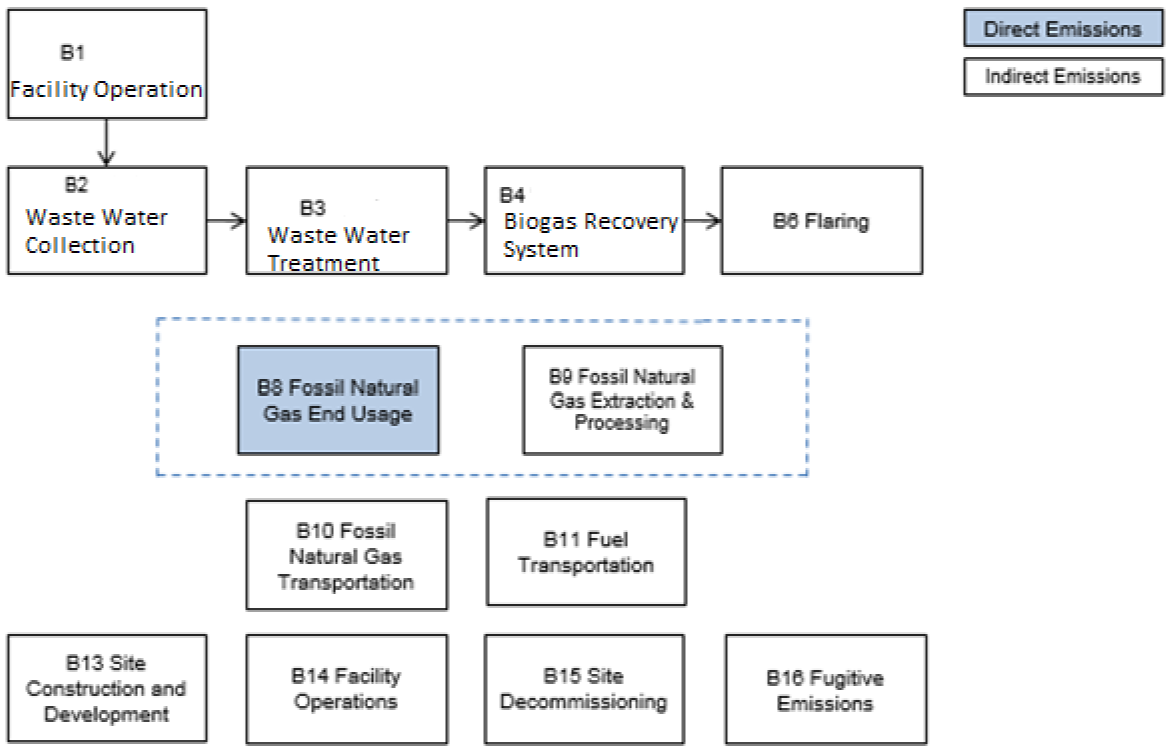


Figure 4: Project Process Flow Diagram – Anaerobic Waste Water Treatment

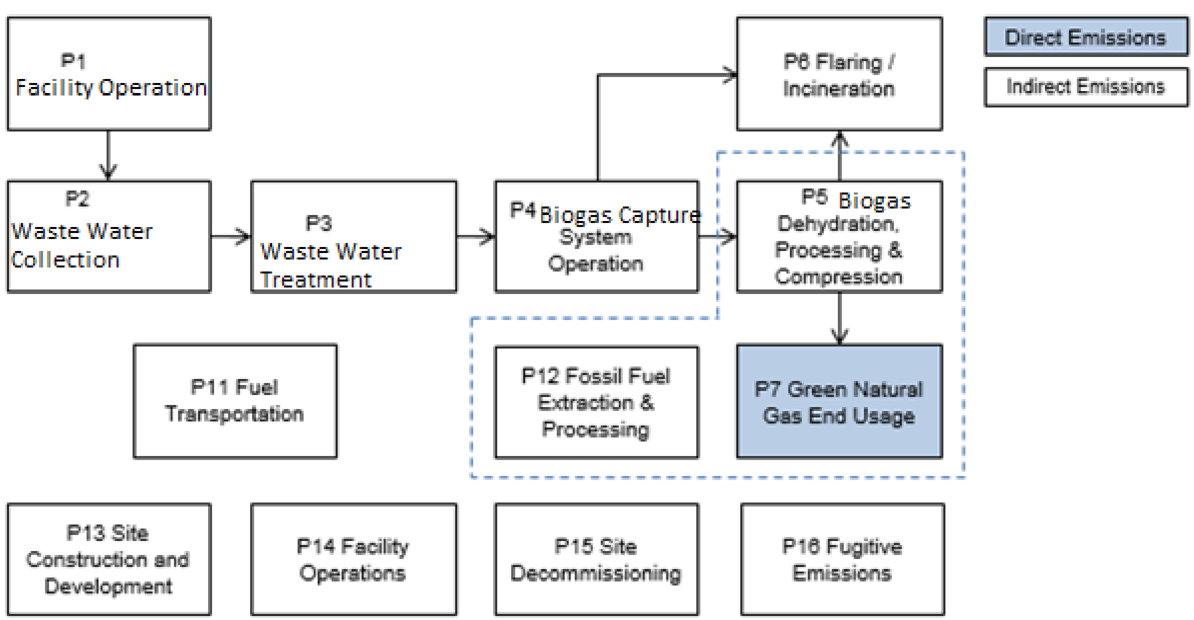

Table 1 -- Identification of Emissions Sources

| Emissions Source (Number) | | (Name) | Description | Emissions Analysis | Explanation for Exclusion |
|---|---|---|---|---|---|
| P1 | B1 | Waste Generation | Solid waste or waste water is produced within the jurisdictions adjacent to the facility being analyzed. | Excluded | Waste is generated in either scenario; therefore, emissions in the baseline and project scenarios are equivalent. |
| P2 | B2 | Waste Collection, Transportation & Disposal | Waste or waste water is collected, transported, processed and disposed in the facility being analyzed. | Excluded | Waste is collected and disposed of in either scenario; therefore, emissions in the baseline and project scenarios are equivalent. |
| P3 | B3 | Waste Decomposition | Organic waste decomposes and generates LFG or biogas, largely comprised of carbon dioxide and methane. A portion of the LFG/biogas reaches the surface and is emitted into the atmosphere. | Excluded | Waste decays in either scenario; therefore, emissions in the baseline and project scenarios are approximately equivalent. Note: the landfill gas/biogas that is collected is described in the following emissions source. |
| P4 | B4 | LFG or Biogas Recovery System Operation | Engines drive pumps and blowers used to recover LFG or biogas from the facility | Excluded | Landfill gas or biogas is collected in either scenario, either for flaring or converting into Green Natural Gas depending on the scenario. Emissions resulting from the collection of landfill gas in the baseline and project scenarios are equivalent. |
| P5 | | LFG Dehydration, Processing & Compression | LFG or biogas is dehydrated, chilled, and compressed (biogas example)<br>OR<br>LFG is dehydrated, chilled, compressed and processed to meet commercial natural gas pipeline quality requirements (biomethane example) | Included:<br>$CO_2$, $CH_4$, $N_2O$ | Emissions associated with energy (fossil fuel or electricity) consumed to process and compress the biogas or biomethane.<br>No exclusions. |
| P6 | B6 | Flaring / Incineration | In the baseline scenario, LFG or biogas is combusted in a flare stack. A supplemental fossil fuel may be used to ensure more complete combustion.<br>In the project scenario, waste gases may be destroyed in a flare. LFG or biogas flaring is used | Excluded | $CO_2$ emissions resulting from combustion of biogas are excluded because they are considered to be biogenic (part of the natural carbon cycle).<br>$CO_2$ emissions associated with combustion of supplemental fossil fuels and $CH_4$ emissions from incomplete combustion are excluded as the |

| Emissions Source (Number) | | (Name) | Description | Emissions Analysis | Explanation for Exclusion |
|---|---|---|---|---|---|
| | | | only in upset scenarios or when the Green Natural Gas system is unavailable. | | emissions from flaring are likely greater in the baseline scenario.<br><br>$N_2O$ excluded as this emissions source is assumed to be very small. |
| P7 | | Green Natural Gas End Usage | Green Natural Gas (biogas) is combusted in downstream end use equipment.<br><br>OR<br><br>Green Natural Gas (biomethane) is injected into transmission/distribution pipeline for combustion downstream in end use equipment. | Included:<br><br>$CH_4$, $N_2O$ | $CO_2$ emissions are excluded because they are considered to be biogenic (part of the natural carbon cycle). |
| | B8 | Fossil Natural Gas End Usage | Conventional fossil-derived natural gas is combusted in downstream end use equipment. | Included:<br><br>$CO_2$, $CH_4$, $N_2O$ | No exclusions. |
| | B9 | Fossil Natural Gas Extraction & Processing | Conventional fossil-derived natural gas is extracted and processed by natural gas production companies. | Included:<br><br>$CO_2$, $CH_4$, $N_2O$ | No exclusions. |
| | B10 | Fossil Natural Gas Transportation | Conventional fossil-derived natural gas is transported from production regions to distribution regions, which involves compression through the pipeline system. | Excluded | Emissions associated with transmission of natural gas are difficult to estimate within a reasonable margin of error and are assumed to be very small compared to the emissions associated with combustion or extraction and processing of fossil natural gas. |
| P11 | B11 | Fossil Fuel Transportation | Conventional fossil-derived fuel is transported from production regions to the facility where it may be used to operate facility equipment.<br><br>Transportation emissions originate from natural gas compression equipment through the pipeline system or from local delivery trucks. | Excluded | Emissions associated with transportation of energy (fossil fuel or electricity) to operate facility equipment are generated in either scenario; therefore, emissions in the baseline and project scenarios are equivalent. |

| Emissions Source (Number) | | Emissions Source (Name) | Description | Emissions Analysis | Explanation for Exclusion |
|---|---|---|---|---|---|
| P12 | | Fossil Fuel Extraction & Processing | Supplemental fossil fuels that are combusted in landfill/biogas processing equipment are processed by natural gas production companies upstream of the site. | Included: $CO_2$, $CH_4$, $N_2O$ | Note: if the landfill processing equipment does not use supplemental fossil fuels, this emissions source is excluded. |
| P13 | B13 | Site Construction & Development | Civil infrastructure and the facility are prepared and constructed. | Excluded | Facility construction and development occurs in both scenarios. Emissions in the baseline and project scenario are similar and small compared to the emissions of the total project when amortized over the project lifetime. |
| P14 | B14 | Facility Operations | Facility infrastructure (such as support buildings) are operated including electrical and heating operation. | Excluded | Emissions in the baseline and project scenario are similar and small compared to the emissions of the total project when amortized over the project lifetime. |
| P15 | B15 | Site Decommissioning | The site and equipment are disassembled or demolished once the landfill is no longer in operation. | Excluded | Emissions in the baseline and project scenario are similar and small compared to the emissions of the total project when amortized over the project lifetime. |
| P16 | B16 | Fugitive Emissions | Unintentional small releases of gas occur throughout Green Natural Gas and conventional Natural gas processing systems and pipelines. | Excluded | Fugitive emissions occur in both scenarios and in most cases will be larger in the baseline. Therefore, it is conservative to exclude this emissions source. |

# 2. Quantification of Emission Reductions

The emission reductions associated with the use of Green Natural Gas versus fossil-derived natural gas can be expressed as the equation:

$$\boxed{Emission\ Reduction = Emissions_{Baseline} - Emissions_{Project}}$$

The emissions sources identified as material to the emissions calculation in Table 1 are included below.

$$Emissions\ Baseline = Emissions_{Fossil\ Natural\ Gas\ Extraction\ \&\ Processing} + Emissions_{Fossil\ Natural\ Gas\ Usage}$$

$$Emissions\ Project = Emissions_{LFG\ \ Dehydration, Processing\ \&\ Compression} + Emissions_{Fuel\ Extraction\ \&\ Processing} + Emissions_{Green\ Natural\ Gas\ Usage}$$

The formulae that follow describe the quantification of each emissions source.

### Fossil Natural Gas Extraction & Processing (B9) *Indirect emissions source*

$$Emissions_{\ Natural\ Gas\ Extraction\ \&\ Processing} = Emissions_{CO_2} + Emissions_{CH_4} + Emissions_{N_2O}$$

$$Emissions_{\ CO_2, CH_4, N_2O} = V_{Equivalent\ volume\ naturalgas\ displaced} \times EF_{gas} \times GWP$$

Where:

$V_{Equivalent\ volume\ naturalgas\ displaced}$ = volume[7] of gas at STP

$EF_{gas}$ = Emission factor for natural gas extraction & processing by each greenhouse gas (see Table 1)

### Fossil Fuel Extraction & Processing (P12) *Indirect emissions source*

$$Emissions_{\ Fossil\ Fuel\ Extraction\ \&\ Processing} = Emissions_{CO_2} + Emissions_{CH_4} + Emissions_{N_2O}$$

$$Emissions_{\ CO_2, CH_4, N_2O} = \sum_{i=0}^{n} \left(Q_i \times EF_{i,g} \times GWP\right)$$

Where:

$Q_i$ = Quantity of fossil fuel i[8]

n = Number of fossil fuels

$EF_{i,g}$ = Emission factor for fossil fuel i (extraction & processing) for each greenhouse gas g (see Table 1)

g = Greenhouse Gas, $CO_2$, $CH_4$ or $N_2O$

[7] Use standard temperature and pressure, under same conditions as EFs

[8] Quantity of fuel quantified in units (i.e. energy, volumetric) aligned with the emission factor to be used.

### LFG/Biogas Dehydration, Processing & Compression (P5) *Indirect emissions source*

$$Emissions_{\,Dehydration\,\&\,Processing\,System} = Emissions_{CO_2} + Emissions_{CH_4} + Emissions_{N_2O} + Emissions_{ele}$$

$$Emissions_{\,CO_2,CH_4,N_2O} = V_{fuel} \times EF_{fuel} \times GWP$$

Where:

$V_{fuel}$ = Volume of fuel consumed by LFG/Biogas processing equipment

$EF_{fuel}$ = Emission factor for each fuel combusted, by gas (see Table 1)

$$Emissions_{ele} = Q_{ele} \times EF_{ele}$$

Where:

$Q_{ele}$ = Quantity of electricity consumed by LFG/Biogas processing equipment

$EF_{ele}$ = Electricity emission factor (see Table 1)

### Fossil or Green Natural Gas Usage (B8, P7) *Direct emissions source*

$$Emissions_{Fossil\,or\,Green\,Natural\,Gas\,Usage} = Emissions_{CO_2} + Emissions_{CH_4} + Emissions_{N_2O}$$

$$Emissions_{\,CO_2,CH_4,N_2O} = Q_{fuel} \times EF_{fuel} \times GWP$$

Where:

$Q_{gas}$ = Quantity of fuel in energy terms (GJ)[9]

$EF_{gas}$ = Emission factor for natural gas (B8) or biogas (P7) combusted (see Table 1)

Combusting Green Natural Gas produces very small quantities of methane and nitrous oxide emissions (less than 1% of the total) that are not biogenic. These are equivalent to the methane and nitrous oxide emissions associated with combusting fossil natural gas. Overall, switching from conventional (fossil-derived) natural gas to Green Natural Gas results in GHG emission reductions in excess of 99%.

[9] For projects in Alberta, site specific gas analyses are preferred to determine the HHV of the facility natural gas and facility biogas. Alberta Emission factors are provided on a volumetric basis. If site specific HHVs are not available Alberta default HHV values can be applied.

# Part III – Operating/Quality Standards and Methodology Applicability for Green Natural Gas Projects

To meet this standard a Green Natural Gas displacement project facility shall meet the following operational requirements and applicability criteria:

1) **Operations standards:** The gas collection operations at the Green Natural Gas project must meet all government environmental and operating requirements.
    a) Landfill installation must be approved for operation by the governing jurisdiction as evidenced by the Installation Report and a current Certificate of Authorization.
    b) Anaerobic waste water treatment plants must be approved for operation by the governing jurisdiction as evidenced by Environmental Approval to operate the facility.

2) **Quality of Green Natural Gas (biogas):** If the Green Natural Gas is to be transported to the end user via a dedicated or purpose-built pipeline from the landfill, i.e. it never enters a distribution or transmission pipeline system, while still processed for removal of water vapour and some large particulate matter, it does not have to meet a receiving pipeline's natural gas quality standards. Demonstrating compliance with the Green Natural Gas project requirements requires monitoring and measurement of the energy content of the gas.
    a) The volume of Green Natural Gas must be metered using a custody transfer meter, which is calibrated according to the schedule provided by the manufacturer or required by Measurement Canada;
    b) The methane content of the Green Natural Gas shall be monitored continuously and used to determine the energy content of the gas for emissions quantification purposes.

3) **Quality of Green Natural Gas (biomethane):** If the Green Natural Gas is to be injected into a utility's distribution or transmission pipeline system, it must meet the receiving pipeline's natural gas quality standard. Demonstrating compliance requires monitoring and measurement of the quality of the gas, as well as confirmation of the quality by the pipeline operator.
    a) The volume of biomethane must be metered using a custody transfer meter, which is calibrated according to the schedule provided by the manufacturer or required by Measurement Canada;
    b) The gross heating value of the biomethane injected into the pipeline shall meet a minimum level defined by the local natural gas distribution or transmission operator;
    c) The oxygen content of the biomethane shall not exceed a level defined by the local natural gas distribution or transmission operator;
    d) The concentration of hydrogen sulphide in the biomethane shall not exceed a level defined by the local natural gas distribution or transmission operator;
    e) The concentration of volatile organic compounds in the biomethane shall not exceed a level defined by the local natural gas distribution or transmission operator.

4) **Protocol Applicability:** In addition to the operating and quality standards listed above, the Green Natural Gas project must demonstrate the following criteria are met.
   a) The Green Natural Gas project must be additional to all regulatory requirements at the local, regional, provincial, or federal level;
   b) The environmental attributes associated with Green Natural Gas must not be used for regulatory compliance purposes (therefore not used as a feedstock in a GHG-regulated market);
   c) For a landfill, the Green Natural Gas project must use a baseline condition in which landfill gas is captured and flared – only fossil-derived natural gas displacement is eligible to create emission reductions;
   d) For an anaerobic waste water treatment plant, the Green Natural Gas project must use a baseline condition in which biogas is vented to atmosphere – only fossil-derived natural gas displacement is eligible to create emission reductions.
   e) The Green Natural Gas must be transported to market/end user via pipeline or via a dedicated biogas fuel piping system within a facility.

# Appendix A

Table A1, below, provides sample GHG emission factors for use with this protocol. These emission factors change from time to time; current values are available from the sources referenced below.

Table A1: Sample Greenhouse Gas Emission Factors

| Emissions Source | Gas | Unit | Factor (Ontario) | Factor (British Columbia) | Factor (Quebec) | Factor (Alberta) |
|---|---|---|---|---|---|---|
| **Electricity**[10] | $CO_2e$ | kg/kWh | 0.043 | 0.021 | 0.002 | 0.64[11] |
| **Natural Gas Extraction & Processing**[12] | $CO_2$<br>$CH_4$<br>$N_2O$ | kg/m$^3$<br>kg/m$^3$<br>kg/m$^3$ | 0.133<br>0.0026<br>0.000007 | 0.133<br>0.0026<br>0.000007 | 0.133<br>0.0026<br>0.000007 | 0.133[13]<br>0.0026<br>0.000007 |
| **Gasoline or Diesel Production**[14] | $CO_2$<br>$CH_4$<br>$N_2O$ | kg/L<br>kg/L<br>kg/L | | 0.138<br>0.0109<br>0.000004 | | |
| **Natural Gas/Biomethane Combustion**[15] **(energy basis)** | $CO_2$<br>$CH_4$<br>$N_2O$ | kg/GJ<br>g/GJ<br>g/GJ | 49.03<br>0.966<br>0.913 | 50.0<br>0.966<br>0.913 | 49.01<br>0.966<br>0.913 | 50.026[16]<br>0.9650<br>0.8607 |
| **Natural Gas/Biomethane Combustion**[17] **(volumetric basis)** | $CO_2$<br>$CH_4$<br>$N_2O$ | kg/m$^3$<br>kg/m$^3$<br>kg/m$^3$ | 1.888<br>0.000037<br>0.000035 | 1.926<br>0.000037<br>0.000035 | 1.887<br>0.000037<br>0.000035 | 1.918[18]<br>0.000037<br>0.000033 |

[10] Consumption greenhouse gas intensity factors. Environment Canada, *National Inventory Report, 1990-2015: Greenhouse Gas Sources and Sinks in Canada, Part 3*, 2017. http://www.ec.gc.ca

[11] *ESRD Carbon Offset Emission Factors Handbook* version 1.0, Table 2 Climate Change, Government of Alberta, March 2015.

[12] Clearstone Engineering Ltd. On behalf of the Canadian Association of Petroleum Producers (CAPP), *A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide ($H_2S$) Emissions by the Upstream Oil and Gas Industry*, Calgary, 2004.

[13] *ESRD Carbon Offset Emission Factors Handbook* version 1.0, Table 4 Climate Change, Government of Alberta, March 2015.

[14] Clearstone Engineering Ltd. On behalf of the Canadian Association of Petroleum Producers (CAPP), *A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide ($H_2S$) Emissions by the Upstream Oil and Gas Industry*, Calgary, 2004.

[15] Tables 20-3 and 20-4. Guideline for Quantification, Reporting and Verification of Greenhouse Gas Emissions, Effective July 2017. Ontario Ministry of the Environment and Climate Change, 2017.

[16] Government of Alberta, "Quantification Methodologies for the Carbon Competitiveness Incentive Regulation and the Specified Gas Reporting Regulation", Draft Version 0.02, December 2017, Table 1.1 default HHV

[17] Environment Canada, *National Inventory Report, 1990-2015: Greenhouse Gas Sources and Sinks in Canada, Part 2*, 2017. http://www.ec.gc.ca

[18] *ESRD Carbon Offset Emission Factors Handbook* version 1.0, Table 6 Climate Change, Government of Alberta, March 2015.

| Emissions Source | Gas | Unit | Factor (Ontario) | Factor (British Columbia) | Factor (Quebec) | Factor (Alberta) |
|---|---|---|---|---|---|---|
| **Biogas Combustion[19] (energy basis)** | $CO_2$<br>$CH_4$<br>$N_2O$ | kg/GJ<br>g/GJ<br>g/GJ | 54.6<br>1.0<br>0.1 | | | |
| **Fuel Ratio[20]** | N/A | N/A | 0.97% (Southwestern Zone) | 1.0% (Foothills B.C.) | 1.15% (Eastern Zone) | |

The basic unit of measure used in GHG quantification exercises is mass of $CO_2$ equivalent ($CO_2e$). The factors used to convert mass of $CH_4$ and $N_2O$ to $CO_2e$ for comparison purposes are the following global warming potentials: 25 kg $CO_2e$/kg $CH_4$; and 298 kg $CO_2e$/kg $N_2O$.[21]

Table A2: Guidelines for Emissions Source Monitoring

| Emissions Source/ Measurement Parameter | Measurement Procedure | Measurement Frequency (Minimum) | QA/QC Procedures |
|---|---|---|---|
| **$CH_4$ Content of Green Natural Gas** | Gas chromatograph | Continuously if available minimum monthly sampling | Gas chromatograph calibration annually or according to manufacturer specifications |
| **Quantity of Green Natural Gas** | Metered | Continuously | Meter calibration annually or according to manufacturer specifications |
| **Quantity of Electricity Consumed in Green Natural Gas Processing** | Metered | Continuously if available minimum assume rated power or equipment and 24hr 7 day per week operations | Purchase invoices from third-party supplier or operations validation of equipment specifications and rated power |
| **Volume of Fuels Consumed for Flaring and Incineration** | Inventory based on purchase invoices | Annually | Third-party invoices |

[19] Emission factors for combustion of landfill gas (biogas). Table 20-2. Guideline for Quantification, Reporting and Verification of Greenhouse Gas Emissions, Effective July 2017. Ontario Ministry of the Environment and Climate Change, 2017.
[20] TransCanada Pipelines Mainline Average Summer 2012 Fuel Ratios.
http://www.transcanada.com/customerexpress/mainline.html
http://www.transcanada.com/customerexpress/3677.html
[21] Intergovernmental Panel on Climate Change, Climate Change 1995: Second Assessment Report. Available at http://www.ipcc.ch/pdf/climate-changes-1995/ipcc-2nd-assessment/2nd-assessment-en.pdf

## Glossary of Terms & Acronyms

| | |
|---|---|
| Additional | Extent to which the project produces greater environmental benefit than would have been achieved in the absence of the project. Regulatory additionality specifically addresses the extent to which the project provides greater environmental benefit than is required by law. |
| Baseline Scenario | The pre-project state, before the construction and operation of the project. |
| Biogas | Biogas is landfill gas that has been cleaned up (water and large particulates have been removed), the resulting gas is comprised of 40-60% $CH_4$ and 40-60% $CO_2$.<br><br>Biogas is gas collected from the waste water treatment plant, the resulting gas is comprised of 70-74% $CH_4$ and 20-24% $CO_2$. |
| Biogenic $CO_2$ Emissions | $CO_2$ emissions resulting from the natural decomposition of organic matter. |
| Biomethane | Biomethane is landfill gas that has been cleaned up to meet utility transmission or distribution pipeline specifications. Biomethane is equivalent to fossil-derived natural gas in its $CH_4$ content (approx. 95-97%). |
| $CH_4$ | Methane |
| $CO_2$ | Carbon Dioxide |
| Combustion | The oxidation of fuel that releases water and carbon dioxide from the exothermic reaction. |
| Destruction Efficiency | The efficiency of the combustion device in oxidizing the methane to carbon dioxide. |
| Functional Equivalence | A comparison proving that the Project and the Baseline scenarios provide the same function across inputs and outputs (i.e. metered volume of landfill or waste water treatment gas). This type of comparison requires a common metric or unit of measurement for comparison between the Project and Baseline activity and emissions profile. |
| GHG | Greenhouse Gas |
| Green Natural Gas | Green Natural Gas can be either Biogas or Biomethane that is combusted by an end user/customer to displace conventional fossil-derived natural gas. |
| $H_2S$ | Hydrogen Sulphide |
| Landfill | A defined area of land or excavation that receives or has previously received waste. |

| | |
|---|---|
| Landfill Gas (LFG) | Gas resulting from the decomposition of organic waste in a landfill, typically comprised primarily of methane, carbon dioxide and other trace gases. Landfill gas is the byproduct from the natural decomposing organic matter created in an anaerobic condition. |
| Landfill Gas Project | Installation and operation of infrastructure that collects landfill gas and either combusts the gas locally, or processes the gas to be utilized for local electricity generation or injects it into a pipeline for use as an alternative fuel to conventional natural gas fuel. |
| $N_2O$ | Nitrous Oxide |
| Project Scenario | Utilization of conventional (fossil derived) natural gas |
| Waste Water Treatment Project | Installation and operation of infrastructure that collects biogas from an anaerobic waste water treatment facility and either combusts the gas locally, or processes the gas to be utilized for local electricity generation. |