Appendix F

Greenhouse Gas Emissions

EXECUTIVE SUMMARY

The greenhouse gas (GHG) emissions inventory for the proposed Prince Rupert Gas Transmission Project (the Project) is presented in this Technical Data Report. Sources of GHG emissions arising from activities during construction and operation include:

Construction

- Off-road equipment
- On-road vehicles
- Propane-fired heaters
- Marine vessels
- Land clearing residuals and open burning

Operation

- Stationary combustion at stations
- Fugitive emissions
- Natural gas venting
- Aerial patrols and pipeline maintenance

The GHG emissions from the construction of the pipeline, compressor stations, and meter station are estimated to be 3.2 Mt CO_2e over the four years of construction. The construction of the pipeline sections makes up the majority of the GHG construction emissions (approximately 98%) due to the contribution of the land clearing and biomass burning emissions.

The GHG emissions from the operation of the Project are estimated to be 1.9 Mt CO_2e/year on average for at least 40 years. The majority of GHG emissions (95%) originate from the natural gas fuelled turbines at the compressor stations.

ACRONYMS AND ABBREVIATIONS

AIR .... Application Information Requirements

APM .... Aerial Patrol and Maintenance

bcf/d .... billion standard cubic feet per day

BC MOE .... British Columbia Ministry of Environment

BC OGC .... British Columbia Oil and Gas Commission

CH_4 .... methane

CO_2 .... carbon dioxide

CO_2e .... carbon dioxide equivalent

EAO .... Environmental Assessment Office

GHG .... greenhouse gas

GWP .... global warming potential

GRI .... Gas Research Institute

HFC .... hydrofluorocarbons

LNG .... liquefied natural gas

IPCC .... Intergovernmental Panel on Climate Change

KP .... kilometre post

N_2O .... nitrous oxide

PFC .... perfluorocarbon

Project .... Prince Rupert Gas Transmission Project

PRGT .... Prince Rupert Gas Transmission Ltd.

SF_6 .... sulfure hexafluoride

US EPA .... United States Environmental Protection Agency

WCI .... Western Climate Initiative

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1 INTRODUCTION

This appendix presents information for the emissions inventory of greenhouse gases (GHGs) generated by the Project. Best available information and methodologies have been used in this assessment. In the absence of specific regulatory requirements for the assessment of GHG emissions within and Application for an Environmental Assessment Certificate in British Columbia, this approach was considered to be the most appropriate, however, may differ from other proposed projects.

Project activities and physical works included in the construction and operation inventories are described in the final Application Information Requirements (AIR).These include the operation of heavy mobile equipment, vehicles, marine vessels during construction, and compressor stations during operation.

Mitigation and management plans as well as ongoing monitoring activities proposed for project activities and physical works are also included in this report.

Activities such as construction and operation of construction camps are considered to be intermittent and/or transient in nature, with very low quantities of GHGs released to the atmosphere. These activities are therefore not included in the inventory.

2 PROJECT DETAILS

The Project includes construction and operation of a sweet natural gas pipeline from a point near Hudson's Hope, British Columbia (BC) to the proposed Pacific NorthWest liquefied natural gas (PNW LNG) export facility near Prince Rupert, at Lelu Island, within the District of Port Edward, BC. Prince Rupert Gas Transmission Ltd. (PRGT) is a wholly owned subsidiary of TransCanada Pipelines Limited. Depending on the final route, this Project includes:

- Up to 780 km of 1,219 mm diameter (NPS 48) of land based pipeline
- Up to 120 km of twin 914 mm diameter (NPS 36) of marine pipeline
- Metering station at the delivery points
- Up to eight compressor stations at regular intervals along the pipeline

The Project will have an initial capacity of approximately 2.0 billion cubic feet per day (bcf/d) (56.6 million cubic metres per day) with the potential for expansion up to approximately 3.6 bcf/d (101.9 million cubic metres per day).

The following is a list of the proposed eight compressor stations and locations (kilometre post, KP) along the pipeline route. The KPs starts at 0 km at the east end of the pipeline near Hudson's Hope, BC and progresses westward:

- C1 Johnson Creek compressor station (KP 38)
- C2 Callazon Creek compressor station (KP 125)
- C3 Witter Lake compressor station (KP 223)
- C4 Middle River compressor station (KP 324)
- C5 Morrison Lake compressor station (KP 420)
- C6 Kispiox compressor station (KP 531)
- C7 Borden Lake compressor station (KP 635)
- C8 Ishkeenickh compressor station (KP 726)

For the context of this assessment, the maximum GHG emission scenario included the operation of eight compressor stations, each with:

- Two natural gas-fired reciprocating generators operating continuously at an output rating of 0.5 MW to provide electrical power for the compressor station buildings and stationary equipment
- Two natural gas-fired boilers operating continuously at an output rating of 0.4 MW to provide heat for the compressor station buildings
- Two natural gas-fired turbine compressors operating continuously at an output rating of 26.4 MW to provide gas compression

- Vented and fugitive emissions from pipeline, compressor stations, and a metering station
- Maintenance of pipeline and compressor stations.

It should however be noted that the initial built out (2 bcf/d) will likely include the operation of one turbine driven compressor at each of the C1 and C4 compressor stations and two at the C7 compressor station as per current design. Therefore, the emissions during the operation of the initial build-out would be substantially less than the full build-out scenario considered in this assessment.

Metering stations are used to monitor the amount of gas in the pipeline. They are minor sources of GHG. A meter station is planned to be located at the end of the pipeline on Lelu Island (KP878).

The Project will require ancillary infrastructure during construction, such as access roads, temporary bridges, stockpile sites, borrow sites, contractor yards, and construction camps.

Expansion scenarios for future operation of the pipeline do not involve constructing additional pipeline.

3 METHODS

The GHG assessment for the Project is based on accounting and reporting principles of the GHG Protocol developed by the World Resource Institute and the World Business Council for Sustainable Development (2004). 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. As per the final AIR, direct GHG emissions produced from combustion, fugitive emissions, and vented sources are the focus of this appendix.

Emissions of each of the specific GHGs are multiplied by their global warming potential and are reported as CO_2e. The global warming potential (GWP) of these GHGs are CO_2 = 1.0, CH_4 = 25, N_2O = 298, SF_6 = 23,900. HFC gases range from 140 to 11,700, and PFC gases range from 6,500 to 9,200 (IPCC 2007).

The following GHGs are included in the GHG assessment:

- CO_2
- CH_4
- N_2O

The following GHGs have been excluded from the GHG assessment as explained below:

- SF_6 – These emissions can be found in insulating gas used in electrical switch breakers. However, the Project does not use insulating gas that contains SF_6.
- HFCs and PFCs – These products 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 this assessment.

On this basis, carbon dioxide equivalents for the project are calculated as:

$$CO_2e\ (massCO_2 \times 1.0) + (massCH_4 \times 25) + (mass\ N_2O \times 298)$$

4 GHG EMISSIONS DURING CONSTRUCTION

Project activities during construction will result in releases of greenhouse gases (GHGs) to the atmosphere. The equipment inventories provided in this section include only project equipment that is expected to release GHGs emissions (i.e., equipment with internal combustion engines). The equipment lists and operational schedules are based on the best available information.

Sources of GHGs during construction are:

- Off-road equipment
- On-road vehicles
- Propane-fired heaters
- Marine vessels used for marine pipeline installation
- Open burning of non-salvaged biomass
- Residual carbon release after land clearing

Detailed estimates of the types, numbers, and total operating hours of off-road equipment, on-road equipment, and heaters are based on historical data and equipment rates developed for similar TransCanada pipeline projects.

Operating hours and emissions information provided from the NOVA Gas Transmission Ltd. Northwest Mainline Expansion Project assessment (Stantec 2011) assessment were used as a basis to scale the respective pipeline section emissions, to calculate a ratio of operating hours per 1 km of pipeline.

For the compressor and meter station construction, the inventory of construction equipment and estimates of construction hours were based on information provided by the Alaska Pipeline Project assessment (Stantec 2012).

The methods and assumptions are described in the following subsections.

4.1 Off-Road Construction Equipment

Off-road equipment used in construction includes heavy equipment units such as tractors, loaders, backhoes, excavators, dozers, and cranes. It is assumed that these units have been retrofitted with more recent parts so that all equipment used in construction can be recognized and considered as 2005 or later models. The engine power specification associated with each piece of equipment has been sourced from manufacturer information.

Emission factors and loads were generated using the United States Environmental Protection Agency (US EPA) NONROAD model (US EPA 2010, 2004a, 2004b) and the NGTL Northwest Mainline Expansion Assessment (Stantec 2011). This is the standard model used in Canada to estimate emissions from non-road equipment.

Emission standards for off-road engines vary with model year due to changing regulations. Canada has adopted the US EPA off-road standards. Prior to 1996, off-road engines were not regulated (referred to as Tier 0). The first emission standards, known as Tier 1 standards, began to be phased in by horsepower rating in 1996. Tier 2 standards began in 2001 and Tier 3 standards in 2006. PRGT assumed that the majority of the equipment consisted of roughly 10% Tier 1 and 90% Tier 2 engines consistent with the NGTL Northwest Mainline Expansion Assessment (Stantec 2011).

The US EPA NONROAD model accounts for the degradation of engine performance over its lifetime due to normal use or misuse (i.e., tampering or negligence). Engine deterioration can increase exhaust emissions, which usually leads to a loss of combustion efficiency and can increase the exhaust and non-exhaust emissions. The model also accounts for variation in emissions due to transient operation of the engines. While developing emission factors, non-road engines are primarily tested with steady-state tests, which may not be representative of real world conditions. A transient adjustment factor is included in the model because actual emissions may be greater due to differences in load, engine speed, and other differences due to transient demand.

Emission factors developed using the US EPA NONROAD model for the NGTL Northwest Mainline Expansion Assessment (Stantec 2011) have been matched up to construction equipment for the Project. For some equipment, exact matches were not available, so emission factors were selected for similar equipment with similar sized engines and similar function. Emissions are calculated based on the following equation:

$$\begin{aligned} Emissions\ (tonnes) &= Operating\ Time\ (h) \times Maximum\ Engine\ Power\ (hp) \times Load\ Factor \\ &\times Emission\ Factor\ \left(\frac{g}{hp\ h}\right) \times Unit\ Conversion\ \left(\frac{tonnes}{10^6 g}\right) \end{aligned}$$

The estimated GHGs from off-road diesel equipment during construction of the pipeline, compressor stations, and meter station are presented in Table 1.

Table 1: GHG Emissions from Off-road Diesel Equipment, Construction

Site Under Construction	Emissions (tonnes)*				Percent of Total Off-road Equipment Emissions
	CO_2	CH_4	N_2O	CO_2e	
Johnson Creek compressor station (KP 38)	305	0.02	0.1	343	0.1%
Callazon Creek compressor station (KP 125)	305	0.02	0.1	343	0.1%
Witter Lake compressor station (KP 223)	305	0.02	0.1	343	0.1%
Middle River compressor station (KP 324)	305	0.02	0.1	343	0.1%
Morrison Lake compressor station (KP 420)	305	0.02	0.1	343	0.1%
Kispiox compressor station (KP 531)	305	0.02	0.1	343	0.1%
Borden Lake compressor station (KP 635)	305	0.02	0.1	343	0.1%
Ishkeenickh compressor station (KP 726)	305	0.02	0.1	343	0.1%
Pipeline	214,004	12	88	240,634	98.8%
Meter station	102	0.01	0.04	114	0.05%
TOTAL	**216,548**	**12**	**89**	**243,494**	**100%**

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

4.2 On-road Construction Equipment

The majority of on-road vehicles used during the construction phase will be highway legal trucks. This assessment considers 37 different types of on-road vehicles operating at an average speed of 25 km/h, which includes driving to the site and around the site. This average speed is used to convert the total operating hours to the total distance travelled for each vehicle.

The standard model used in Canada to estimate emissions from on-road vehicles is MOBILE6.2C developed by Environment Canada. This is the Canadian version of the US EPA MOBILE6 model. MOBILE6.2C is a computer program that estimates emission factors for emissions from gasoline and diesel highway motor vehicles.

The MOBILE6.2C derived emission factors from the NGTL Northwest Mainline Expansion Assessment (Stantec 2011) were applied to calculate emissions for the Project. The emission factors assume the vehicles were between the 2005 to 2010 model years and the age distribution of the vehicles is assumed to be evenly distributed between these years. Similar to the NONROAD model, MOBILE6.2C estimates vehicle class-specific emission factors using a database developed from emission tests conducted under standardized conditions for temperature, fuel, and driving cycle. Environmental and age factors are incorporated into the model to account for the possible deterioration in engine performance with age and the effects of climate on exhaust and non-exhaust emissions. Each Project vehicle is classified corresponding to the MOBILE6.2C vehicle classifications. Emissions from on-road equipment are calculated based on the following equation:

$$Emissions\ (tonnes) = Emission\ Factor\ \left(\frac{g}{mile}\right) \times Operating\ time\ (hr) \times Speed\left(\left(\frac{km}{hr}\right) \times Unit\ Conversion\ \left(\frac{0.621\ mile}{1\ km}\right) \times \left(\frac{tonnes}{10^6 g}\right)$$

The estimated GHGs from on-road diesel equipment during construction of the pipeline, compressor stations, and meter station are presented in Table 2.

Table 2: GHG Emissions from On-road Diesel Equipment, Construction

Site Under Construction	Emissions (tonnes)*				Percent of Total On-road Equipment Emissions
	CO_2	CH_4	N_2O	CO_2e	
Johnson Creek compressor station (KP 38)	222	0.002	0.002	222	0.3%
Callazon Creek compressor station (KP 125)	222	0.002	0.002	222	0.3%
Witter Lake compressor station (KP 223)	222	0.002	0.002	222	0.3%
Middle River compressor station (KP 324)	222	0.002	0.002	222	0.3%
Morrison Lake compressor station (KP 420)	222	0.002	0.002	222	0.3%
Kispiox compressor station (KP 531)	222	0.002	0.002	222	0.3%
Borden Lake compressor station (KP 635)	222	0.002	0.002	222	0.3%
Ishkeenickh compressor station (KP 726)	222	0.002	0.002	222	0.3%
Pipeline	80,511	1	1	80,737	97.8%
Meter station	74	0.001	0.001	74	0.1%
TOTAL	**82,358**	**1**	**1**	**82,589**	**100%**

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

4.3 Propane Heaters

During construction of the pipeline segments, the office trailers at the site will be heated using propane heaters. The total office trailer heating hours associated with the construction phase is estimated at 864 hours for each pipeline spread, compressor station, and meter station. These values are based on historical information for similar projects.

The estimate of heater emissions uses US EPA AP-42 emission factors for propane-fired heaters (US EPA 1995) and the following equation:

$$Emissions\ (t) = Emission\ Factor\ \left(\frac{lb}{gallon}\right) \times Heating\ Value\ \left(\frac{gallon}{Btu}\right) \times Power\ \left(\frac{Btu}{hour}\right) \times Operating\ Time\ (hour/year) \times Unit\ Conversion\ \left(\frac{tonne}{2{,}204.6\ lb}\right)$$

Estimated GHG emissions from heaters used during pipeline, compressor stations, and meter station construction are presented in Table 3.

Table 3: GHG Emissions from Propane Heaters, Construction

Site Under Construction	Emissions (tonnes)*				Percent of Total Heater Emissions
	CO_2	CH_4	N_2O	CO_2e	
Johnson Creek compressor station (KP 38)	1,606	0.026	0.115	1,641	3.8%
Callazon Creek compressor station (KP 125)	1,606	0.026	0.115	1,641	3.8%
Witter Lake compressor station (KP 223)	1,606	0.026	0.115	1,641	3.8%
Middle River compressor station (KP 324)	1,606	0.026	0.115	1,641	3.8%
Morrison Lake compressor station (KP 420)	1,606	0.026	0.115	1,641	3.8%
Kispiox compressor station (KP 531)	1,606	0.026	0.115	1,641	3.8%
Borden Lake compressor station (KP 635)	1,606	0.026	0.115	1,641	3.8%
Ishkeenickh compressor station (KP 726)	1,606	0.026	0.115	1,641	3.8%
Pipeline	27,300	0.4	2	27,897	65.4%
Meter station	1,606	0.030	0.120	1,641	3.8%
TOTAL	**41,753**	**1**	**3**	**42,666**	**100%**

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

4.4 Marine Vessels

The marine pipeline will be laid down on the seabed from construction vessels. US EPA methods and emission factors for preparing mobile source port-related emission inventories (ICF Consulting 2009) were applied to the marine construction emissions. Twelve different types of vessels are included in the calculations for seabed preparation, pipe laying, and pipe tie-in and burying. Total operating hours, duration, and load factors from past TransCanada projects are used in these calculations. Emission calculations are based on the following equation:

$$\begin{aligned} Emissions\ (t) = {} & Maximum\ Continuous\ Rating\ Power\ (kW) \\ & \times Load\ Factor\ (percent\ of\ vessel's\ total\ power\ in\ use) \times Operating\ Time\ (h) \\ & \times Emission\ Factor\ \left(\frac{g}{kW\ h}\right) \times Unit\ Conversion\ \left(\frac{t}{10^6 g}\right) \end{aligned}$$

Estimated GHG emissions from marine vessels used during marine pipeline construction are presented in Table 4.

Table 4: GHG Emissions from Marine Vessels

Site Under Construction	Emissions (tonnes)*			
	CO_2	CH_4	N_2O	CO_2e
Pipeline	39,459	5.150	1.140	39,928

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

4.5 Land Clearing Residuals and Biomass Burning

Clearing will involve the removal of trees and other vegetation. The width of the project footprint is conservatively assumed to be 100 m over the up to 780 km of the land-based pipeline for the purposes of this assessment. However, the actual construction right-of-way is anticipated to be 50 m. The conservative assumption accounts for clearing of temporary workspace, access roads and ancillary infrastructure. These are conservative estimates because it is assumed the project footprint is covered in consistent forest cover, although some areas are not forested, such as watercourse crossings or rocky areas.

The GHGs released during open burning of the biomass are estimated for each pipeline section, compressor station, and meter station. In order to estimate CO_2e emissions related with land clearing and associated decay, eco-region specific emission factors from Dymond (2013) are applied. These emission factors are based on the BC eco-region classification, which follows the British Columbia administrative forest boundaries. The pipeline crosses the Northeast, Omineca, and the Skeena eco-region. The emission factors are based on uproot and burn activities and include 19 years of decay (release of residual carbon into the atmosphere) after the initial year of disturbance (refer to Table 5).

PRGT has assessed the volume of merchantable timber over each spread of the pipeline construction sequence. To compensate for areas that may not be easily accessible, it is estimated that 85% of the merchantable timber will be salvaged. The resulting percentage of salvageable timber over each spread is applied to the uproot and burn calculations.

Land clearing emissions calculations are based on the following:

$$Emissions\ (t\ CO_2e) = Area\ Burned\ (ha) \times Emission\ Factor\ of\ Ecoregion\ \left(\frac{t\ CO_2e\ emitted}{ha\ burned}\right)$$

Table 5: Open Burning and Decay Emission Factors for Eco-region and Process

Eco-region	Emission Factor CO_2e/ha	Process
North East	220	Uproot and burn
Omineca	302	Uproot and burn
Skeena	342	Uproot and burn
North East	180	Decay (total for 19 yrs after disturbance)
Omineca	196	Decay (total for 19 yrs after disturbance)
Skeena	228	Decay (total for 19 yrs after disturbance)

As per the Tier 1 approach from the IPCC Guidelines for National GHG Inventories for Agriculture, Forestry and Other Land Use (IPCC 2006), the post disturbance residual decay emissions are assumed to be released within one year of the disturbance.

The total area to be cleared for each pipeline section and the estimated emissions of GHGs due to land clearing during pipeline, compressor stations, and meter station construction are shown in Table 6.

Table 6: GHG Emissions from Land Clearing and Residual Decay, Construction

Site Under Construction	Emission (tonnes CO_2e)	
	Biomass Burning	Residual Decay
Compression Stations	15,225	21,499
Pipeline	1,184,596	1,608,640
Meter station	521	511
TOTAL	1,200,342	1,630,650

4.6 Summary of Construction GHG Emissions

The quantities of GHGs released during the construction of the pipeline, compressor stations, and meter station are summarized in Table 7. Construction of the pipeline sections makes up the majority of the GHG construction emissions (approximately 98%) because of the land clearing activities and biomass burning and decay.

Table 7: Total GHG Emissions from Construction, Over 4 years

Site	Emission Rates (tonnes)*				Percent of Total Construction Emissions
	CO_2	CH_4	N_2O	CO_2e	
Off-road construction equipment	216,548	12	89	243,494	7.5%
On-road construction equipment	82,357	1	1	82,589	2.5%
Marine vessels	39,459	5	1	39,928	1.2%
Propane-fired heaters	41,753	1	3	42,666	1.3%
Biomass Uproot and Burning	-	-	-	1,200,342	37.1%
Biomass Decay	-	-	-	1,630,650	50.3%
Totals	**380,117**	**19**	**94**	**3,329,669**	**100%**

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

5 GHG EMISSIONS DURING OPERATION

Operations are scheduled to commence once the Project facilities are constructed and are proposed to continue for more than 40 years. Four activities contribute to the GHG emissions:

- Stationary combustion of natural gas in compressors
- Fugitive emissions
- Natural gas venting
- Aerial patrols and pipeline maintenance

Methods for estimating emissions from the above activities are described in the following sections. Maximum operating durations, loads, and full build-out conditions were considered in the emission inventory.

5.1 Stationary Combustion

Combustion sources are mainly from fuel being burned in the compressor stations. The combustion sources from compressor station include gas turbine compressor engines, generator engines, and boilers. A meter station is a negligible source of GHGs.

While detailed engineering and unit selection have not been finalized the following assumptions are representative of the maximum GHG emission scenario.

- Two turbine driven compressors will be operating all year round at an output rating of 26.4 MW in each of the eight compressor stations.
- Two generators will be operating all year round at an output rating of 0.5 MW in each of the eight compressor stations.
- Two boilers will be operating all year round at an output rating of 0.4 MW in each of the eight compressor station.

The quantities of GHGs released to the atmosphere are estimated from fuel consumption rates and the equipment specific-data sheets and emissions factors from the Western Climate Initiative Final Essential Requirements of Mandatory Reporting document (WCI 2011). Expected natural gas higher heating values are used to adjust WCI emission factors for the Project. These emission factors are presented in Table 8.

Table 8: WCI Emission Factors for Natural Gas Combustion

WCI Table 20-3 Emission Factors (kg/GJ)	WCI Table 20-4 Emission Factors (g/GJ)	
CO_2	CH_4	N_2O
50	49.58	1.305

The following equation is used to estimate the emissions of CO_2 (WCI.23, Methodology 1):

$$CO_2\ Emissions\ (tonnes) = Fuel\ Consumption\ (m^3) \times Higher\ Heating\ Value\ \left(\frac{GJ}{m^3}\right) \times Emission\ Factor\ \left(\frac{kg\ CO_2}{GJ}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{1000\ kg}\right)$$

The following equation is used to estimate the emissions of CH_4 and N_2O (WCI.24, Methodology 1):

$$CH_4\ or\ N_2O\ Emissions\ (tonnes) = Fuel\ Consumption\ (m^3) \times Higher\ Heating\ Value\ \left(\frac{GJ}{m^3}\right) \times Emission\ Factor\ \left(\frac{g}{GJ}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{10^6\ g}\right)$$

The GHG emissions associated with the operation of stationary combustion equipment at their maximum operating capacity and in full build-out condition are summarized in Table 9. The total CO_2e emission rates are 1.8 Mt CO_2e/y. The meter station was considered to have negligible combustions sources.

Table 9: Annual GHG Emissions from Stationary Combustion Equipment, Operation

Site	Emission Rates (tonnes/year)*				Percent of Total Combustion Emissions
	CO_2	CH_4	N_2O	CO_2e	
Johnson Creek compressor station (KP 38)	219,745	218	6	226,902	12.5%
Callazon Creek compressor station (KP 125)	219,745	218	6	226,902	12.5%
Witter Lake compressor station (KP 223)	219,745	218	6	226,902	12.5%
Middle River compressor station (KP 324)	219,745	218	6	226,902	12.5%
Morrison Lake compressor station (KP 420)	219,745	218	6	226,902	12.5%
Kispiox compressor station (KP 531)	219,745	218	6	226,902	12.5%
Borden Lake compressor station (KP 635)	219,745	218	6	226,902	12.5%
Ishkeenickh compressor station (KP 726)	219,745	218	6	226,902	12.5%
TOTAL	**1,757,961**	**1,743**	**46**	**1,815,214**	**100.0%**

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

5.2 Fugitive Sources

The GHG emissions associated with fugitive leaks from system components were calculated using the "Estimation of Air Emissions from the Canadian Natural Gas Transmission, Storage and Distribution System" Methodology Manual prepared for the Canadian Energy Partnership for Environmental Innovation (CEPEI) (Clearstone 2007). This manual provides methods, emission factors, and equipment schedules recognized by the BC GHG Reporting Regulation Methodology Manual (BC MOE 2011).

The emissions are calculated per length of pipeline or per station. The expected natural gas composition used in conjunction with CEPEI emission factors to calculate fugitive GHG emissions for the Project are based on the following equation:

$$
\begin{aligned}
&Emissions\ (tonnes) \\
&= \sum Equipment\ Count \\
&\times Number\ of\ Components\ per\ Equipment (based\ on\ Component\ Schedules) \\
&\times Average\ Emission\ Factor for\ each\ type\ of\ component\ \left(\frac{kg}{TOC \times hr}\right) \\
&\times Mass\ Fraction \left(\frac{CH_4\ or\ CO_2}{TOC}\right) \times Unit\ Conversion\ \left(\frac{8760\ hr}{yr}\right)
\end{aligned}
$$

Fugitive GHG emissions associated with the operation of the pipeline are presented in Table 10. The compressor stations contributed most of the fugitive emissions because they contain most of the components that can contribute to fugitive emissions. The total CO_2e emissions are estimated to be 56,156 tonnes CO_2e/y.

Table 10: Annual GHG Emissions from Fugitive Sources, Operation

Site	Emission Rates (tonnes/year)*				Percent of Total Fugitive Emissions
	CO_2	CH_4	N_2O	CO_2e	
Johnson Creek compressor station (KP 38)	3	271	-	6,780	12%
Callazon Creek compressor station (KP 125)	3	271	-	6,780	12%
Witter Lake compressor station (KP 223)	3	271	-	6,780	12%
Middle River compressor station (KP 324)	3	271	-	6,780	12%
Morrison Lake compressor station (KP 420)	3	271	-	6,780	12%
Kispiox compressor station (KP 531)	3	271	-	6,780	12%
Borden Lake compressor station (KP 635)	3	271	-	6,780	12%

Table 10: Annual GHG Emissions from Fugitive Sources, Operation (cont'd)

Site	Emission Rates (tonnes/year)*				Percent of Total Fugitive Emissions
	CO_2	CH_4	N_2O	CO_2e	
Ishkeenickh compressor station (KP 726)	3	271	-	6,780	12%
Pipeline	-	6	-	145	0.3%
Meter station	1	71	-	1,773	3%
TOTAL	**24**	**2,245**	**-**	**56,156**	**100%**

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

5.3 Venting

Methane releases from venting differ from fugitive emissions in that these releases are typically voluntary actions associated with activities or produced when emergency situations require a rapid reduction of system pressure. Blowdowns are an example of these venting events. Emission factors used in this assessment are from the Interstate Natural Gas Association of America (INGAA) guideline document (2005). The emission factors used for blowdowns or system venting are based on studies and represent typical natural gas transmission activities calculated per length of pipeline or number of compressor and meter stations. Estimated venting emissions are based on the following equations:

$$Station\ Emissions\ (tonnes) = Number\ of\ stations\ \times Emission\ Factor\ \left(\frac{lb}{station \times year}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{2204\ lb}\right)$$

$$Pipeline\ Emissions\ (tonnes) = Pipeline\ Length(km)\ \times Emission\ Factor\ \left(\frac{lb}{mile \times year}\right) \times Unit\ Conversion\ \left(\frac{1\ mile}{0.621\ km}\right) \times \left(\frac{1\ tonne}{2204\ lb}\right)$$

The GHG emissions associated with venting activities are presented in Table 11. The emission rates are considered to be consistent between the various compressor stations or meter station. The total vented CO_2e emissions are calculated to be 45,890 tonnes CO_2e/year. The largest contributors of vented emissions are the compressor stations.

Table 11: Annual GHG Emissions from Venting Activities, Operation

Site	Emission Rates (tonnes/year)*				Percent of Total Venting Emissions
	CO_2	CH_4	N_2O	CO_2e	
Johnson Creek compressor station (KP 38)	-	174	-	4,357	9%
Callazon Creek compressor station (KP 125)	-	174	-	4,357	9%
Witter Lake compressor station (KP 223)	-	174	-	4,357	9%
Middle River compressor station (KP 324)	-	174	-	4,357	9%
Morrison Lake compressor station (KP 420)	-	174	-	4,357	9%
Kispiox compressor station (KP 531)	-	174	-	4,357	9%
Borden Lake compressor station (KP 635)	-	174	-	4,357	9%
Ishkeenickh compressor station (KP 726)	-	174	-	4,357	9%
Pipeline	-	428	-	10,697	23%
Meter station	-	14	-	338	1%
TOTAL	-	1,836	-	45,890	100%

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

5.4 Aerial Patrols and Maintenance

Patrol and routine maintenance of pipeline, and compressor and meter stations will be performed by personnel using both single engine and twin engine helicopters, depending on the activity. Routine maintenance activities may require up to 12 personnel and, therefore, a twin engine helicopter may be needed. Information regarding maintenance travel was obtained from TransCanada's past experience. A Bell 206 helicopter or similar unit will be used for aerial patrols and operated twice a year with an average speed of 220 km/h. A Bell 412 helicopter or similar unit will be used for routine maintenance of the pipeline, Middle River (KP 324) and Borden Lake (KP 635) compressor stations. Routine maintenance of the pipeline will occur annually while the compressor stations will be maintained weekly.

Manufacturer specifications are used to calculate fuel consumption rates at the recommended cruise speed. Environment Canada emissions factors for the combustion of aviation turbo fuel (EC 2011) are used to calculate GHG emissions based on the following equation:

$$Emissions\ (tonnes) = Number\ of\ Patrols\ per\ Year\ \times Fuel\ Consumption\ \left(\frac{L}{hr}\right) \times Cruise\ Time\ per\ Patrol\ (hr)\ \times Emission\ Factor\ \left(\frac{g}{L}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{10^6 g}\right)$$

The GHG emissions associated with aerial patrols and maintenance activities are presented in Table 12. The largest contributor of GHGs is the weekly maintenance at the compressor stations, which amounts to 307 tonnes CO_2e /y.

Table 12: Annual GHG Emissions from Aerial Patrols and Maintenance

Site	Emission Rates (tonnes/year)*				Percent of Total APM Emissions
	CO_2	CH_4	N_2O	CO_2e	
Middle River compressor station (KP 324)	200	0.002	0.01	201	66%
Borden Lake compressor station (KP 635)	86	0.001	0.002	86	28%
Pipeline	19	0.0002	0.001	19	6%
Meter station	-	-	-	-	-
TOTAL	304	0.003	0.01	307	100%

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

5.5 Summary of GHG Emissions, Operation

Major sources of GHGs include combustion sources at the compressor stations such as boilers, generators, and compressors. A summary of the total GHG emissions from project operations is provided in Table 13. Emissions include

- Two natural gas-fired reciprocating generators operating continuously at an output rating of 0.5 MW
- Two natural gas-fired boilers operating continuously at an output rating of 0.4 MW
- Two natural gas-fired turbine compressors operating continuously at an output rating of 26.4 MW
- Vented and fugitive emissions from pipeline, compressor stations, and a metering station
- Maintenance of pipeline and compressor stations

Table 13: Annual GHG Emissions from Operation

Site	Emission Rates (tonnes/year)*				Percent of Total Project Emissions
	CO_2	CH_4	N_2O	CO_2e	
Johnson Creek compressor station (KP 38)	219,748	663	6	238,038	12.4%
Callazon Creek compressor station (KP 125)	219,748	663	6	238,038	12.4%
Witter Lake compressor station (KP 223)	219,748	663	6	238,038	12.4%
Middle River compressor station (KP 324)	219,948	663	6	238,240	12.4%
Morrison Lake compressor station (KP 420)	219,748	663	6	238,038	12.4%
Kispiox compressor station (KP 531)	219,748	663	6	238,038	12.4%
Borden Lake compressor station (KP 635)	219,834	663	6	238,125	12.4%
Ishkeenickh compressor station (KP 726)	219,748	663	6	238,038	12.4%
Pipeline	19	434	0.001	10,860	0.6%
Meter station	0.8	84	-	2,112	0.1%
TOTAL	**1,758,289**	**5,824**	**46**	**1,917,567**	**100 %**

Note: * Aggregated totals may not equal disaggregated values in this table due to rounding.

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