Greenhouse Gas Project Plan

Highway 101 Landfill Gas Capture Project

Prepared by
3P Analysis and Consulting

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Introduction

This Project Plan describes the GHG reductions from the capture and combustion of landfill gas and generation of electricity the province of Nova Scotia, Canada.

Disclaimer

Although the project was started well before the ISO 14064 standard was released, this document attempts to create an ISO compliant project document and was prepared well after implementation of the project. As such, not all data monitoring and collection was implemented originally to support an ISO document. Such discrepancies, assumptions and estimates are noted in the report.

Name of the Project Proponent

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GHG Programs

According to Halifax Renewable Energy Corporation (HREC) and the Regional Municipality of Halifax, the landfill is not subject to Canadian regulations requiring it to collect its landfill gas. The site is owned by the Regional Municipality of Halifax, which has entered into a 20-year gas rights agreement with HREC.

Intended User(s) of this Report

The intended users of this report are the Halifax Renewable Energy Corporation and the purchaser. This report will form the basis of the quantification of the GHG emission reductions which are required under the contract the two organizations have entered into. This report will be verified by an independent third party and the subsequent verification statement will be submitted to both parties.

Project Description

The approximately 84-acre landfill opened in 1976 and accepted waste until 1997. Approximately 4 million tons of material was deposited at the site. Gas is extracted from seventy-five vertical collection wells installed in the landfill. A network of pipes is used to transport the collected gas from the wells to the power plant located at the eastern edge of the landfill. High pressure, centrifugal blowers and compressors located at the power plant apply vacuum to the collection piping to extract LFG (landfill gas) from the wells.

Electrical power is generated via combustion in two (2) GE/Jenbacher reciprocating engines that are specifically designed to operate on LFG. The in-service date of both engines was October 12, 2006 and the Effective Date was November 1, 2006. Each of the two engine sets is rated to produce roughly 1,063 kilowatts of electricity. According to manufacturer specifications, the GE/Jenbacher engines input energy at full load is 9,995 MBTU/hr. The heat rate is therefore 9402.6 BTU/kW-hr based on the lower heating value. Landfill gas destruction for the time period covered in this report was calculated using electricity production data.

A LFG flare is available as a back-up to the generating station, although the power plant accepts all of the LFG that is recovered.

The LFG is first treated to remove moisture and particulates. The treated LFG is then pressurized, cooled and injected into engines that are coupled to generators. Combustion of the gas in the engines powers the generators to produce electricity that is then delivered to the electrical grid.

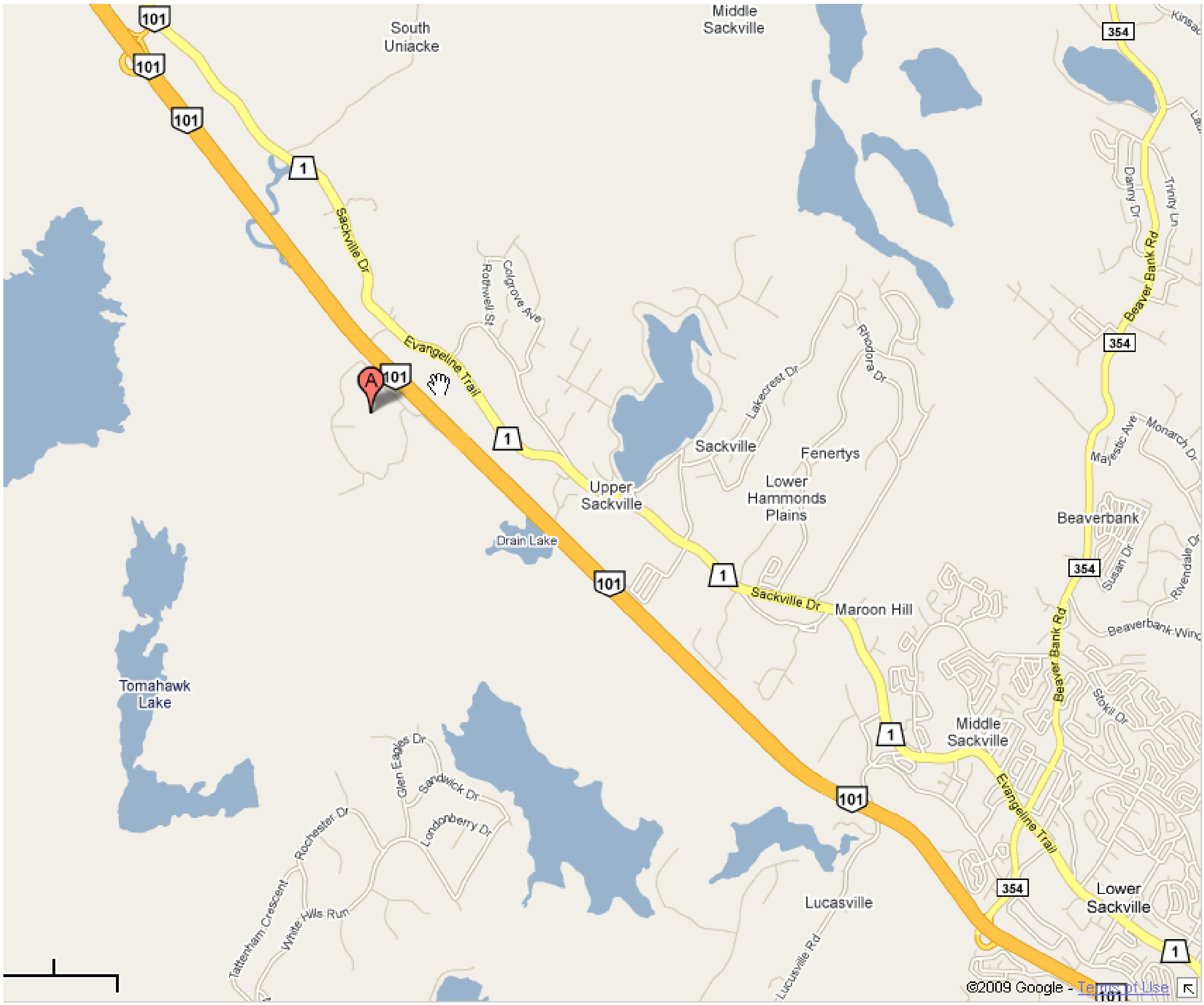
A DI.ANE XT control system is used to record information about each engine's performance including engine operating hours, engine pressure and temperature, and exported electricity. The DI.ANE's electronic logging system records data from the engines and stores it in an on-site database where it is held for three months. On-site system operators also complete performance logs for each engine daily.

In addition to the above mentioned engine data logging system, a methane measurement and data logging system was installed in early 2008. This system measures the flow rate and concentration of methane as it flows from the landfill site into the engines. This data logging system became fully operational in April 2008.

Project Location

The landfill is located on Highway 101 in Sackville, Nova Scotia. It is referred to as the 'Highway 101 Landfill', the 'Sackville Landfill' and the 'Mt. Uniacke Landfill'.

The center of the landfill is at latitude is +44° 48' 40.18", longitude is -63° 46' 32.90". Below is a map taken from Google Maps.



South Uniacke
Middle Sackville
Sackville Dr
Evangeline Trail
Rothwell St
Colgrove Ave
Lakecrest Dr
Rhodora Dr
Sackville
Fenertys
Upper Sackville
Lower Hammonds Plains
Drain Lake
Maroon Hill
Beaverbank
Beaver Bank Rd
Danny Dr
Trinity Ln
Majestic Ave
Monarch Dr
Susan Dr
Rivendale Dr
Beaverbank Wind
Stokil Dr
Middle Sackville
Tomahawk Lake
Glen Eagles Dr
Sandwick Dr
Londonberry Dr
Rochester Dr
Tattenham Crescent
White Hills Run
Lucasville
Lucasville Rd
Lower Sackville
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Identification of Project SSRs (Sources, Sinks and Reservoirs)

Based on industry related project documents, the project SSRs were organized in a Life Cycle Diagram in Figure 1. Descriptions of each of the SSRs and their classification as controlled, related or affected are provided in Table 1.

Figure 1 – Project Elements

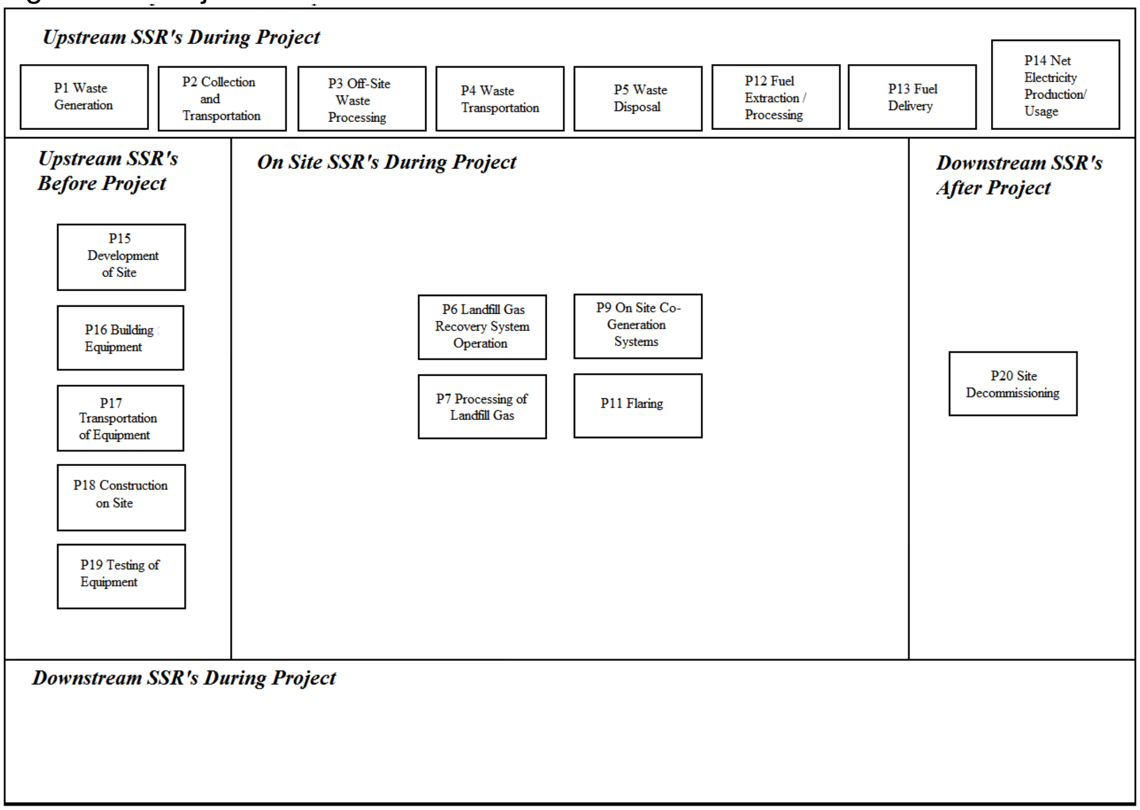


Table 1 – Project SSRs

1. SSR	2. Description	3. Controlled, Related or Affected
Upstream SSRs during Project Operation		
P1Waste Generation	Streams of solid waste are produced in a number ways, depending on the source of these residues. Quantities for each of the energy inputs related to the generation of the waste streams would be contemplated to evaluate functional equivalence with the baseline condition.	Related
P2 Collection and Transportation	Solid waste may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SSR, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P3 Off-Site Waste Processing	Solid waste may be processed using a series of mechanical processes, heavy equipment and conveyors. This equipment would be fuelled by diesel, gasoline, or natural gas resulting in GHG emissions, or electricity. Quantities and types for each of the energy inputs would be tracked.	Related
P4 Waste Transportation	Organic residues may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SSR, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P5 Waste Processing and Disposal	Waste may be handled at a disposal site by transferring the waste from the transportation container, spreading, burying, processing, otherwise dealing with the waste using a combination of loaders, conveyors and other mechanized devices. This equipment would be fuelled by diesel, gasoline or natural gas, resulting in GHG emissions. Other fuels may also be used in some rare cases. Quantities and types for each of the energy inputs may need to be tracked.	Controlled
P12 Fuel Extraction and Processing	Each of the fuels used throughout the on-site component of the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SSRs are considered under this SSR. Volumes and types of fuels are the important characteristics to be tracked.	Related
P13 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SSRs and there is no other delivery.	Related
P14 Net Electricity Production/ Usage	Electricity may be required for operating the facility. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Related
Onsite SSRs during Project Operation		
P6 Landfill Gas Recovery System Operation	Landfill gas recovery systems require compressors and other equipment for the gathering and distribution of the gas at the project facility. This equipment may be fuelled by diesel, gasoline or natural gas, resulting in GHG emissions. Other fuels, such as landfill gas, may also be used in some rare cases. Quantities and types for each of the	Controlled

	energy inputs may need to be tracked.	
P7 Processing of Landfill Gas	Landfill gas will likely have a higher concentration of carbon dioxide and other impurities than may be acceptable for the any number of uses. Mechanical equipment may be required to treat the landfill gas in order meet the required specifications. This may require several energy inputs such as natural gas and diesel. Quantities and types for each of the energy inputs would be tracked.	Controlled
P9 On Site Co-Generation Systems	On site co-generation systems may be included at the project site. This generation could require the combustion of landfill gas, and may be supplemented by fossil fuels precipitating greenhouse gas emissions. Volumes and types of fuels are the important characteristics to be tracked.	Controlled
P11 Flaring	Flaring of the landfill gas may be required during upset conditions or during maintenance. Emissions of greenhouse gases would be contributed from the combustion of the LFG as well as from any natural gas used in flaring to ensure more complete combustion. Quantities of LFG being flared and quantities of any pilot fuels or supplemental fuels would need to be tracked.	Controlled
Downstream SSRs during Project Operation		
None		
Other		
P15 Development of Site	The site may need to be developed. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	Related
P16 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related

Baseline Scenarios

The baseline is the most appropriate and best estimate of a reference case for which the project can be compared to. The baseline scenario covers the same time period as the project.

The following six steps were used in identifying baseline candidates:
1. Define the product or service provided by the project activity
2. Identify possible types of baseline candidates
3. Define and justify the geographic area and the temporal range used to identify baseline candidates
4. Define and justify any other criteria used to identify baseline candidates
5. Identify a final list of baseline candidates
6. Identify baseline candidates that are representative of common practice. In identifying the baseline candidates that are of common practice, then those baseline scenarios whose GHG emissions are higher than those of common practice can be eliminated from the list of potential baseline candidates.

In order to appropriately select baseline candidates, the project activity must be clearly defined so as to select baseline scenarios/candidates that provide the same service. In this case, the service provided is the management of municipal solid waste (MSW). Therefore, alternative methods for the management of MSW will be considered as baseline candidates. The geographic area considered will be all of Nova Scotia and the temporal range will include the years 2005 to 2012. The table below lists potential baseline scenarios considering the project description and SSRs, alternative project types, activities and technologies, data availability, reliability and limitations and any other relevant information concerning present or future conditions.

Project Activity	Baseline Candidates
Landfill gas capture, combustion and electricity generation	1. Business as usual (no LFG capture and destruction) 2. Capture & flare 3. Capture & conversion to methanol (fuel) 4. Waste Incineration 5. Composting

Justification of Baseline Scenario

In order to arrive at a final baseline candidate, a barriers test was performed. The following barriers were utilized in assessing each baseline candidate:
- Financial
- Legal requirements

- Technology availability
- Resource & Data availability
- Infrastructure

The table below lists the barriers associated with each of the identified baseline candidates.

The procedure selected addresses the principals of transparency (clear process to list all potential baseline scenarios) , relevance (all relevant baseline scenario and additional information are considered), completeness (all potential baseline scenarios are considered), consistency (same barriers are applied to all potential baseline scenario in order to be as objective as possible) and conservativeness (the option that is the most likely, and that will not over-estimate the emission reduction is selected).

Based on the comparative assessment of barriers, the business as usual scenario in which there is no capture and flare system in place, was identified as the most appropriate baseline scenario.

Barrier	Project (capture, combust to generate electricity)	Current state (No capture and flare system in place)	Capture and flare	Capture and conversion to methanol	Waste Incineration	Composting
Financial	High costs associated with implementation of a new infrastructure	No barrier	Medium to High costs associated with implementation of a new infrastructure	Cost of infrastructure is prohibitive	Capital cost and cost of infrastructure is prohibitive	Capital cost and cost of infrastructure is prohibitive
Legal Requirements	Not required by law	Not required by law	Not required by law	Not required by law	Not required by law	Not required by law
Technology availability	No barrier	No barrier	Lack of proven technology to achieve these objectives	Lack of proven technology to achieve this activity	No barrier	No barrier
Infrastructure	No barrier	No barrier	No barrier	No barrier	No barrier	No barrier
Resource & Data availability	No barrier	No barrier	Lack of resources and data available for comparative purposes	Lack of resources and data available for comparative purposes	No barrier	No barrier

Additionality

There are three basic issues that need to be resolved to determine if the project is additional:

- is the project a legal requirement

Since there is no federal, provincial or municipal legislation that requires that landfills in Nova Scotia install landfill gas collection and destruction systems. Therefore, the project is additional. More background information on the lega/legislative aspects of Additionality are in Appendix 3.

- Is the project common practice

Approximately only 7% of landfills in Canada have landfill gas collection and destruction systems. There are none in Nova Scotia, Canada. Therefore, the project is additional.

- Is there a financial burden that emission credits can alleviate

There are considerable financial burdens that were undertaken by the project proponent. These include the purchasing of materials, construction costs and negotiations with local electrical authorities. These costs are hoped to be offset by the selling of the emission credits generated by the project. Currently this project is not financially viable without the sale of the emission credits. Therefore, the project is additional.

Identification of Baseline SSRs (Sources, Sinks and Reservoirs)

Based on industry related project documents, the baseline SSRs were organized in a Life Cycle Diagram in Figure 2. Descriptions of each of the SSRs and their classification as controlled, related or affected are provided in Table 2.

Figure 2 – Baseline Elements

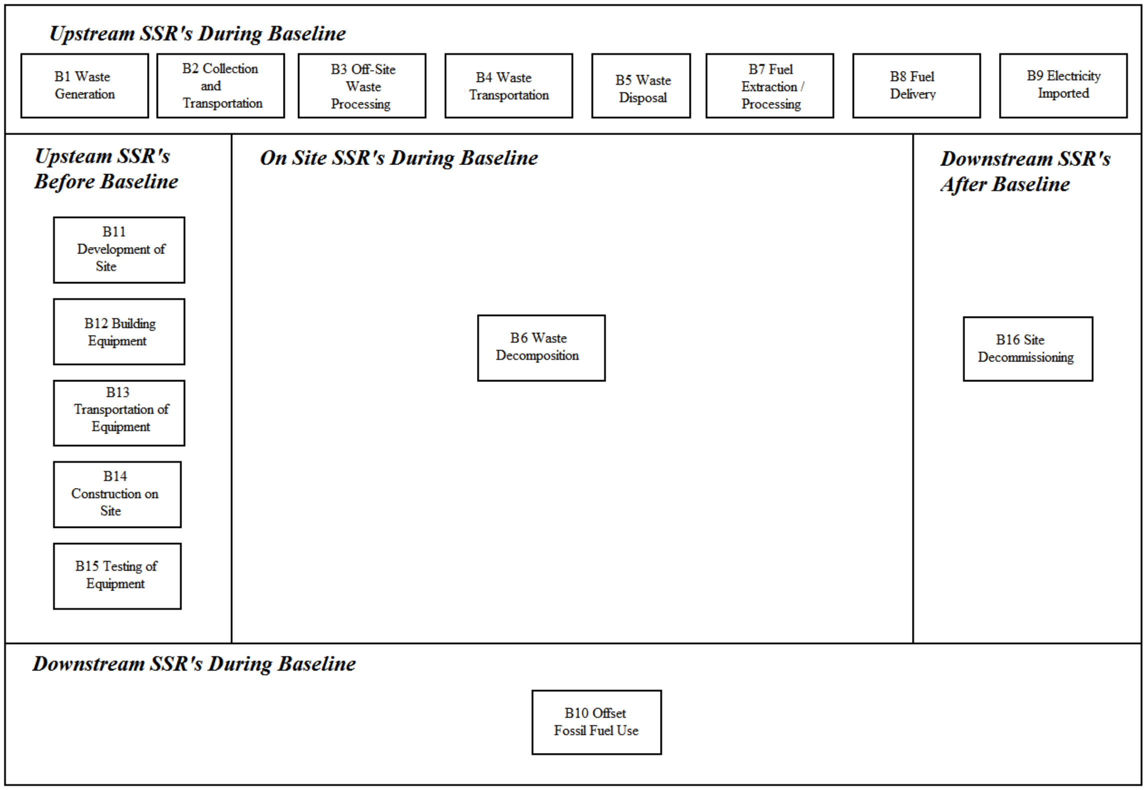

Upstream SSR's During Baseline
B1 Waste Generation
B2 Collection and Transportation
B3 Off-Site Waste Processing
B4 Waste Transportation
B5 Waste Disposal
B7 Fuel Extraction / Processing
B8 Fuel Delivery
B9 Electricity Imported
Upsteam SSR's Before Baseline
B11 Development of Site
B12 Building Equipment
B13 Transportation of Equipment
B14 Construction on Site
B15 Testing of Equipment
On Site SSR's During Baseline
B6 Waste Decomposition
Downstream SSR's After Baseline
B16 Site Decommissioning
Downstream SSR's During Baseline
B10 Offset Fossil Fuel Use

Table 2 – Baseline SSRs

1. SSR	2. Description	3. Controlled, Related or Affected
Upstream SSRs during Baseline Operation		
B1Waste Generation	Streams of solid waste are produced in a number ways, depending on the source of these residues. Quantities for each of the energy inputs related to the generation of the waste streams would be contemplated to evaluate functional equivalence with the baseline condition.	Related
B2 Collection and Transportation	Solid waste may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B3 Off-Site Waste Processing	Solid waste may be processed using a series of mechanical processes, heavy equipment and conveyors. This equipment would be fuelled by diesel, gasoline, or natural gas resulting in GHG emissions, or electricity. Quantities and types for each of the energy inputs would be tracked.	Related
B4 Waste Transportation	Organic residues may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SSR, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B5 Waste Disposal	Waste may be handled at a disposal site by transferring the waste from the transportation container, spreading, burying, processing, otherwise dealing with the waste using a combination of loaders, conveyors and other mechanized devices. This equipment would be fuelled by diesel, gasoline or natural gas, resulting in GHG emissions. Other fuels may also be used in some rare cases. Quantities and types for each of the energy inputs may need to be tracked.	Controlled
B7 Fuel Extraction and Processing	Each of the fuels that may be offset by the consumption of the landfill gas used off-site would need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SSR. Volumes and types of fuels are the important characteristics to be tracked.	Related
B8 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SSRs and there is no other delivery.	Related
B9 Electricity Imported	Electricity may be produced off-site to cover the electricity demand not being produced by the landfill gas recovery facility. This electricity will be produced at an emissions intensity as deemed appropriate. Measurement of the gross quantity of electricity produced by the facility will need to be tracked to quantify this SSR.	Related
Onsite SS's during Baseline Operation		
B6 Waste Decomposition	Waste may decompose in the disposal facility resulting in the production of methane. Disposal site characteristics and mass disposed of at each site may need to be tracked.	Controlled
Downstream SS's during Baseline Operation		
B10 Offset Fossil Fuel Use	Fossil fuel use may occur off-site to cover the energy that may be supplied by the landfill gas exported from the landfill gas recovery facility. Volumes and types of fuels are the important characteristics to be tracked.	Related
Other		
B11 Development of	The site of the material processing and disposal facilities may need to be developed. This could include civil infrastructure such as access to	Related

Site	electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	
B12 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
B13 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination, or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related
B14 Construction on Site	The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity.	Related
B15 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
B16 Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

Selection of Relevant SSRs for the Project and the Baseline

Each of the SSRs from the project and baseline condition were compared and evaluated as to their relevancy using the guidance provided in Annex VI of the "Guide to Quantification Methodologies and Protocols: Draft", dated March 2006 (Environment Canada). The justification for the exclusion or conditions upon which SS's may be excluded is provided in Table 3 below. All other SSRs listed previously are included.

Table 3 – Relevant SSRs

1. Identified SSR	**2. Baseline (C, R, A)**	**3. Project (C, R, A)**	**4. Include or Exclude from Quantification**	**5. Justification for Exclusion**
Upstream SSRs				
P1Waste Generation	N/A	Related	Exclude	Excluded as the generation of solid waste are not impacted by the implementation of the project and as such the baseline and project conditions will be functionally equivalent.
B1Waste Generation	Related	N/A	Exclude	
P2 Collection and Transportation	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely functionally equivalent to the baseline scenario.
B2 Collection and Transportation	Related	N/A	Exclude	
P3 Off-Site Waste Processing	N/A	Related	Exclude	Excluded as the off-site processing of solid waste is not impacted by the implementation of the project and as such the baseline and project conditions will be functionally equivalent.
B3 Off-Site Waste Processing	Related	N/A	Exclude	
P4 Waste Transportation	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely functionally equivalent to the baseline scenario.
B4 Waste Transportation	Related	N/A	Exclude	
P5 Waste Disposal	N/A	Controlled	Exclude	Excluded as the disposal of waste at the site is not impacted by the implementation of the project and as such the baseline and project conditions will be functionally equivalent.
B5 Waste Disposal	Controlled	N/A	Exclude	
P12 Fuel Extraction and Processing	N/A	Related	Exclude	No additional fuel is required for the project operation
B7 Fuel Extraction and Processing	Related	N/A	Exclude	Excluded based on conservative principle as well as any additional fuel used during the baseline would be negligible.
P13 Fuel Delivery	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely greater under the baseline condition.
B8 Fuel Delivery	Related	N/A	Exclude	
P14 Net Electricity Production/ Usage	N/A	Related	Include	N/A
B9 Electricity	Related	N/A	Exclude	Excluded based on conservative principle

Imported				as well as any additional fuel used during the baseline would be negligible.
Onsite SSRs				
P6 Landfill Gas Recovery System Operation	N/A	Controlled	Include	N/A
P7 Processing of Landfill Gas	N/A	Controlled	Include	N/A
P9 On Site Co-Generation Systems	N/A	Controlled	Include	N/A
P11 Flaring	N/A	Controlled	Include	N/A. Pilot fuel for flare stack is excluded as this has been shown to be immaterial.
B6 Waste Decomposition	Controlled	N/A	Include	N/A
Downstream SSRs				
B10 Offset Fossil Fuel Use	Related	N/A	Exclude	No additional off site Fossil Fuel Use is present in Baseline.
Other				
P15 Development of Site	N/A	Related	Exclude	Emissions from site development are not material given the long project life, and the minimal site development typically required.
B11 Development of Site	Related	N/A	Exclude	Emissions from site development are not material for the baseline condition given the minimal site development typically required.
P16 Building Equipment	N/A	Related	Exclude	Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required.
B12 Building Equipment	Related	N/A	Exclude	Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required.
P17 Transportation of Equipment	N/A	Related	Exclude	Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required.
B13 Transportation of Equipment	Related	N/A	Exclude	Emissions from transportation of equipment are not material for the baseline condition given the minimal transportation of equipment typically required.
P18 Construction on Site	N/A	Related	Exclude	Emissions from construction on site are not material given the long project life, and the minimal construction on site typically required. See Appendix 2 for calculations.
B14 Construction on Site	N/A	Related	Exclude	Emissions from construction on site are not material for the baseline condition given the minimal construction on site typically required.
P19 Testing of Equipment	N/A	Related	Exclude	Emissions from testing of equipment are not material given the long project life, and the minimal testing of equipment typically required.
B15 Testing of	Related	N/A	Exclude	Emissions from testing of equipment are

Equipment				not material for the baseline condition given the minimal testing of equipment typically required.
P20 Site Decommissioning	N/A	Related	Exclude	Emissions from decommissioning are not material given the long project life, and the minimal decommissioning typically required.
B16 Site Decommissioning	Related	N/A	Exclude	Emissions from decommissioning are not material for the baseline condition given the minimal decommissioning typically required.

Figure 3 and Figure 4 show the SSRs for monitoring in the Project and Baseline, respectively

Figure 3 Project SSRs for monitoring (grey background)

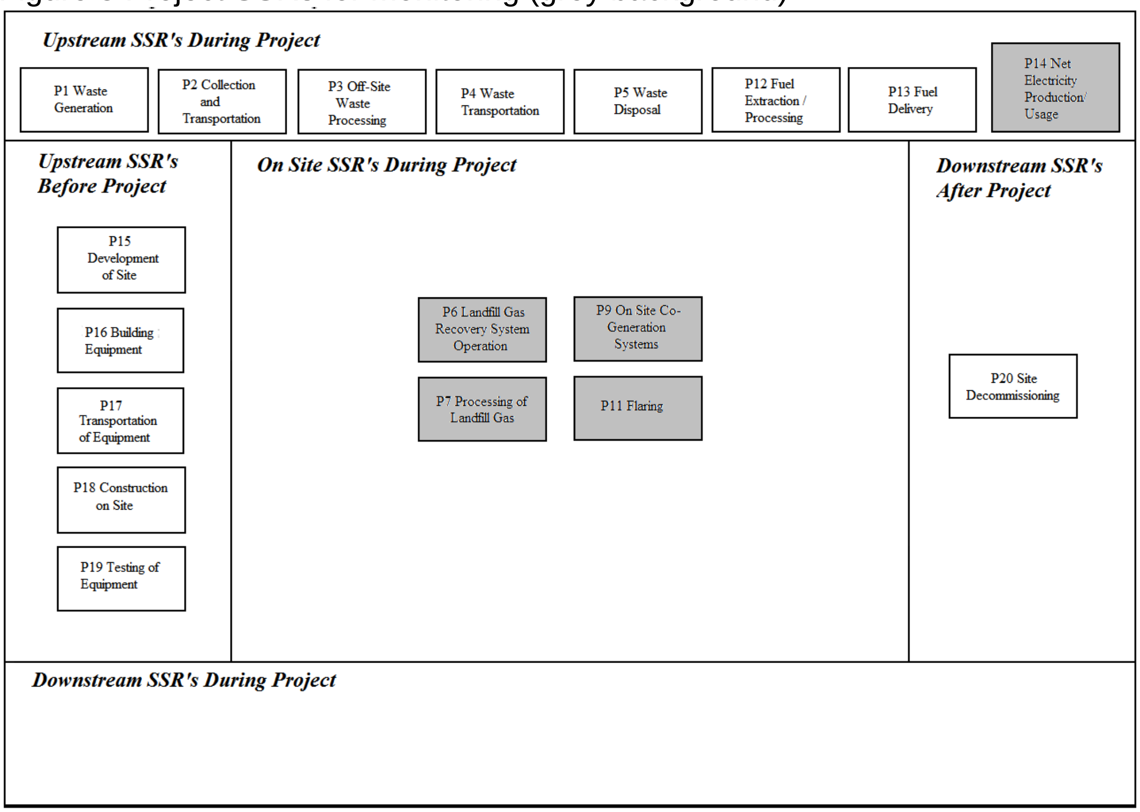
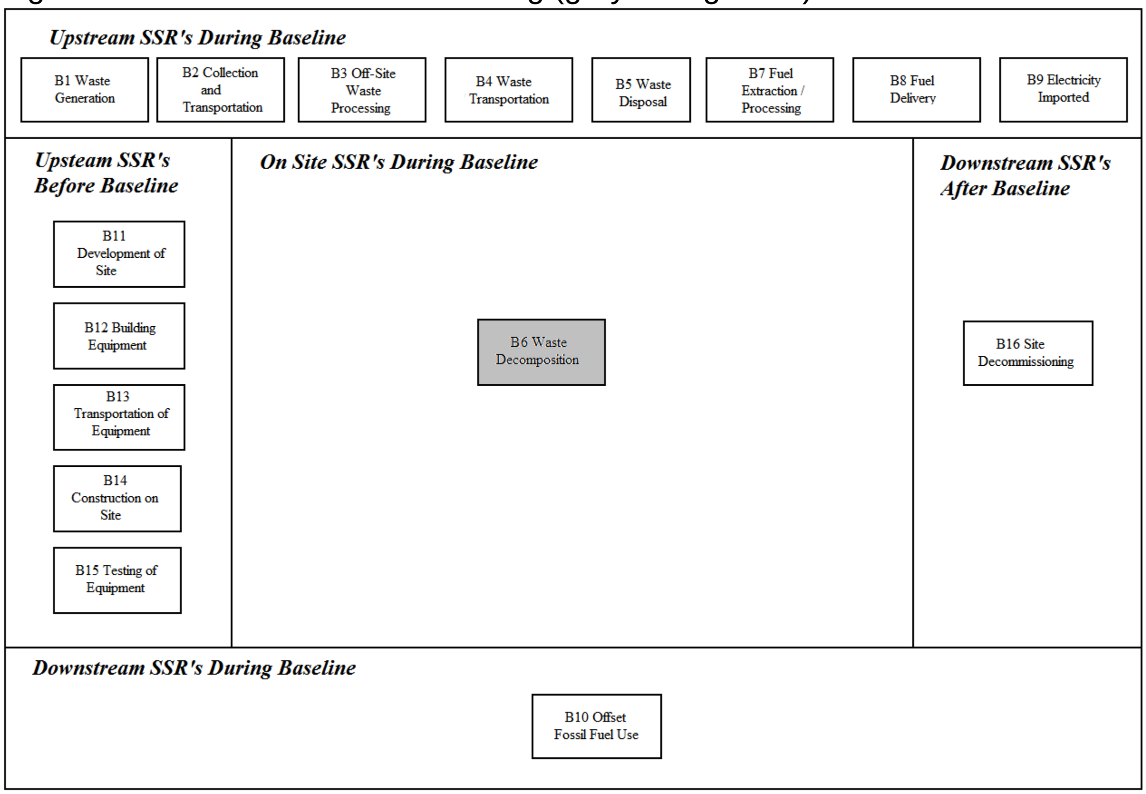


Figure 4 Baseline SSRs for monitoring (grey background)



GHG Emission Reduction Calculations

As outlined above, there are two systems for measuring and quantifying the emission reductions from the project:

Methodology 1 – Electricity output of engine – Chicago Climate Exchange protocol - Jan 1, 2008 to Mar 31, 2008

This methodology was taken from the "CHICAGO CLIMATE OFFSET PROJECT PROTOCOL - Landfill Methane Collection and Combustion Offset Projects" protocol document. The amount of methane destroyed is based on a calculation using the generated electricity as the activity data, as follows:

$$Tonnes_{CH_4} = \left(ELEC_{(generated)} \times HO_{(engine)} \times MolWt_{CH_4} \times GasCons \times VolConv \times GWP_{CH_4}\right) / 1{,}000{,}000 / LHV_{CH_4} \times DE$$

Where

$Tonnes_{CH_4}$ - Tonnes of methane destroyed, in tonnes CO2e

$ELEC_{(generated)}$ - Electricity generated in kWh, measured monthly

$HO_{(engine)}$ - Heat output of generator based on Btu input, 9402.6 Btu/kWh

LHV_{CH_4} - Lower heating value of methane, 918.35 Btu/ft3

$MolWt_{CH_4}$ - Molecular weight of methane, 16.04 g/mole

$GasCons$ - Gas constant, 0.041632 mole/litre

$VolConv$ - Volume conversion, 28.32 litres/ft3

GWP_{CH_4} - Global Warming Potential of methane, 21

DE - Destruction Efficiency, 0.992, taken from Emission Reductions Supply Agreement, Schedule 'B' (page 6)

Methodology 2 – Measured Methane and Specified Calculation from Emission Reduction Benefits Supply Agreement – Apr 1, 2008 to Dec 31, 2008

The amount of emission reductions is based on the Ideal Gas Law and is the following:

$$Tonnes_{CH_4} = \left(PV / RT \times MWt_{CH_4}\right) / 1{,}000{,}000 \times GWP_{CH_4} \times DE$$

Where

$Tonnes_{CH_4}$ - Tonnes of methane destroyed, in tonnes CO2e

P - Pressure, in atmospheres, at the measurement point.
V - Volume of methane, in cubic meters
R - Gas constant, .08205 m3.atm / mole.°K
T - Absolute temperature, in °K, at the measurement point
MWt_{CH_4} - Molecular weight of methane, 16.04 g/mole
GWP_{CH_4} - Global Warming Potential of methane, 21
DE - Destruction Efficiency, 0.992

The monitoring system became fully operational on April 5, 2008. .

Relevant Good Practice Guidance Used in the Project

Relevant good practice guidance procedures and criteria used to quantify the emission reductions from this project include:

- CHICAGO CLIMATE OFFSET PROJECT - Landfill Methane Collection and Combustion Offset Projects protocol
- Alberta Specified Gas Emitters Regulation – Quantification Protocol for Landfill Gas Capture and Combustion
- WRI/WBCSD GHG Protocol for Projects, December 2005
- ISO 14064-2 2006
- CCX® Project Guidelines: Landfill Gas Version 1

Appendix 1 – CCX formulas

Formulas from the CHICAGO CLIMATE OFFSET PROJECT PROTOCOL - Landfill Methane Collection and Combustion Offset Projects

Equation 1b

$$CH_{4recovered} = \left(kWh \times \left[BTU / kWh\right]\right) / 918.5$$

Where the Lower Heating Value of methane has been used as this was how the heat rate of the engine generator was stated in this case.

This can be rewritten as Equation 1bx

$$CH_{4recovered} = \left(ELEC_{(generated)} \times HO_{(engine)}\right) / LHV_{CH_4}$$

Equation 2

$$CH_{4combusted} = \left(CH_{4recovered} \times 16.04 \times \left[1/10^6\right] \times \left[1/24.04\right] \times 28.32\right) \times DE$$

This can be rewritten as Equation 2x:

$$CH_{4combusted} = \left(CH_{4recovered} \times MolWt_{CH_4} \times GasCons \times VolConv\right) / 1{,}000{,}000 \times DE$$

Equation 4

$$ER = \left(CH_{4combusted} \times 21 \times (1 - OF)\right) - PE$$

This can be rewritten as Equation 4x

$$Tonnes_{CH_4} = \left(CH_{4combusted} \times GWP_{CH_4} \times (1 - OF)\right) - PE$$

Where both OF and PE are both 0 for this project.

Combining Equations 1bx, 2x and 4x

$$Tonnes_{CH_4} = \left(ELEC_{(generated)} \times HO_{(engine)} \times MolWt_{CH_4} \times GasCons \times VolConv \times GWP_{CH_4}\right) / 1{,}000{,}000 / LHV_{CH_4} \times DE$$

Appendix 2 – Calculations of construction emissions

Construction of a Landfill gas collection system at the Hy.101 landfill in Sackville, Nova Scotia for the purpose of collecting the LFG and utilizing it as a fuel to generate renewable energy and to reduce emissions of a greenhouse gas(methane).

Details on the "carbon footprint" of the construction of the collection system.

In November 2005 Highland commenced construction of the LFG collection system. The system consisted of 74 drilled wells and HDPE electrofused piping to connect the wells to a gas processing facility where the LFG was used as fuel to generate renewable energy.

The total time of construction was 5 months (Nov 2005 to Mar 2006). The wells were drilled in 10 weeks and the piping was installed in 16 weeks.

During the construction phase a drilling rig using a Caterpillar diesel engine as a power source for the drill was used as well as a Caterpillar backhoe (4200) for backup support trenching, and to install the piping.

The drilling rig was utilized for 400 hours. The fuel consumption for the machine was 20 litres per hour. Therefore the diesel fuel consumption for this machine at the construction site was 8000 litres of diesel fuel.

The backhoe was utilized for 1000 hours and consumed 10 litres per hour. Therefore the diesel fuel consumption for the backhoe at the construction site was 10,000 litres.

Total diesel fuel consumption for both vehicles during construction was 18,000 litres.

Using an emission factor of 2.3 kg CO2e /litre diesel, gives about 41 tonnes CO2e emitted during the construction of the collection system. This amount is negligible compared to the expected emission reductions of approximately 40,000 to 50,000 tCO2e per year.

See calculations:
Reference: Government of Canada GHG Inventory as submitted to the UNFCCC
Page 620 (table 11-12) Emission factors for energy mobile combustion sources
Diesel Vehicles:
Emit 2.3 kilograms of CO2e per litre of fuel consumed

Appendix 3 – Demonstration of Legal Additionality Requirements

Highway 101 Landfill, Sackville, Nova Scotia

Investigation into the legislative/legal requirements of the landfill as relating to the capture and destruction of landfill gas.

2001/2003
Highland Energy first investigated the regulatory requirements regarding the Highway 101 Landfill while it was conducting its "due diligence" when negotiating the gas rights agreement with Halifax Regional Municipality (HRM). In our process of inquiry, and in discussions with HRM and the Nova Scotia Dept. of Environment, it was confirmed to Highland that there was no regulatory requirement to capture and combust the landfill gas being generated at the site. Based on this information, Highland executed an agreement with HRM to obtain ownership of the landfill gas in exchange for sharing in the revenue derived from Highland's efforts to achieve commercial benefits from the collection and utilization of the landfill gas. Emission reductions are specifically cited in the gas rights agreement negotiated with HRM.

2005
Highland entered into an agreement to sell all of the emission reductions created between 2008 and 2012 to a third party. Both parties conducted their "due diligence" with regards to the additionality of the emission reductions and both parties concluded that there was no regulatory obligation to capture and combust the landfill gas. Therefore, both agreed that the project was "additional". This mutual conclusion regarding additionality was written into the contract.

2008
Highland applied to the Chicago Climate Exchange (CCX) to offer the emission reductions created in 2007 for sale on the CCX. A validation/verification report was prepared including the question of additionality. Again it was determined, after contacting the Nova Scotia Dept. of Environment, that there was no regulatory requirement to capture and combust the landfill gas thus making the project additional to any regulatory requirement to do so.

2009
Further investigation, relating to a verification report for the third party purchaser of the emission reductions, with the Nova Scotia Dept. of Environment reveals that, in the standard application form to be filed with the department for approval of the construction of a "Municipal Solid Waste Landfill", there is no requirement to control, collect or combust the landfill gas created at the proposed site.

In subsequent conversations with personnel from the Nova Scotia Dept. of Environment the individuals spoken to affirmed that:

1) Older closed landfills, such as Highway 101 Landfill in Sackville, Nova Scotia, were never subject to any regulation with regards to control and disbursal of landfill gas and would not be subject to regulation in the future.

2) There are no regulations requiring new landfills to control and disburse landfill gas.

Given this information it is possible to conclude that the Highway 101 Landfill in Sackville, Nova Scotia:

1) Was never, in the past, subject to regulation requiring the capture and combustion of the landfill gas
2) Is not, at this time, subject to regulation requiring the capture and combustion of the landfill gas
3) Will not be, in the future, subject to regulation requiring the capture and combustion of the landfill gas.

Therefore the Highway 101Landfill at Sackville, Nova Scotia meets all legal and legislative requirements regarding additionality.

Attached is a letter from Nova Scotia Department of Environment outlining the regulatory requirements for landfills.

Greenhouse Gas Quantification Report 2008

Highway 101 Landfill Gas Capture Project

Prepared March 12, 2010 by 3P Analysis and Consulting

Table of Contents

Introduction

This report describes the GHG reductions from the capture and combustion of landfill gas and generation of electricity in the province of Nova Scotia, Canada.

This report focuses on the quantification of GHG reductions for the period from January 1, 2008 to December 31, 2008

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GHG Programs

According to the Halifax Renewable Energy Corporation and the Regional Municipality of Halifax, the landfill is not subject to Canadian regulations requiring it to collect its landfill gas. The site is owned by the Regional Municipality of Halifax, which has entered into a 20-year gas rights agreement with the Halifax Renewable Energy Corp.

Intended User(s) of this Report

The intended users of this report are the Halifax Renewable Energy Corporation and the purchaser of the emission credits. This report will form the basis of the quantification of the GHG emission reductions which are required under the contract the two organizations have entered into. This report will be verified by an independent third party and the subsequent verification statement will be submitted to both parties.

GHG Assertions

The project has adhered to the previously established measurement plan and has achieved **44,802** tonnes of CO_2 equivalent reductions for the period from Jan 1, 2008 to December 31,2008.

Project Description

The approximately 84-acre landfill opened in 1976 and accepted waste until 1997. Approximately 4 million tons of material was deposited at the site. Gas is extracted from seventy-five vertical collection wells installed in the landfill. A network of pipes is used to transport the collected gas from the wells to the power plant located at the eastern edge of the landfill. High pressure, centrifugal blowers and compressors located at the power plant apply vacuum to the collection piping to extract LFG (landfill gas) from the wells.

Electrical power is generated via combustion in two (2) GE/Jenbacher reciprocating engines that are specifically designed to operate on LFG. The in-service date of both engines was October 12, 2006 and the Effective Date was November 1, 2006. Each of the two engine sets is rated to produce roughly 1,063 kilowatts of electricity. According to manufacturer specifications, the GE/Jenbacher engines input energy at full load is 9,995 MBTU/hr. The heat rate is therefore 9402.6 BTU/kW-hr based on the lower heating value.

A LFG flare, which was in use prior to start-up of the power plant, remains available as a back-up to the generating station, although the power plant accepts all of the LFG that is recovered.

The LFG is first treated to remove moisture and particulates. The treated LFG is then pressurized, cooled and injected into engines that are coupled to generators. Combustion of the gas in the engines powers the generators to produce electricity that is then delivered to the electrical grid.

A DI.ANE XT control system is used to record information about each engine's performance including engine operating hours, engine pressure and temperature, and exported electricity. The DI.ANE's electronic logging system records data from the engines and stores it in an on-site database where the last three months are held before being overwritten. None of this data is used in the calculation of GHG emissions. On-site system operators also complete performance logs for each engine on a daily basis.

In addition to the above mentioned engine data logging system, a measurement and data logging system was installed in early 2008. This system measures the flow rate and concentration of methane as it flows from the landfill site into the engines. The system totalizes methane gas flow on a second by second basis and at midnight each day, the following is stored:

- Date/Time for this record
- Total methane gas volume flow for the previous 24 hours
- Percentage of methane (at midnight)
- Percentage of O2 (at midnight)

The systems does not log or store any other data. This daily data can be exported out to an Excel compatible spreadsheet file. The data logging system became fully operational in April 2008.

GHG Emissions Reductions from the Project

As outlined in the Project Plan, there are two methodologies for measuring and quantifying the emission reductions from the project:

Methodology 1 – Electricity output of engine – Chicago Climate Exchange protocol - Jan 1, 2008 to Mar 31, 2008

This methodology was taken from the "CHICAGO CLIMATE OFFSET PROJECT PROTOCOL - Landfill Methane Collection and Combustion Offset Projects" protocol document. The amount of methane destroyed is based on a calculation using the generated electricity as the activity data, as follows:

$$Tonnes_{CH_4} = \left(ELEC_{(generated)} \times HO_{(engine)} \times MolWt_{CH_4} \times GasCons \times VolConv \times GWP_{CH_4}\right) / 1{,}000{,}000 / LHV_{CH_4} \times DE$$

Where

$Tonnes_{CH_4}$ - Tonnes of methane destroyed, in tonnes CO2e

$ELEC_{(generated)}$ - Electricity generated in kWh, measured monthly

$HO_{(engine)}$ - Heat output of generator based on Btu input, 9402.6 Btu/kWh

LHV_{CH_4} - Lower heating value of methane, 918.35 Btu/ft3

$MolWt_{CH_4}$ - Molecular weight of methane, 16.04 g/mole

$GasCons$ - Gas constant, 0.041632 mole/litre

$VolConv$ - Volume conversion, 28.32 litres/ft3

GWP_{CH_4} - Global Warming Potential of methane, 21

DE - Destruction Efficiency, 0.992, taken from Emission Reductions Supply Agreement, Schedule 'B' (page 6)

A table of measured and calculated values for the Jan 1, 2008 to March 31, 2008 time period is located in the Appendix – Table 1.

Methodology 2 – Measured Methane and Specified Calculation from Emission Reduction Benefits Supply Agreement – Apr 1, 2008 to Dec 31, 2008

The amount of emission reductions is calculated using the calculation outlined in the Emission Reduction Benefits Supply Agreement between Halifax Renewable Energy Corporation and the purchaser of the emission credits (Schedule B, page 7). The calculation is based on the Ideal Gas Law and is the following:

$$Tonnes_{CH_4} = \left(PV / RT \times MWt_{CH_4}\right) / 1{,}000{,}000 \times GWP_{CH_4} \times DE$$

Where

$Tonnes_{CH_4}$ - Tonnes of methane destroyed, in tonnes CO2e
P - Pressure, in atmospheres, at the measurement point.
V - Volume of methane, in cubic meters
R - Gas constant, .08205 m3.atm / mole.°K
T - Absolute temperature, in °K, at the measurement point
MWt_{CH_4} - Molecular weight of methane, 16.04 g/mole
GWP_{CH_4} - Global Warming Potential of methane, 21
DE - Destruction Efficiency, 0.992

The monitoring system became fully operational on April 5, 2008. The first 4 days of April 2008 were estimated using the average of the remaining days of April. In addition, there were two days, June 23, 2008 and November 25, 2008, when the data logger did not measure any methane. This was due to maintenance on the data logger. Both of these days have been set to 0 measurement.

The summary table of the data is included in the Appendix –Table 1, which covers the period from Apr 1, 2008 to Dec 31, 2008

Relevant Good Practice Guidance Used in the Project

Relevant good practice guidance procedures and criteria used to quantify the emission reductions from this project include:

- Emission Reduction Benefits Supply Agreement between Halifax Renewable Energy Corporation and purchaser of emission credits
- CHICAGO CLIMATE OFFSET PROJECT - Landfill Methane Collection and Combustion Offset Projects protocol
- Alberta Specified Gas Emitters Regulation – Quantification Protocol for Landfill Gas Capture and Combustion
- WRI/WBCSD GHG Protocol for Projects, December 2005
- ISO 14064-2 2006

Date and Time Period of the Report

This report covers the period from January 1, 2008 to December 31, 2008.

Appendix 4A – Table 1– Monthly Summary of Landfill Gas Emisson Reductions , Jan 1, 2008 to Dec 31, 2008

Calculation of methane destroyed - 2008					
	Volume of Landfill Gas Delivered at 1 atmospheric pressure (note 2) [m3]	Electrical Generation [MWh]	Average % Methane Content %	Quantity of Methane Delivered [kg]	Quantity of CO2e Emission Reductions from Combustion [t CO_2e]
January (note 1)	560,157.15	834.15	-	160,202.95	3,364.26
February (note 1)	524,017.98	740.80	-	142,274.91	2,987.77
March (note 1)	560,157.15	808.36	-	155,249.45	3,260.24
April	631,416.38	769.35	47.0%	195,604.49	4,107.69
May	632,617.03	800.83	47.5%	197,389.06	4,145.17
June	503,180.91	680.80	47.4%	161,570.37	3,392.98
July	499,561.28	637.49	51.8%	169,446.56	3,558.38
August	498,603.98	726.08	54.3%	178,237.45	3,742.99
September	503,305.04	721.10	54.7%	179,696.64	3,773.63
October	617,408.62	813.05	51.6%	209,766.39	4,405.09
November	490,410.22	758.32	48.6%	182,193.40	3,826.06
December	592,632.57	759.37	51.9%	201,796.29	4,237.72
Total	6,613,468.32	9,049.71		2,133,427.96	**44,801.99**

note 1 - these three months use the CCX calculation methodology
note 2 - the CCX methodology does not calculate LFG volume, the volumes for the first three months are estimated from the averages of the measured data.