APPENDIX A

Capital Regional District (CRD)

Life Cycle Greenhouse Gas (GHG) Analysis of Landfill Gas Utilization Scenarios at the Hartland Landfill

June 10, 2019

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Disclaimer

The information compiled for this report has been prepared for the purpose of estimating greenhouse gas (GHG) emissions to compare the aspects and GHG related impacts of two enhanced landfill gas utilization scenarios at the Hartland Landfill.

Readers of this report should ensure that they are aware of the assumptions made in the analysis and any limitations so created. The author assumes no responsibility or liability for any action or activity that is based upon information in this report - whether or not the reader has interpreted the information correctly.

The report includes estimated depictions of the inputs and outputs of the scenarios based on a combination of literature review, third party studies, and data from the Capital Regional District (CRD). These characteristics are representative and generic for the scenarios modeled but may represent the impact or emissions of any future activity. Readers are specifically cautioned that this work does not constitute any form of a pre-design, design, or facility specification document, and does not define GHG emissions or environmental impact specifications for either scenario. It is not suitable for tendering or procurement, for facility permitting, regulatory approval submissions, or for cost estimation.

Stantec has completed this analysis using reasonably ascertainable information, obtained from a desktop review of official documentation, informal data compilations, and telephone conversations. The assessment represents the information provided at the time of the assessment. Stantec did not conduct direct GHG emissions monitoring, site visits or other environmental sampling and analysis in conjunction with this analysis. Stantec Consulting Ltd. (Stantec) liability is limited to the amount of Stantec's fees for undertaking this work. Stantec disclaims liability for use by any other party and for any other purpose.

Abbreviations

AB	Alberta
BC	British Columbia
CRD	Capital Regional District
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CIRAIG	Canadian International Reference Centre for the Life Cycle of Products, Processes and Services
CSA	Canadian Standards Association
EEIO	Environmental Economic Input Output
GHG	Greenhouse gas
GJ	Giga Joule
ISO	International Standards Organization
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
NIR	National Inventory Report
N_2O	Nitrous oxide
RNG	Renewable Natural Gas
SETAC	Society for Environmental Toxicology and Chemistry
t	Tonne
WRI	World Resources Institute

Executive Summary

The Capital Regional District's (CRD) Hartland Landfill, located in Victoria, BC, collects landfill gas through a comprehensive network of gas collection infrastructure. Currently, the landfill gas is utilized for power generation at a 1.6-megawatt electricity generation facility; any unutilized landfill gas is flared on site. The volume of gas collected at the landfill has exceeded the capacity of the current power generation equipment and, as a result, CRD is evaluating two enhanced utilization scenarios under a life cycle greenhouse gas (GHG) emissions lens. The two scenarios considered are:

- Generate Renewable Natural Gas (RNG) - This scenario involves installing an RNG gas processing plant at Hartland Landfill to upgrade the landfill gas to RNG. This would also require the construction of a 7.4-kilometer (km) pipeline to connect to the main FortisBC gas pipeline.
- Generation of Green Power– This scenario involves adding another genset, and associated infrastructure, to double this electrical generating capacity. No additional transmission lines are required in the original installation or required for the proposed expansion.

In both scenarios, project related construction would commence March 2, 2020, projects would be operational January 1, 2022 for a period of 25 years. Each scenario assumes that the landfill would provide a minimum of 200,000 GJ of landfill gas per year over the operational life of the scenarios.

While each scenario will have a small physical footprint, the effects related to GHG emissions, are expected to extend beyond the physical boundaries of the landfill itself. Specifically, the Green Power scenario will result in the displacement of electricity consumed in BC, whereas the RNG Scenario will result in the displacement of natural gas consumed in BC.

The life cycle GHG assessment includes the assessment of construction, operation, and major rehabilitative maintenance GHG related emissions, but does not include decommissioning, supply chain, or embodied / product GHG emissions. This is on the basis that detailed components and breakdown of the equipment required for each is not yet known, there is limited publicly available published data on the embodied / product emissions associated with the construction of RNG and LNG electrical generation facilities, and distribution networks. When decommissioning does occur, it is expected that the project in either scenario would be recycled and reused resulting in minimal GHG emissions.

Table E-1 presents a summary comparison of the two scenarios. It shows that the RNG scenario can result a reduction of more than 263,000 tonnes of GHG emissions over 25 years which is nearly a 95-fold improvement over the Green Power scenario.

Table E-1 Scenario Comparison Summary

Stage	RNG Scenario (tCO_2e)	Green Power Scenario (tCO_2e)	Difference (tCO_2e)	Difference (Percent)
Facility Construction	730	632	98	16%
Energy Distribution Infrastructure Construction	550		550	100%
Operation	9,936	1,589	8,348	525%
Maintenance		1	(1)	-100%
Avoided Energy GHG Emissions	(275,039)	(5,011)	(270,028)	5,389%
Decommissioning	Not Reviewed	Not Reviewed	-	-
Total GHG Emissions (tCO_2)	**(263,822)**	**(2,789)**	**(261,033)**	**9,360%**

*Notes to Table: * No additional transmission and distribution lines are required under this scenario; however, if one of equivalent length to the pipeline was constructed, it is estimated that the construction activities would add an additional 313 tCO_2e, reducing the net benefit to (2,476) tCO_2e.*

This difference between the two scenarios is due to the already low GHG emissions intensity of the BC electrical grid, and the low utilization efficiency of the gensets (34.8%). As natural gas stationary combustion equipment has a higher fuel utilization efficiency (80-90%) the emissions intensity per unit of energy is much lower than compared to electricity generation.

This outcome should not be assumed to apply in the same way in other locations. For instance, there can be a case made to produce electricity from landfill gas in regions with high emission intensity electricity generation (e.g. in Alberta, when the electricity grid is supplied by coal).

1.0 INTRODUCTION

The following section provides an overview of the project scope and objectives.

1.1 CONTEXT

The Capital Regional District's (CRD) Hartland Landfill collects landfill gas through a comprehensive network of gas collection infrastructure. Currently Hartland Landfill gas is utilized for power generation and the resulting electricity is sold to BC Hydro. The volume of gas collected at the landfill has exceeded the capacity of the current power generation equipment and, as a result, CRD is evaluating two enhanced utilization alternatives:

- Renewable Natural Gas (RNG) - Install a gas processing plant at Hartland Landfill to upgrade the landfill gas to RNG, and install a 7.4-kilometer (km) pipeline to connect to the main FortisBC gas pipeline (the RNG Scenario);
- Green Power - Expand the existing power generation equipment to provide additional electricity into the BC Hydro electrical grid (the Green Power Scenario).

This study uses Life Cycle Assessment (LCA) as a framework to evaluate and compare the greenhouse gas (GHG) emissions resulting from the two scenarios. The use of the LCA framework enables the consideration of a range of inputs and outputs, the inclusion of upstream or downstream activities; and allows for the relative 'burdens and benefits' of energy consumption and displacement to be evaluated. It is important to note that an LCA does not assess site-specific impacts to ecological or human health. Such information is typically compiled in a risk assessment, usually when a utilization technology has been selected.

1.2 PROJECT SCOPE

This study uses a life cycle GHG assessment to evaluate the GHG emissions from the two scenarios for landfill gas utilization at the Hartland Landfill (the Facility). The study boundary extends to fuel extraction and processing (upstream) with the downstream boundary being limited to the displacement of downstream natural gas consumption (in the RNG scenario) and the displacement of BC Hydro generated electricity (in the Green Power Scenario). The study specifically includes the assessment of construction, operation, and major rehabilitative maintenance GHG related emissions, but does not include decommissioning, supply chain, or embodied / product GHG emissions. This is on the basis that detailed components and breakdown of the equipment required for each scenario is not yet known, there is limited publicly available published data on the embodied / product emissions associated with the construction of RNG and LNG electrical generation facilities, and distribution networks.[1] When decommissioning does occur, it is expected that the

[1] Embodied or product emissions are all the emissions associated with the production and use of a specific product, from cradle to grave, including emissions from raw materials, manufacture, transport, storage, sale, use and disposal (WRI, 2004).

facilities and infrastructure in either scenario would be recycled and re-used, and thus the GHG emissions impact immaterial.

For the purposes of comparability, the GHG emissions associated with the construction of the existing landfill gas utilization system was also included in the assessment.

1.3 PROJECT OBJECTIVES

While some comparative observations are made between the two scenarios, the primary intent of the study was to complete a life cycle GHG assessment of each scenario through to end uses, considering avoided emissions resulting from displacement of other energy types. The specific project objectives of this life cycle GHG emissions assessment are to:

- Identify the energy inputs and outputs associated with each scenario;
- Quantify these inputs and outputs at a planning level of accuracy; and
- Create an equivalent basis for comparison of the scenarios.

2.0 OVERVIEW OF LIFE CYCLE GREENHOUSE GAS ASSESSMENTS

This section provides an overview of the life cycle GHG assessment. It will be of interest to readers not familiar with the approach.

2.1 LIFE CYCLE GREENHOUSE GAS ASSESSMENTS

A life cycle GHG assessment is a technique for assessing potential GHG impacts associated with a product or process by:

- Compiling an inventory of relevant inputs and outputs of material and energy during a product manufacture or system operation;
- Evaluating the relative potential impacts associated with those inputs and outputs; and
- Interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.

The concept was initiated for documenting energy flows in the 1970s. In the 1980s and 1990s, standardized terminology and methodology was developed - initially by the Society for Environmental Toxicology and Chemistry (SETAC), with subsequent ISO standards established through the 14000 series of environmental management standards in the late 1990s. Many national standards organizations including the Canadian Standards Association (CSA) have been involved with the development of the methodologies.

The ISO system of environmental management provides guidance for conducting LCA studies. In this framework, LCA consists of four stages. These stages are:

1. **Goal Definition and Scoping**: The process to be studied is described and the boundaries for analysis are established.
2. **Inventory**: The inputs and outputs of each process are compiled. This includes inputs of energy and raw materials and outputs which can include products, energy, wastes, by-products, or contaminant emissions.
3. **Assessment**: The inputs and outputs may be grouped according to their category of environmental impact (e.g. global warming, ozone depletion, human health impact, aquatic toxicity, etc.). This is done to transform the inventory - which is on a material basis towards the effect. A life cycle GHG emissions assessment is based on an inventory of GHG emissions produced and displaced to which the location of these GHG emissions is frequently unknown and as such, a life cycle GHG assessment is not a site-specific impact assessment tool.

4. **Interpretation**: The results are placed in context and qualified. Limitations on interpretation are made clear, data shortcomings are highlighted, and any subjective assessments or assumptions are reviewed. In some life cycle studies this stage is used to define potential improvements in the process.

It is important to note that the process is iterative. That is, as the subsequent stages are executed and new knowledge is obtained, it is used to re-evaluate the previous stages.

An ideal life cycle assessment would track all production processes from their elementary stages of raw material extraction, energy consumption, and would follow waste emissions to the final disposal of all the components (a “cradle-to-grave” analysis). In practical studies, some process steps are excluded in the analysis in order to conserve resources, and / or focus on specific issues of interest. Components that are not tracked all the way to the ‘cradle’ or ‘grave’ are represented as product flows in the life cycle GHG emissions assessment.

2.1.1 Strengths & Limitations

A life cycle GHG emissions assessment should be considered as one tool in a greater toolbox for environmental evaluation. As such, it is a complement to other forms of evaluation such as environmental risk analysis or site-specific environmental impact assessment. Each of these tools has a unique frameworks and specific areas of focus. To provide some context, the utility of a life cycle GHG emissions analysis as a tool is discussed in the following sections.

2.1.1.1 Strengths of Life Cycle GHG Emissions Assessments

Characteristics and corresponding advantages of life cycle GHG emissions assessment as an analysis tool include that it:

- Defines a clear goal and scope for the study based on the desired function to be achieved.
- Defines the analysis boundaries based on a common function - i.e. the product to be produced. Defining the function ensures that environmental burdens are measured, not by materials produced, but by the function they accomplish. This is most important when there are markedly different methods to accomplish an objective and they are being compared.
- Allows for a methodical documentation of resource and material inputs and outputs. This is useful for situations where different options have different resource uses, or where the consumption or emission occurs away from the point of product use.
- Allows for a large number of emissions that are inventoried to be categorized and grouped according to a smaller number of potential environmental impacts.
- Can produce results which are numerical and quantifiable and (within the limits of the data accuracy) are not subject to value judgments or preferences.

- Does not attempt to monetize emissions or combine them into a single measure. The impact categories are maintained as independent categories of environmental impact. This allows these characteristics to be openly compared and trade-offs made through a decision analysis or attribute trade-off process.

- Defines the potential environmental impact of all options by the same suite of relevant environmental impacts.

2.1.1.2 Limitations of Life Cycle GHG Emissions Assessments

A life cycle GHG emissions assessment also has its limitations, which affect the interpretation of the results and the quantified impacts. These include that:

- The inventory and impact assessment are frequently limited by data availability and data uncertainties.

- Most impact assessment characterization factors do not easily address threshold limits for environmental impacts of compounds, fine scale temporal and spatial resolution, or site-specific issues.

2.2 LIFE CYCLE GHG EMISSIONS ASSESSMENT DATA SOURCES

Life cycle data often comes from a number of sources. These include:

- **Literature and Databases**: Numerous life cycle studies have already been performed and these can be used as research material to compile information. These study results must be compiled carefully to ensure that the assumptions used are appropriate to the situation at hand. Many life cycle software programs contain databases of past life cycle study result. A list of these databases can be found here. Many of these databases are proprietary systems (and thus do not communicate with one another), country, or process / product specific and thus can be limited in application. For example, the Athena Institute provides a building material LCA database, whereas the Carnegie Mellon database is a life cycle database associated with the production of packaging. To use many of these databases, a detailed product inventory is required, and the focus is typically on a particular product.

- **Reporting Databases and Permit Information**: Many industry sectors are required to report their consumption of certain materials, emissions to the environment, and waste streams generated through systems like the National Pollutant Release Inventory (NPRI) in Canada. As well national agencies and industry associations compile statistics on numerous inventory-relevant material flows such as energy production and consumption. These can be used to determine industry totals for emissions. however, without production data, which is usually confidential, or aggregated to a national level, an accurate intensity value of production or a process cannot easily be derived.

- **Process Inventories**: This is the traditional life cycle method in which each component of the product system is documented – by counting and tabulating information. In a manufacturing setting this literally can mean reviewing or estimating energy consumption, counting the production of widgets and estimating the energy use per widget, and throughout the value creation process. The World

Resources Institute (WRI) has recently released the Corporate Value Chain (Scope 3) Standard which provides a framework to assess product based GHG emissions.

- **Environmental Economic Input-Output (EEIO) Models**: These models are adapted from economic input-output analysis to include emissions and resource consumption. Input-output analysis was first developed by Wassily Leontief in the 1930s for economics. EEIO models start with a matrix of industry sectors in the economy. Based on the production of material in one sector (the rows) the amount of material that sector requires from other sectors (the columns) are defined, and the matrix elements define the magnitude of the demand. For example, the production of $1 million worth of steel requires the inputs of $x worth of coal, $y worth of electricity, $z worth of truck transportation, etc. To be used in life cycle analysis, the EEIO model maps the GHG emissions and consumption from industry sectors to their economic output – e.g. if the steel industry produces x million of dollars of economic activity, and y tonnes of air emissions, then the emission per dollar of activity can be calculated. By inputting a dollar amount of steel purchased, the associated 'economy average' emission can be determined. EEIO models are limited in that they rely on the homogeneity principle which assumes that each sector in an economy produces a single or homogeneous good or service and carries an identical embodied environmental impact (Kitzes, 2013). Further, the data is typically collected at the national level for both financial and GHG emission accounts to which assumptions have to be made to apply it to a product or scenario reporting level which can introduce biases and uncertainties.

3.0 METHODOLOGY

The methods used to estimate GHG emissions in each of the scenarios are based on accounting and reporting principles of the GHG Protocol developed by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (2014). This protocol is an internationally accepted accounting and reporting standard for quantifying and reporting GHG emissions. The guiding principles of the protocol for compiling an inventory of GHG data are relevance, completeness, consistency, transparency, and accuracy which align with IS0-14064-2. In cases where uncertainty is high, conservative quantification parameters and assumptions were applied, resulting in a conservative estimate of GHG emissions reductions (WRI, 2004).

3.1 PROJECT SCENARIOS

The Capital Regional District's (CRD) Hartland Landfill collects landfill gas through a comprehensive network of gas collection infrastructure. Currently, the landfill gas is utilized for power generation and the resulting electricity is sold to BC Hydro; any unutilized landfill gas is flared on site. The volume of gas collected at the landfill has exceeded the capacity of the current power generation equipment and, as a result, CRD is evaluating two enhanced utilization alternatives: upgrade to an RNG processing facility, and the expansion of the existing power generation equipment to generate additional electricity. Each scenario is described below.

The quantification is based on the landfill providing a minimum of 200,000 GJ of usable landfill gas, and any addition fuel would increase the net impact of both scenarios.

3.1.1 RNG Scenario

This scenario involves installing an RNG gas processing plant at Hartland Landfill to upgrade the landfill gas to RNG. This would also require the construction of a 7.4-kilometer (km) pipeline to connect to the main FortisBC gas pipeline.

3.1.2 Green Power Scenario

The current 1.6-megawatt electricity generation facility was commissioned in 2004. The Green Power scenario involves adding another genset, and associated infrastructure, to double this electrical generating capacity. No additional transmission lines were required in the original installation or required for the proposed expansion.

3.2 PROJECT BOUNDARY

3.2.1 Spatial

In both scenarios, the project would be constructed at the Hartland Landfill located in Victoria, BC.

While each project will have a small physical footprint, the effects related to GHG emissions are expected to extend beyond the physical boundaries of the landfill itself. Specifically, the Green Power Scenario will result in the displacement of electricity generated by BC Hydro, resulting in a reduction of GHG emissions, whereas the RNG Scenario will result in the displacement of natural gas consumed in BC, and will also result in a reduction of GHG emissions. Because GHG emissions disperse in the atmosphere, the boundaries of this assessment are being used to depict the limits of this assessment and are not the physical boundaries of the landfill.

3.2.2 Temporal

For both scenarios, the temporal boundaries considered include construction, operation and major rehabilitative maintenance phases. Construction and commissioning of the projects, in both scenarios, are anticipated to commence March 2, 2020 and be commissioned by December 31, 2021. Furthermore, in both scenarios, each project is scheduled to operate January 1, 2022 and is expected to operate for a period of 25 years.

For the purposes of comparability, the GHG emissions associated with the construction of the existing landfill gas utilization system was also included in the study.

The life cycle GHG emissions assessment includes the assessment of construction, operation, and major rehabilitative maintenance GHG related emissions, but does not include decommissioning, supply chain, or embodied / product GHG emissions. This is on the basis that detailed components and breakdown of the equipment required for each is not yet known, there is limited publicly available published data on the embodied / product emissions associated with the construction of RNG and LNG electrical generation facilities, and distribution networks. When decommissioning does occur, it is expected that the facility and infrastructure in either scenario would be recycled and reused, and thus the impact on the GHG emissions assessment immaterial.

3.3 GREENHOUSE GAS (GHG) EMISSIONS CONSIDERED

A GHG can be any atmospheric gas that absorbs and re-emits infrared radiation, thereby acting as a thermal blanket for the planet and warming the lower levels of the atmosphere. GHGs are released to the atmosphere from several natural and anthropogenic (human activity) sources (IPCC, 2014).

Emissions of each of the specific GHGs are multiplied by their 100-year global warming potential (GWP) and are reported as carbon dioxide equivalent (CO_2e). The GWP of these GHGs are:

- Carbon dioxide (CO_2) = 1.0
- Methane (CH_4) = 25
- Nitrous oxide (N_2O) = 298
- Sulphur hexafluoride (SF_6) = 22,800
- Nitrogen trifluoride (NF_3) = 17,200

- Hydrofluorocarbon (HFC) gases range from 12 to 14,800
- Perfluorocarbon (PFC) gases range from 7,390 to 17,340 (IPCC 2014)

Not all GHGs listed above are applicable to this study. Those included in this assessment are CO_2, CH_4 and N_2O. Four GHGs have been excluded from the GHG assessment for reasons explained below:

- SF_6—This gas can be found in insulating gas used in electrical switch breakers. However, the Green Power Scenario is not expected to use insulating gas that contains SF_6. If the Green Power Scenario does use a SF_6 breaker it would be a closed cycle system and would not escape into the atmosphere.
- NF_3—This gas is used in industrial processes related to semiconductors and liquid-crystal display panels. It also occurs in certain types of solar panels and chemical lasers. NF_3 will not be used or released in either scenario.
- HFCs and PFCs—These gases are not expected to be used; however, if used, the systems are designed to not release any of these substances. Therefore, HFCs and PFCs were not included in either scenario.

On this basis, carbon dioxide equivalents (CO_2e) for each scenario are calculated as:

$$\text{Tonnes } CO_2e = (\text{tonnes } CO_2 \times 1.0) + (\text{tonnes } CH_4 \times 25) + (\text{tonnes } N_2O \times 298)$$

3.4 GREENHOUSE GAS (GHG) EMISSIONS SCOPES CONSIDERED

The assessment considered all direct and indirect GHG emissions as well as any emission reductions associated with each scenario. Direct, indirect, and other indirect emissions are defined by the GHG Protocol as follows:

- **Direct GHG Emissions**: GHG emissions or removals from sources or sinks that are owned or controlled by the project owner, and within the defined project or scenario boundary. At the GHG inventory level, direct emissions are also commonly referenced as Scope 1 emissions (GHG Protocol, 2018).
- **Indirect GHG Emissions**: GHG emissions or removals that are of consequence to the project but occur at GHG sources or sinks not owned or controlled by the applicant (GHG Protocol, 2018). For example, reduced electricity consumption would be considered indirect as the GHG emissions generated to create the electricity are outside of a project's boundaries.
- **Other Indirect GHG Emissions**: GHG emissions, excluding scope 2, that arise upstream and downstream as a result of the operation or manufacture of a good or service.

These scopes are depicted in Figure 3-1.

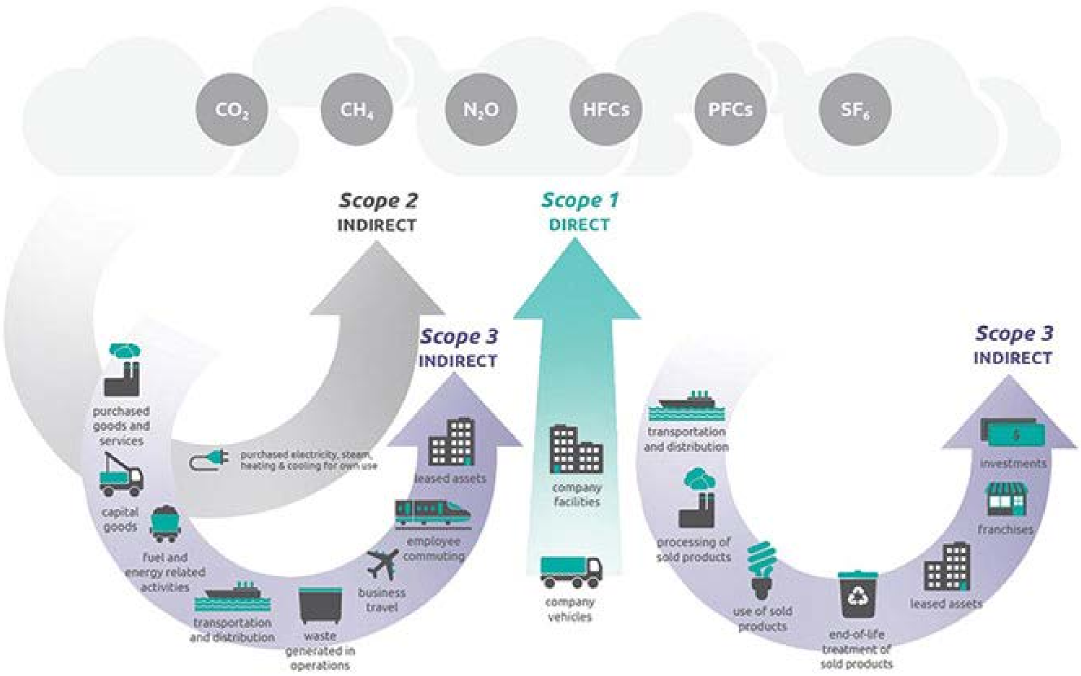

Figure 3-1 Overview of GHG Emissions Scopes (GHG Protocol, 2018)

The following direct and indirect GHG emission sources and removals have been assessed for each Scenario (Table 3-1).

Table 3-1 Scenario GHG Emissions Sources and Removals

Phase	Item	Description	Source / Removal	Direct / Indirect	Scope
Green Energy Scenario GHG Emissions Sources					
Construction	Construction—Mobile Equipment	GHG emissions are expected from the use of heavy construction equipment and on-road and off-road vehicles (e.g., construction equipment, cranes, and transport vehicles).	Source	Direct	Scope 1
Operation	Upstream – Natural Gas and Diesel Fuel Extraction & Processing	GHG emissions associated with the extraction and processing of diesel and natural gas.	Source	Indirect	Scope 3
	Operation—Propane Consumption	GHG emissions resulting from the combustion of propane as part of the project's operation.	Source	Direct	Scope 1
	Operation—Electricity Consumption	GHG emissions resulting from the off-site generation of electricity as part of the operation of the project.	Source	Indirect	Scope 2

Phase	Item	Description	Source / Removal	Direct / Indirect	Scope
	Operation – Electricity Generation	GHG emissions associated with the generation of electricity in BC which would be displaced through the generation of electrical power by the project and result in a reduction of GHG emissions	Removal	Indirect	Scope 2
Maintenance	Operation—Diesel Consumption	GHG emissions resulting from the combustion of diesel as part of project's major rehabilitative maintenance regime.	Source	Direct	Scope 1
RNG Scenario GHG Emissions Sources					
Construction	Construction—Mobile Equipment	GHG emissions are expected from the use of heavy construction equipment and on-road and off-road vehicles (e.g., construction equipment, cranes, and transport vehicles).	Source	Direct	Scope 1
Operation	Upstream – Natural Gas and Diesel Fuel Extraction & Processing	GHG emissions associated with the extraction and processing of diesel and natural gas.	Source	Indirect	Scope 3
	Operation—Natural Gas Consumption	GHG emissions resulting from the combustion of natural gas as part of the project's operation.	Source	Direct	Scope 1
	Operation—Electricity Consumption	GHG emissions resulting from the off-site generation of electricity as part of the operation of the project.	Source	Indirect	Scope 2
	Operation - RNG Generation	GHG emissions from natural gas that would be displaced through the generation of RNG the project and result in a reduction of GHG emissions	Removal	Indirect	Scope 3
	Operation - RNG Combustion	GHG emissions the combustion of RNG in stationary equipment.	Source	Indirect	Scope 3

3.5 GHG EMISSION CALCULATION PROCEDURES

GHG emissions resulting from the operation of the projects in each scenario are based on data provided by the CRD.

To estimate the fuel consumption GHG emissions, appropriate fuel-based emission factors in the 2017 BC Best Practices Methodology for Quantifying GHG Emissions were applied (BC MOE, 2019). As the CRD is in a preliminary evaluation stage, a detailed on-road and off-road construction equipment inventory could not be derived.

To estimate construction GHG emission for each scenario, environmental economic input-output model (EEIO) derived emission factors, expressed in tCO_2e/$million, were obtained from the Canadian International Reference Centre for the Life Cycle of Products, Processes and Services (CIRAIG)TM open input output model. The CIRAIGTM factors include those for 234 commodity classes based on NAICS classification. As the emission factors were derived in 2009, they were adjusted for inflation using an inflation factor of 1.3281 (Bank of Canada, 2019). The CRD provided construction cost estimates for each scenario which were used in conjunction with the CIRAIGTM factors. It is assumed that the emission factors derived from those contained within the CIRAIGTM database, adjusted for inflation, result in an overly conservative estimate of GHG emissions.

Upstream diesel and natural gas extraction and processing GHG emissions were estimated using emission factors derived in the Alberta Offset Emission Factors Handbook as no similar BC-based emission factors are available (Alberta, 2018). There is no publicly available upstream extraction and processing emission factor for propane.

No embodied / product GHG emissions were estimated as part of the assessment.

Details on the emissions factors used in the analysis are presented in Appendix A.

3.6 METHODOLOGY ASSUMPTIONS

3.6.1 RNG Scenario

A number of assumptions were applied to facilitate the RNG Scenario analysis, as identified below:

- The construction costs identified for the RNG option – Membranes Plus Guild Equilibrium PSA – as identified in the report “Renewable Natural Gas Technical Feasibility Design Report” were used to estimate the construction GHG emissions (CRD, 2018). It is assumed that the identified construction costs are still representative of this option.
- The project is being constructed on a grey field site and thus no carbon sinks are being disturbed.
- The project requires the construction of a 7.4 km natural gas pipeline to connect to the Fortis natural gas system
- The 7.4 km pipeline will be constructed along an existing right of way which will not result in a loss of forest and will have a minimal disturbance to soils.
- The pipeline is assumed to release small amounts of fugitive emissions which have been estimated using the pipeline length and IPCC natural gas derived emission factors.
- The landfill will generate 200,000 GJ of usable landfill gas.
- The project displaces natural gas at the current GHG emissions intensity of 0.04987 GJ/tCO_2e.
- It is assumed that the natural gas emissions intensity does not change over the life of the project.

- The project consumes electricity and renewable natural gas to operate.
- The project has a 25 year operational life.
- The project will be shut down for 2 weeks every year (or 351 days) to which the landfill gas is flared.
- The project will consume 125 GJ of electricity and 13 GJ of renewable natural gas daily.
- The membrane system will need to be changed out every 5-years which will result in an additional 2-week downtime to which the landfill gas is flared.
- No additional maintenance vehicles, resulting in fossil fuel consumption, are required to operate the project.
- It is assumed that all stationary fuel combustion equipment has a combustion efficiency of 99%.
- The fugitive landfill gas volumes do not change in either scenario.

3.6.2 Green Energy Scenario

A number of assumptions were applied to facilitate the Green Energy Scenario analysis, as identified below:

- It is assumed that the 2003 construction costs of the existing facility, once adjusted for inflation, and doubled for the addition of the expansion of this project would be representative had the project been constructed today.
- The project is being constructed on a grey field site and thus no carbon sinks are being disturbed.
- No additional transmission lines are required to be constructed as a result of the project.
- No transmission, distribution and line losses are accounted for as the transfer switch and transformer are on site.
- The landfill will generate 200,000 GJ of usable landfill gas.
- The current genset is a Caterpillar G3520 LE 20-cylinder engine, which according, to the CRD has a utilization efficiency of 29.4%.
- The additional genset would be a similar sized engine with a maximum utilization efficiency of 40.1%.
- An average utilization efficiency of 34.8% was applied (29.4% + 40.1% / 2 gensets).
- The project displaces electricity at the current GHG emissions intensity of 0.003 GJ/tCO_2e.
- It is assumed that the BC Hydro emissions intensity does not change over the life of the project.
- It is assumed that all stationary fuel combustion equipment has a combustion efficiency of 99%.
- The project consumes electricity and propane to operate.

- The project has a 25 year operational life.
- The project will be shut down for 2 weeks every year (or 351 days) to which the landfill gas is flared.
- The project will consume 5.7 GJ of electricity and 0.01 GJ of propane daily.
- The gensets will need to be removed and overhauled every 5-years which will result in an additional 24-week downtime to which the landfill gas is flared.
- The following assumptions have been made to estimate the maintenance GHG emissions associated with the project:
  - It is assumed that a crane will be operated onsite for 2 working days (8 hours/day) for each genset.
  - It is assumed that the gensets would be transported and overhauled in Victoria, BC.
  - On- and Off-road equipment are powered with diesel fuel and have no emission controls installed.
  - Round trip travel is required to transport equipment to the landfill. With one direction being a full load and the return trip is empty, the use of average fuel consumption rates was assumed to be appropriate.
- No additional maintenance vehicles, resulting in fossil fuel consumption, are required to operate the project.
- The fugitive landfill gas volumes do not change in either scenario.

3.6.3 Factors Not Assessed

The following factors were not included in this assessment:

- Embodied / product emissions associated with the creation and transportation of project equipment and infrastructure.
- Embodied / product emissions associated with construction on-road and off-road equipment.
- Embodied / product emissions associated with downstream stationary combustion equipment using the energy from either project (e.g. boilers using the RNG).
- Wear and tear and incremental maintenance to existing roadways as a result of vehicle traffic.
- Maintenance and repairs to on-site vehicles.
- Incidental fuel consumption associated with operations of either project.
- Materials and compounds used in small quantities in either project that may result in GHG emissions (e.g. paints, glues, cleaning products, road salts, asphalt repair, fertilizers or pesticides, etc.)

- Sanitary sewer discharges from staff activities on site.
- Electrical transmission, distribution and line losses which can range from 5-7% were not included as these were determined to be outside of the project boundaries.
- Decommissioning activities for the removal of buildings and facilities at the end of the operating life of either project.

3.7 UNCERTAINTIES

Life cycle GHG assessments include numerous assumptions to establish scenario boundaries and to model various components. To understand the impact of some of these assumptions, sensitivity analysis was performed by adjusting parameters known to affect results. Table 3-2 presents a summary of the parameters exhibiting the greatest influence over the GHG results. It should be noted that the selection of parameters is based on the parameters provided by the CRD, and the author's judgment and experience in compiling the inventory - and not on a detailed sensitivity analysis of all parameters.

Table 3-2 Overview of Assumptions Affecting the GHG Results

Assumption	Value Used	Range of Potential Values	Increasing the value used will…	
			RNG Scenario	Green Power Scenario
GHG Intensity of Consumed and Avoided Electricity in BC	10.67 tCO_2e / GWh as reported by the BC Government	From: - 0 (renewable) - 360 tCO_2 / GWh (gas turbine electricity) - 800 t CO_2 / GWh (coal-fired electricity)	Reduce net scenario GHG emissions since the project consumes electricity.	Increase the net scenario GHG emissions since the project would displace more GHG emissions.
EEIO Emission Factors	See Appendix B	Published sources range from $24 tCO_2e/$M to over $3,000 tCO_2e/$M.	Increase construction GHG emissions	Increase construction GHG emissions
Landfill Gas Capture Rate	200,000 GJ (~69% capture rate) as provided by the CRD	Published sources report landfill gas generation rates can be as low as 20% (poor collection) to as high as 85% (excellent capture after cell closure). The CRD has a capture target of 75%	Increase the net scenario GHG emissions since the project would displace more natural gas GHG emissions through the generation of RNG. The CRD estimates this could be up to 400,00 GJ.	Increase the net scenario GHG emissions since the project would displace more GHG emissions, up to the limit of the gensets capacity. Once the limit has been met, the remaining gas would be flared and result in declining net GHG emissions.
Electrical Generation Efficiency	Gensets are 34.8% efficient as provided by the CRD	Published sources report a range of 30% to 50% with 40% as the default.	No impact	Increase the net scenario GHG emissions since the project would displace more GHG emissions.
Natural Gas Pipeline	29 tCO_2e / km Natural Gas Pipeline	Published sources report a range of 10	Reduce net scenario GHG emissions since	No impact

Fugitive Emissions		tCO_2e / km to 200 tCO_2e / km	the project results in fugitive emissions.	

4.0 LIFE CYCLE GREENHOUSE GAS ASSESSMENT RESULTS

The life cycle GHG assessments for each scenario is presented in the following sections.

4.1 SCENARIO 1: RNG UTILIZATION

This scenario involves installing an RNG gas processing plant at Hartland Landfill to upgrade the landfill gas to RNG. This would also require the construction of a 7.4-kilometer (km) pipeline to connect to the main FortisBC gas pipeline.

The project net GHG emissions are presented in Table 4-1. The project scenario GHG emissions (column A) includes GHG emissions associated with construction GHG emissions, project related operational GHG emissions from fuel consumption, and fugitive GHG emissions associated with the 7.4 km natural gas pipeline. Total construction GHG emissions are estimated to result in a onetime release of 1,281 tCO_2e with 730 tCO_2e resulting from the construction of the facility and 551 tCO_2e associated with the construction of the RNG pipeline.

The operation of the project will result in an average release of 397 tCO_2e per year. Of these annual average GHG emissions, 132 tCO_2e are from the consumption of RNG and electricity to operate the RNG facility, 208 tCO_2e are fugitive emissions from the RNG pipeline, and 58 tCO_2e are from the downstream combustion of RNG. The fugitive GHG emissions are a conservative overestimate of the likely GHG emissions as the estimate is based on a natural gas pipeline and not an RNG pipeline (due to a lack of available data on RNG pipeline fugitive GHG emissions).

The project scenario removals are from the volume of natural gas that would be displaced as a result of the project. In terms of energy displaced, this would be on average of 192,268 GJ per year resulting in an average GHG avoidance of 11,002 tCO_2e per year.

The total net GHG emissions are the remaining GHG emissions that would occur while the RNG project is operational. Over 25 years, the RNG scenario is estimated to cumulatively avoid the release of 263,822 tCO_2e. This is summarized in Table 4-1.

Table 4-1 RNG Scenario Net GHG Emissions

Year	Total Project Scenario Emissions (A) (tCO_2e)	Total Project Scenario Removals (B) (tCO_2e)	Total Net Project Emissions & Removals (A-B) (tCO_2e)
Construction	1,281	-	1,281
Year 1	399	11,005	(10,607)
Year 2	399	11,005	(10,607)
Year 3	399	11,005	(10,607)

Year	Total Project Scenario Emissions (A) (tCO_2e)	Total Project Scenario Removals (B) (tCO_2e)	Total Net Project Emissions & Removals (A-B) (tCO_2e)
Year 4	399	11,005	(10,607)
Year 5	393	10,988	(10,594)
Year 6	399	11,005	(10,607)
Year 7	399	11,005	(10,607)
Year 8	399	11,005	(10,607)
Year 9	399	11,005	(10,607)
Year 10	393	10,988	(10,594)
Year 11	399	11,005	(10,607)
Year 12	399	11,005	(10,607)
Year 13	399	11,005	(10,607)
Year 14	399	11,005	(10,607)
Year 15	393	10,988	(10,594)
Year 16	399	11,005	(10,607)
Year 17	399	11,005	(10,607)
Year 18	399	11,005	(10,607)
Year 19	399	11,005	(10,607)
Year 20	393	10,988	(10,594)
Year 21	399	11,005	(10,607)
Year 22	399	11,005	(10,607)
Year 23	399	11,005	(10,607)
Year 24	399	11,005	(10,607)
Year 25	393	10,988	(10,594)
Lifespan Total	**11,217**	**275,039**	**(263,822)**

4.2 SCENARIO 2: GREEN POWER GENERATION

The project scenario involves adding another genset, and associated infrastructure, to double the current electrical generating capacity of 1.6 MW. No additional transmission lines were required in the original installation or required for the proposed expansion.

Unlike the RNG scenario where the estimated energy that would be displaced is 192,268 GJ per year, the volume of grid-based electricity in the Green Power scenario would be an average of 66,813 GJ due to the various energy losses of the gensets, and downtime due to major rehabilitative maintenance (Table 4-2).

Table 4-2 Green Power Scenario Net Energy Generation

Year	Landfill Gas Generation (GJ)	Net Energy Generation (GJ)
Year 1	192,329	66,834

Year	Landfill Gas Generation (GJ)	Net Energy Generation (GJ)
Year 2	192,329	66,834
Year 3	192,329	66,834
Year 4	192,329	66,834
Year 5	192,023	66,728
Year 6	192,329	66,834
Year 7	192,329	66,834
Year 8	192,329	66,834
Year 9	192,329	66,834
Year 10	192,023	66,728
Year 11	192,329	66,834
Year 12	192,329	66,834
Year 13	192,329	66,834
Year 14	192,329	66,834
Year 15	192,023	66,728
Year 16	192,329	66,834
Year 17	192,329	66,834
Year 18	192,329	66,834
Year 19	192,329	66,834
Year 20	192,023	66,728
Year 21	192,329	66,834
Year 22	192,329	66,834
Year 23	192,329	66,834
Year 24	192,329	66,834
Year 25	192,023	66,728
Total	**4,806,689**	**1,670,325**

The Green Power scenario project GHG emissions are presented in Table 4-3. The project scenario GHG emissions (column A) includes GHG emissions associated with construction GHG emissions, and project related operational GHG emissions from fuel consumption. Facility construction emissions are estimated to result in a onetime release of 632 tCO_2e, with operational and maintenance GHG emissions accounting for 64 tCO_2e / year. Of these annual operational and maintenance GHG emissions, 58 tCO_2e result from the combustion of landfill gas in the generators, 5.6 tCO_2e result from the consumption of electricity and propane, with the remainder of the GHG emissions being associated with rehabilitative maintenance activity diesel consuming equipment (which occurs every 5 years).

The project scenario removals are associated with the grid-based energy and associated GHG emissions that would be displaced as a result of the project. In terms of energy displaced, this would be on average of 66,813 GJ per year resulting in an average GHG avoidance of 201 tCO_2e per year.

The total net GHG emissions are the remaining GHG emissions that would occur while the green power project is operational. Over 25 years, the scenario is estimated to cumulatively avoid the release of 2,789 tCO_2e. This is summarized in Table 4-3.

Table 4-3 Green Energy Net GHG Emissions

Year	Total Project Scenario Emissions (A) (tCO_2e)	Total Project Scenario Removals (B) (tCO_2e)	Total Net Project Emissions & Removals (A-B) (tCO_2e)
Construction	632	-	632
Year 1	64	201	(136)
Year 2	64	201	(136)
Year 3	64	201	(136)
Year 4	64	201	(136)
Year 5	62	200	(139)
Year 6	64	201	(136)
Year 7	64	201	(136)
Year 8	64	201	(136)
Year 9	64	201	(136)
Year 10	62	200	(139)
Year 11	64	201	(136)
Year 12	64	201	(136)
Year 13	64	201	(136)
Year 14	64	201	(136)
Year 15	62	200	(139)
Year 16	64	201	(136)
Year 17	64	201	(136)
Year 18	64	201	(136)
Year 19	64	201	(136)
Year 20	62	200	(139)
Year 21	64	201	(136)
Year 22	64	201	(136)
Year 23	64	201	(136)
Year 24	64	201	(136)
Year 25	62	200	(139)
Lifespan Total	**2,222**	**5,011**	**(2,789)**

4.3 COMPARISON OF SCENARIOS

Table 4-4 presents a summary comparison of the two scenarios. It shows that the RNG scenario can result in a reduction of more than 263,000 tonnes of GHG emissions over 25 years which is almost a 95-fold improvement over the Green Power scenario.

Table 4-4 Scenario Comparison Summary

Stage	RNG Scenario (tCO_2e)	Green Power Scenario (tCO_2e)	Difference (tCO_2e)	Difference (Percent)
Facility Construction	730	632	98	16%
Energy Distribution Infrastructure Construction	550		550	100%
Operation	9,936	1,589	8,348	525%
Maintenance		1	(1)	-100%
Avoided Energy GHG Emissions	(275,039)	(5,011)	(270,028)	5,389%
Decommissioning	Not Reviewed	Not Reviewed	-	-
Total GHG Emissions (tCO_2)	**(263,822)**	**(2,789)**	**(261,033)**	**9,360%**
*Notes to Table: * No additional transmission and distribution lines are required under this scenario; however, if one of equivalent length to the pipeline was constructed, it is estimated that the construction activities would add an additional 313 tCO_2e, reducing the net benefit to (2,476) tCO_2e.*				

This difference between the two scenarios is due to the already low GHG emissions intensity of the BC electrical grid, and the low electrical generation efficiency of the gensets (34.8%). As natural gas stationary combustion equipment is typically more efficient (80-90%) the emissions intensity per unit of energy is much lower than compared to electricity generation.

This outcome should not be assumed to apply in the same way in other jurisdictions. For instance, there a GHG emission reduction case can made to produce electricity from land fill gas in Alberta as the electricity grid is supplied by coal. Table 4-5 demonstrates that the Green Power scenario would have the higher GHG emissions reduction benefit in Alberta.

Table 4-5 Jurisdictional Comparison: British Columbia and Alberta Based Project Scenarios

Stage	British Columbia		Alberta	
	RNG Scenario (tCO_2e)	Green Power Scenario (tCO_2e)	RNG Scenario (tCO_2e)	Green Power Scenario (tCO_2e)
Construction	1,281	632	1,281	632
Operation and Maintenance	9,936	1,589	248,478	11,506
Avoided Energy GHG Emissions	(275,039)	(5,011)	(275,039)	(371,183)
Total GHG Emissions (tCO_2)	**(263,822)**	**(2,789)**	**(25,281)**	**(359,046)**

5.0 CONCLUSION

5.1 SCENARIO RESULTS

In BC where power is already clean, with consideration to the two scenarios, the highest GHG reduction potential at the landfill is to use the captured landfill gas to displace natural gas. The outcome of assessment is presented in Table 5-1.

Table 5-1 Scenario Comparison Summary

Stage	RNG Scenario (tCO_2e)	Green Power Scenario (tCO_2e)	Difference (tCO_2e)	Difference (Percent)
Facility Construction	730	632	98	16%
Energy Distribution Infrastructure Construction	550		550	100%
Operation	9,936	1,589	8,348	525%
Maintenance		1	(1)	-100%
Avoided Energy GHG Emissions	(275,039)	(5,011)	(270,028)	5,389%
Decommissioning	Not Reviewed	Not Reviewed	-	-
Total GHG Emissions (tCO_2)	**(263,822)**	**(2,789)**	**(261,033)**	**9,360%**

*Notes to Table: * No additional transmission and distribution lines are required under this scenario; however, if one of equivalent length to the pipeline was constructed, it is estimated that the construction activities would add an additional 313 tCO_2e, reducing the net benefit to (2,476) tCO_2e.*

5.2 REVIEW OF PROJECT OBJECTIVES

This section reviews the results in terms of the project objectives. The objectives and associated comments are:

- Identify the major material and energy inputs and outputs associated with each scenario.

This inventory successfully defined the major inputs and outputs for key phases of each scenario: construction, operation, and maintenance. The CRD provided the necessary construction cost data, and operational and maintenance energy consumption data which accounted for the bulk of the emissions. As a result, the assessment properly identified major contributing inputs and outputs.

- Quantify these inputs and outputs at a planning level of accuracy.

Quantification of most of the inputs and outputs were based on existing deployed systems and are expected to be representative of the actual systems. Where scenario specific information was not available, as was the case of the construction equipment inventory, accepted estimation strategies were used which are based on best practices. This includes using the Canada specific EEIO emission factors to estimate construction emissions based on estimated costs. Additionally, standardized BC emissions factors were used in the analysis which is in alignment with best practice reporting requirements in BC. Several parameters have been discussed as having some uncertainty. However, even given that potential range for these parameters, the values chosen are reasonable for this study.

- Create an equivalent basis for comparison of the scenarios

For the purposes of comparability, the GHG emissions associated with the construction of the existing landfill gas utilization system was also included in the study. Both scenarios assumed the same volume of landfill gas available (i.e., 200,000 GJ), and no changes to the landfill gas collection system was assumed resulting in a no net change in fugitive landfill gas GHG emissions. The outcomes of both scenarios were presented and assessed in terms of tCO_2e.

Appendix A REFERENCES

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Appendix B ASSESSMENT OF CONSTRUCTION AND OPERATIONAL GHG EMISSIONS

This appendix contains the assessment of the direct and indirect GHG emissions of the construction and operation phase for each calendar year, as well as the cumulative total.

B.1 CONSTRUCTION GHG EMISSIONS ASSESSMENT

To estimate construction GHG emission for each scenario, environmental economic input-output model (EEIO) derived emission factors, expressed in tCO_2e/$million, were obtained from the Canadian International Reference Centre for the Life Cycle of Products, Processes and Services (CIRAIG)™ open input output model. The CIRAIG™ factors include those for 234 commodity classes based on NAICS classification. As the emission factors were derived in 2009, they were adjusted for inflation using an inflation factor of 1.3281 (Bank of Canada, 2019). The CRD provided construction cost estimates for each scenario which were used in conjunction with the CIRAIG™ factors. It is assumed that the emission factors derived from those contained within the CIRAIG™ database, adjusted for inflation, result in an overly conservative estimate of GHG emissions.

B.1.1 Construction Costs: RNG Scenario

Table B-1 provides an indicative listing of the estimated costs of construction and associated GHG emissions for the RNG Scenario.

Table B-1 RNG Scenario Construction Costs and Associated GHG Emissions

Item	Economic Value	Emission Factor Reference	Emission Factor (tCO_2e/$ CAD (2019))	GHG Emissions (tCO_2e)
Civil / Structural				
Earthwork/Ground Cover/Fence	$160,000	MPG23B000 - Non-residential building construction	0.0002379	38
Concrete	$280,000	MPG23B000 - Non-residential building construction	0.0002379	67
Building	$1,270,000	MPG23B000 - Non-residential building construction	0.0002379	302
Pipe Racks/Steel	$280,000	MPG23B000 - Non-residential building construction	0.0002379	67
Other				

Item	Economic Value	Emission Factor Reference	Emission Factor (tCO_2e/$ CAD (2019))	GHG Emissions (tCO_2e)
Material Shipping	$318,000	MPS484A00 - General freight truck transportation and moving (used goods) services	0.0008074	257
Total	**$2,308,000**			**730**

B.1.2 Construction Costs: Green Energy Scenario

Table B-2 provides an indicative listing of the estimated costs of construction and associated GHG emissions for the Green Energy Scenario.

Table B-2 Green Energy Scenario Construction Costs and Associated GHG Emissions

Item	Economic Value	Emission Factor Reference	Emission Factor (tCO_2e/$ CAD (2019))	GHG Emissions (tCO_2e)
Civil / Structural				
Site Work & Assembly	$1,071,044	MPG23B000 - Non-residential building construction	0.000238	510
BC Hydro Interconnection	$172,653	MPG23C300 - Electric power engineering construction	0.000180	62
Other				
Transportation	$37,187	MPS484A00 - General freight truck transportation and moving (used goods) services	0.000807	60
Total	**$1,280,883**			**632**

B.1.3 Pipeline and Transmission Line Construction

Pipeline and transmission line GHG emission estimates are based on environmental applications prepared by Stantec. As the applications are not publicly available, the specific source of the information cannot be provided. Table B-3 presents and compares the estimated GHG emissions from pipeline and electrical transmission line construction. As the project scenarios are not expected to significantly disturb soils or remove green space, the GHG emission estimates do not include the removal of biological carbon sinks.

Table B-3 Estimated Pipeline and Transmission Line Construction GHG Emissions

Stage	RNG Scenario (tCO_2e)	Green Power Scenario (tCO_2e)	Difference (tCO_2e)	Difference (Percent)
Construct a 7.4 km natural gas pipeline / electrical transmission line	550	313	238	76%

B.2 EMISSION FACTORS

Unless noted otherwise, the following emission factors have been provided by the BC Government (MOE, 2019).

B.2.1 On-Road GHG Emission Factor

On road operational GHG emissions are calculated using the assumptions identified earlier in the report and the following emission factors in Table B-4.

Table B-4 GHG Emission Factors for On-Road HDV Diesel Equipment

Aspect	Units	Emission Factor
Heavy Duty Diesel On-Road Vehicle	tCO_2e / L	0.002645924

B.2.2 Stationary Energy Emission Factors

RNG and natural gas emission factors are presented in Table B-5.

Table B-5 Stationary Energy Emission Factors

Fuel	Units	Emission Factor
Electricity	tCO_2e / GWh	10.67
Natural Gas	tCO_2e / GJ	0.04987
RNG	tCO_2e / GJ	0.00029
Propane	tCO_2e / GJ	0.06115

B.2.3 Natural Gas Fugitive Pipeline GHG Emission Factor

The following pipeline fugitive emission factor is derived from the IPCC emission factor database. As the factor is based on a 36” natural gas distribution pipeline, the factor has been adjusted by 2/3 to reflect the proposed 6” natural gas pipeline. This is presented in Table B-7.

Table B-6 Natural Gas Fugitive Pipeline GHG Emission Factor

Fuel	Units	Emission Factor
Fugitive Emissions	tCO_2e / km	28.05

B.2.4 Natural Gas & Diesel Extraction and Processing GHG Emission Factors

The following natural gas and diesel extraction and processing emission factors are taken from the Alberta Offset Emission Factors Handbook (Alberta Environment and Sustainable Resource Development, 2015).

Table B-7 Natural Gas & Diesel Extraction and Processing GHG Emission Factor

Fuel	Units	Emission Factor
Diesel	tCO_2e / GJ	0.000016
Natural Gas	tCO_2e / GJ	0.007350