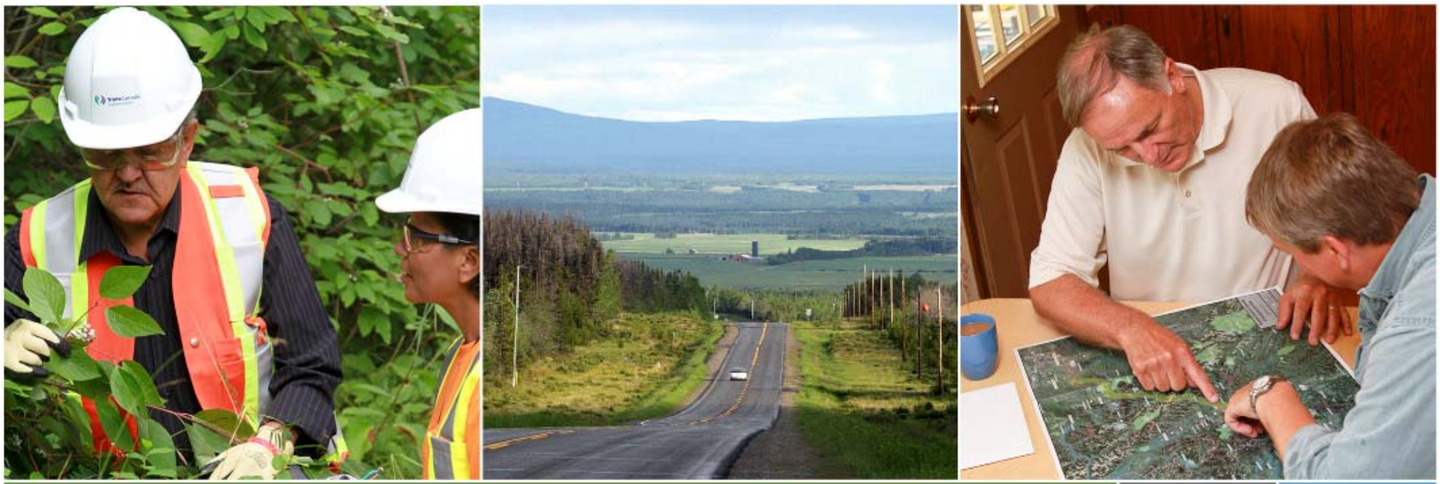

Coastal GasLink
Pipeline Project

Greenhouse Gas Emissions Technical Data Report

March 2014

Revision 1

TransCanada
In business to deliver

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1.0 INTRODUCTION

This technical data report (TDR) considers the potential effects of increased Greenhouse Gas (GHG) emissions produced by the Coastal GasLink Pipeline Project (the Project) on provincial, national, and global emission inventory totals.

The analysis presented herein follows the Canadian Environmental Assessment Agency's (CEAA) prescriptive method for incorporating GHG considerations in environmental assessment (CEAA 2003). This includes the following:

- *Preliminary Scoping for GHG Emission Considerations:* use of readily accessible information to scope out general GHG considerations and the level of detailed required for each
- *Identify GHG Emission Considerations:* jurisdictional considerations, project specifics and industry profile (if available)
- *Assess GHG Emission Considerations*: quantify Project GHG emission and address effects on carbon sinks
- *GHG Emission Management and Mitigation*: jurisdictional requirements, corporate GHG emissions policy, Project mitigation
- *Monitoring, Follow-up and Adaptive Management:* jurisdictional requirements following commissioning and management of reduction measures.

Data from this TDR is used in the assessment of potential adverse effects of the proposed Project on GHG emissions. For data supporting the assessment of the acoustic environment and air quality, see noise TDR (Appendix 2-D) and air quality TDR (Appendix 2-E).

GHG emissions were selected as a valued component (VC) based of anticipated Project-related emissions of GHGs. The findings of this TDR will help identify measures required to avoid or reduce adverse effects on the atmospheric environment during construction and operations.

1.1 OBJECTIVES

The objective of this TDR is to:

- identify GHG jurisdictional considerations and industry profile
- inventory of GHG emissions associated with the proposed Project's construction and operations
- determine the relative contribution of Project GHG emission totals to the provincial and national emission totals

- assess the effects of the Project GHG emission totals in the context of the regulatory and policy environment
- identity proposed migration and management plans, and ongoing monitoring activities

This TDR incorporates the direction provided by the Application Information Requirements (AIR) for the Project (BC EAO 2013). This TDR also refers to the guidance contained in the:

- BC EAO User Guide (BC EAO 2011)
- Fairness and Service Code (BC EAO 2009)
- Proponent Guide for Providing First Nation Consultation Information (BC EAO 2010)
- Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners (CEAA 2003)

1.2 STUDY AREA BOUNDARIES

Because GHGs and climate change are global issues, no study area boundaries are defined for the assessment of GHG emissions. GHG emissions are discussed relative to provincial, federal, and global emissions levels and GHG targets.

2.0 PROJECT DESCRIPTION

Coastal GasLink Pipeline Ltd. (Coastal GasLink) is proposing to construct and operate a 665 km natural gas pipeline from the area near the community of Groundbirch (approximately 40 km west of Dawson Creek, British Columbia [BC]) to the proposed LNG Canada Development Inc. (LNG Canada) liquefied natural gas (LNG) export facility near Kitimat, BC. Coastal GasLink is a wholly owned subsidiary of TransCanada PipeLines Limited. The proposed Project involves:

- construction of 665 km of NPS 48 (1219 mm outside diameter pipe)
- construction and operation of metering facilities at the receipt, intermediate and delivery points, and up to eight compressor stations at regular intervals along the pipeline

The Project will have an initial capacity of approximately 2 to 3 billion cubic feet per day (bcf/d) (56 million cubic metres per day [mmcm/d] to 85 mmcm/d) with the potential for expansion up to approximately 5 Bcf/d.

For the proposed route and locations of the compressor stations, see Figure 2-1. Each compressor station is located at a kilometre post (KP) along the proposed route. The KP starts at 0 km at the east end of the pipeline near Chetwynd, BC and works west:

- C1 Wilde Lake compressor station (KP 0)
- C2 Sukunka Falls compressor station (KP 83)
- C3 Mount Bracey compressor station (KP 163)
- C4 Racoon Lake compressor station (KP 249)
- C5 Clear Creek compressor station (KP 329)
- C6 Segundo Lake compressor station (KP 417)
- C7 Goosly Falls compressor station (KP 492)
- C8 Titanium Peak compressor station (KP 573)

One meter station is located at the first compressor station—Wilde Lake—and one meter station is located at the end of the pipeline near Kitimat (KP 657). A potential future meter station might be installed near Vanderhoof (KP 299).

The proposed Project will require temporary infrastructure during construction, such as access roads, temporary bridges, stockpile sites, borrow sites, contractor yards and construction camps. Expansion scenarios do not involve constructing additional pipeline; only the number and locations of potential future compressor stations. For the purposes of this TDR and the assessment of potential adverse effects on GHG emissions, potential future compressor stations and infrastructure have been assessed.

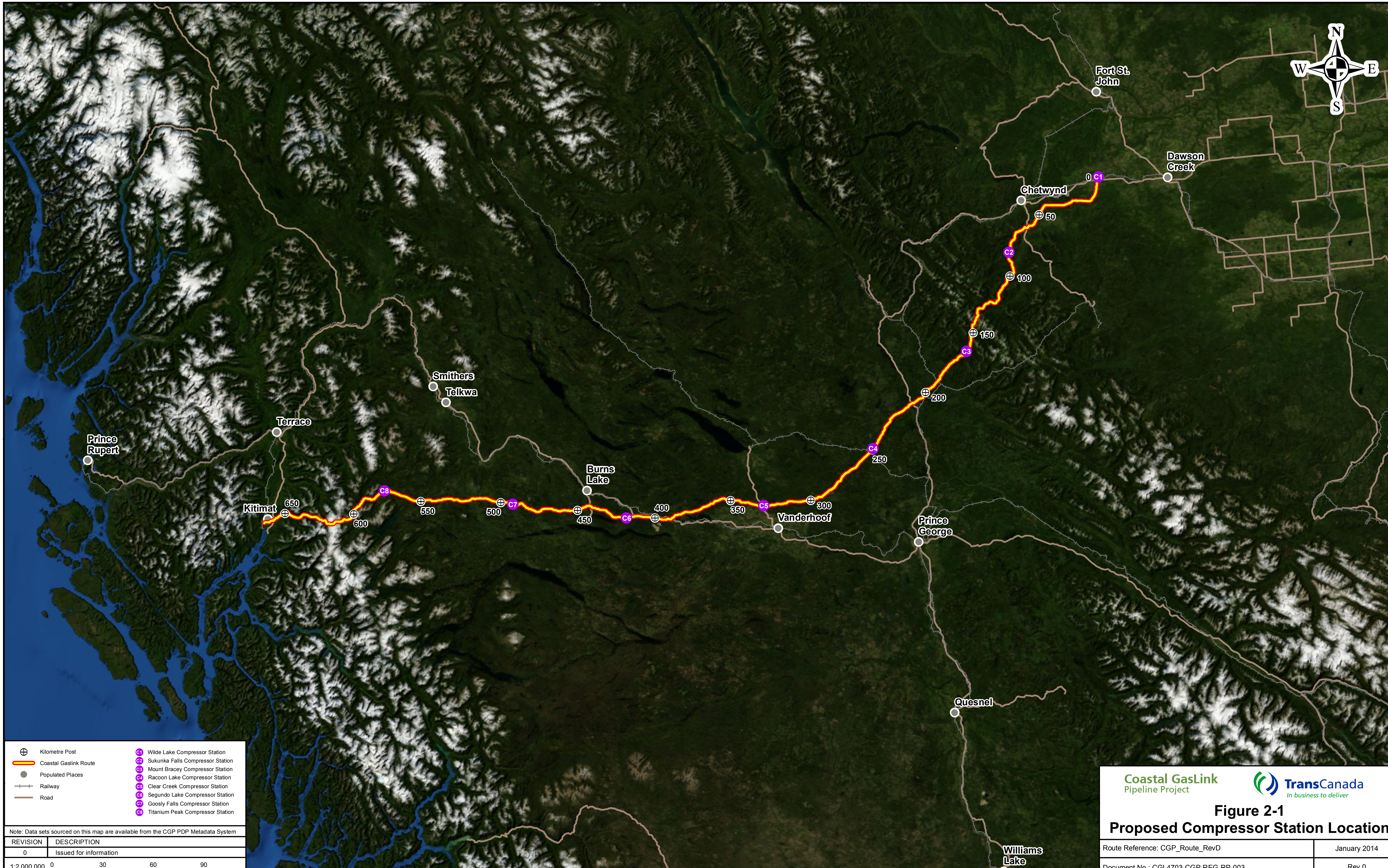

Figure 2-1
Proposed Compressor Station Location

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3.0 BACKGROUND

Climate change is a global issue requiring significant resources to meet complex environmental, energy, economic and political challenges. The science of climate change has not been advanced to the point where a clear cause-and-effect relationship can be established between project-specific or even provincial and national emissions and subtle changes to global climate. The incremental increases in global emissions of GHGs from anthropogenic sources over the past 100 years are thought to be a substantial contributor to climate change (IPCC 2007).

GHGs are emitted from a number of natural and anthropogenic sources. GHG emissions from both anthropogenic and natural sources are reported annually by varying levels of government and emission trends are thoroughly discussed at the provincial, national and global levels. Emissions from biogenic or other sources generally exhibit little variation from one year to the next, and have generally been considered to be nominal when compared with emissions resulting from fossil fuel combustion. However, more attention is being paid to natural GHG emissions as the melting of permafrost and other effects of a warming climate are in turn exacerbating the release of biogenic GHGs into the atmosphere.

Climate changes can be attributed to various causes, the primary factors being:

- Variations in the earth's orbital characteristics—Computer models and historical evidence suggest that changes in Earth's orbital cycles produce climate changes over long cycles (tens of thousands of years).
- Volcanic eruptions—Climatologists have established a link between large volcanic eruptions and short-term, but likely reversible, climate changes.
- Variations in solar output—Changes in the solar energy output can lead to climate changes, as the sun is the fundamental source of energy that drives our climate system. Many of the solar energy output changes are cyclic and poorly understood.
- Increase in GHG concentrations—Climate models that include the above drivers of climate change cannot fully reproduce the observed temperature trend on Earth (over the past century or more) without including the effects of the increased concentrations of GHGs at the lower levels of Earth's atmosphere.

4.0 METHOD

4.1 SELECTION OF KEY INDICATORS

Key indicators (KI) are metrics used to measure and report on the condition and trend of a VC and are identified to focus and facilitate the analysis of interactions between the proposed Project and the VC being assessed. The following key indicators were selected based on previous project assessment, published literature, and guidance from regulators.

There are numerous GHGs in the atmosphere of natural and anthropogenic origin. A GHG is 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. Greenhouse gasses associated with the Project are:

- carbon dioxide (CO_2), which is released through natural processes such as volcanic eruptions and through human activities such as land use changes, burning of fossil fuels, oil and gas processing and deforestation (removal of a carbon sink)
- methane (CH_4), which is a hydrocarbon gas produced through natural sources and is the main component of natural gas. It is also produced by human activities, including the decomposition of wastes in landfills, agriculture and industry based natural gas releases. CH_4 is a far more efficient GHG than CO_2 (higher global warming potential), but is much less abundant in the atmosphere.
- nitrous oxide (N_2O), which is a powerful GHG produced by soil cultivation practices, especially with the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production and biomass burning
- sulphur hexafluoride (SF_6). This human-made, synthetic gas is heavier than air and remains close to the earth's surface. SF_6 is also a particularly potent GHG and is very stable. In Canada the most significant use of SF_6 is in industrial processes that use it as a cover gas or insulating gas.
- hydrofluorocarbons (HFCs), which are a series of synthetic gas that have a large global warming potential because of their long atmospheric lifetimes. The main source of HFCs are refrigerants fluids in industrial processes or use as a cover gas in metal production.
- perfluorocarbons (PFCs), which are a series of human-made gases that were introduced as an alternative to ozone depleting substances. PFCs have a large global warming potential and are primarily used in the manufacturing industry.

4.2 CALCULATION OF CARBON DIOXIDE EQUIVALENT

Total GHG emissions are normally reported as carbon dioxide equivalent (CO_2e), whereby 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 = 21, N_2O = 310, SF_6 = 23,900; HFCs gases range from 140 to 11,700, and PFC gases range from 6,500 to 9,200.

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:

- SF_6. These emissions can be found in insulating gas used in electrical switch breakers. However, the proposed Project does not use insulating gas that contains SF_6.
- HFCs and PFCs, which might be used by the oil and gas industry in small quantities; however, 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 proposed project were calculated as:

$$CO_2e = (\text{mass } CO_2 \text{ x } 1.0) + (\text{mass } CH_4 \text{ x } 21) + (\text{mass } N_2O \text{ x } 310).$$

5.0 REGULATORY CONTEXT

Both the federal and provincial governments have indicated a desire to address the increased GHG emissions potentially affecting climate change and have created strategic-level plans; however, specific policies have not yet been fully implemented. This section will describe the guidance, policy and regulatory context for the assessment of the effects of increased GHG emissions from Project activities.

5.1 INTERNATIONAL REGULATION AND POLICY

The Kyoto Protocol was the first international implementation of a regulated cap-and-trade scheme which set the foundation for many of the emission trading schemes that are currently operating today. Initially adopted on December 11, 1997 in Kyoto, Japan and implemented on February 16, 2005, the purpose of the Kyoto Protocol was to define measurable and binding emission reduction targets for Annex I countries. Annex I Parties include the industrialized countries that were members of the Organization for Economic Co-operation and Development in 1992, plus countries with economies in transition. Annex I countries committed to reducing their collective GHG emissions by 5.2% from 1990 levels. The commitment period extended from 2008 to 2012 for those countries, including Canada that had ratified the protocol. Those that could not reduce their emissions were required to purchase Assigned Amount Units from member nations.

In December 2011, with the Kyoto commitment period coming to a close, Canada exercised its legal right to formally withdraw from the Kyoto Protocol. To fulfill its obligations under the Protocol, Canada would have had to purchase a significant and costly amount of credits to meet the reduction requirement established by Kyoto. Canada's withdrawal was also based on the concern that the United States (US) never ratified the Kyoto Protocol and thus any conflicting climate related legislation with the US may trigger trade imbalances and penalties.

Although Canada withdrew from Kyoto, it still remains a part of the United Nations Framework Convention on Climate Change process for negotiating the next implementation period (post-2020). At present, Kyoto members are negotiating the Durban Platform for Enhanced Action, which is a new climate deal covering all major emitters that is to be agreed by 2015 and take effect in 2020. The results of the recent Doha United Nations Framework Convention on Climate Change talks extends the Kyoto Protocol to 2020, although it covers an increasingly smaller set of countries, as countries such as Russia, Japan and Canada have dropped out.

5.2 FEDERAL REGULATION AND POLICY

The federal government recognizes that climate change is a global issue requiring a global solution and has set a target of reducing Canada's total GHG emissions by 17% from 2005 levels by 2020. This target was announced in early February 2010 following the Copenhagen Accord. However, as of October 2013, Canada will be 122 Mt above the target if current measures continue until 2020 (EC 2013a). Although Canada formally announced its intention to withdraw from the Kyoto Protocol at the United Nations Climate Change Conference in Durban (2011), this is not expected to affect its emissions reduction target.

Like the US, Canada is also pursuing a sector-by-sector regulatory approach that imposes GHG emission reduction rules. For instance, Canada has established rules for the coal-fired power sector and is working on regulations for GHG emissions from Canada’s oil and gas sector. However, the government has yet to officially state how these regulations will work and interact with existing provincial GHG programs.

The federal government’s Turning the Corner Plan, released in April 2007 (EC 2007) and modified in March 2008, outlined an action plan for the regulation of GHGs and other air pollutants from industry. The plan then set a 2010 implementation date for GHG emission-intensity reduction targets, however, this plan has not been yet been implemented. The plan would have set an 18% emission-intensity based reduction target (below 2006 levels) with an annual 2% continuous reduction target for every year post 2010. Minimum inclusion thresholds for oil and gas facilities were proposed as 3,000 t/facility and 10,000 barrels of oil equivalent per day, per company. Much like an emissions trading program, the federal government considers a carbon tax to be off-limits.

Recently, Canada has announced regulations in three sectors—light-duty vehicles, coal-fired electricity generation and heavy-duty vehicles—and plans to announce draft regulations for the oil and gas industry by January 2013 (in the form of a gazette published regulation for consultation). It is expected that the oil and gas regulation will be similar in structure to the other sector regulations that have been released. As such, it can be expected that a federal oil and gas GHG regulation is likely to include the following aspects:

- A performance (or intensity-based) emission reduction standard
- Compliance flexibility through credit transfers both within and between regulated entities
- A price ceiling in the form of a technology fund.

At present, with respect to GHG emissions reporting, Environment Canada requires any facility emitting more than the 50 kt CO_2e report their annual GHG emissions online.

The federal government remains committed to working with provincial and territorial governments and other partners to develop and implement ambitious climate change policies and initiatives. The approaches to climate change vary greatly between the provinces and territories. For example Quebec and California are participating in the Western Climate Initiative, which aims to create a common carbon market, whereas Alberta's Specified Gas Emitters Regulation operates independently of any other province.

5.3 BRITISH COLUMBIA REGULATION AND POLICY

In 2007, the government of British Columbia legislated a provincial GHG reduction target of 33% below 2007 emission levels by 2020 and authorized hard limits ("caps") on GHG emissions through the *Greenhouse Gas Reduction (Cap and Trade) Act* (Government of British Columbia 2008a). An additional provincial target is to reduce GHG emissions to 80% below the 2007 levels by 2050. A Natural Gas Climate Action Working Group was established in 2008 to develop strategies to reduce GHG emissions. The group includes representatives from BC Climate Action Secretariat (CAS), BC MOE, Ministry of Energy and Mines, and the oil and gas industry. The Natural Gas Climate Action Team set interim GHG reduction targets of 6% below 2007 levels by 2012 and 18% by 2016. The 2012 and 2016 targets were legally mandated through the *Greenhouse Gas Reduction Targets Act* (GGRTA) at the end of 2008 (Government of British Columbia 2007). In order to achieve these goals, BC has designed and, in some cases, implemented a suite of policy measures to reduce emissions across the province. These include the following measures:

- Provincial carbon tax, which was introduced in 2008 through the *Carbon Tax Act* (Government of British Columbia 2008b)
- Carbon neutrality mandate for all public sector operations (Carbon Neutral Government Regulation), which is largely achieved through the sourcing of BC-based offsets via the Pacific Carbon Trust (Emissions Offset Regulation)
- Mandatory GHG reporting program (Reporting Regulation)
- Proposed cap and trade and compliance offset scheme.

In addition, the BC Oil and Gas Commission (BC OGC) has released venting and flaring requirements and GHG reduction targets are outlined in the *Clean Energy Act* (Government of British Columbia 2010) as part of BC's energy objectives.

The province's range of climate policies were originally intended to reduce provincial emissions to 55 million tonnes (Mt) of CO_2e or 73% of its 2020 reduction target. When setting this target, the province did not account for the potential scale of development of the shale gas resource in northeast BC, which was in its infancy stage at the time of policy development. These shale gas developments may mean there will be challenges in attaining the original 2020 reduction target.

5.3.1 GHG Reporting/Cap and Trade Scheme

The Province of British Columbia has introduced and passed climate change legislation that connects with strategic actions to reduce GHG emissions. The provincial government has made climate change a top priority through a wide range of measures such as the Climate Action Plan which focuses on seven key sectors including transportation, buildings, waste, agriculture, industry, energy and forestry. Of particular relevance is Bill 18, the *Greenhouse Gas Reduction (Cap and Trade) Act* that authorizes a hard cap on GHG emissions in the province and BC Reg 393/2008, The Emission Offsets Regulation, which defines the requirements for carbon offsets in BC

Enacted in 2010, Bill 18 applies to facilities that emit 10,000 tonnes per year (kt/y) CO_2e or more. Those facilities emitting above 25 kt/y CO_2e are required to have their emissions report verified by a third-party auditor. Those facilities with emissions greater than 10 kt/y CO_2e and less than 25 kt/y CO_2e are only required to report emissions. Linear facilities, such as an oil and gas pipeline, are required to collect and report on each individual facility within the linear facility that emits more than one kt/y CO_2e and is carrying out oil and gas extraction and processing, oil transmission, or carbon dioxide transportation activities. Emissions from mobile drilling rigs are also included in the threshold calculations.

BC had originally intended on harmonizing Bill 18 with the Western Climate Initiative (WCI) program, but has since delayed committing to any form of cap and trade system. The WCI initiative commits signatory states to developing regional targets for reducing GHG emissions, to participate in a GHG registry to track emissions, and to develop a market-based compliance mechanism to meet targets. The WCI represents a regional effort to put limits on GHG emissions in the absence of strong federal leadership in the U.S. and Canada. Currently, the only active members in the WCI are Québec and California.

BC also has a formal carbon offset market; however, this is a voluntary market and has no ties to the current GHG reporting system in place.

5.3.2 Carbon Neutral Government

The British Columbia Emission Offsets Regulation (BC EOR), developed under The GGRTA defines the requirements for carbon offsets in BC The BC EOR establishes the rules and requirements for developing and recognizing carbon offsets generated within BC The BC EOR follows a criteria approach in which the project developer documents and makes assertions in project documents, known as the Project Plan and Project Report, which are each evaluated by separate third party validation and verification bodies (VVB).

Operating within the BC EOR is the BC CAS and the Pacific Carbon Trust (PCT). Specific to defined roles, CAS is the regulator who sets the rules or "boundaries" that the BC carbon market and the PCT must operate within. The PCT, a Crown corporation, is to provide guidance to project developers and VVBs on how to interact with the PCT in order to develop and sell carbon offsets. The PCT's mandate is to buy an adequate amount of BC-based carbon offsets of which the PCT in turn sells the offsets at $25 per tonne of CO_2e to public sector organizations, including school boards and health authorities, to help them meet their legislated requirement to be carbon neutral.

There is no requirement for oil and gas facilities to participate in this program.

5.3.3 Motor Fuel Tax

Motor fuel tax applies to fuels used in internal combustion engines, including industrial equipment (e.g., bulldozers, skidders, chain saws and generators). If a fuel is used to generate power in internal combustion engines, the fuel is subject to motor fuel tax and carbon tax. In addition, the *Motor Fuel Tax Act* (Government of British Columbia 2012) applies to natural gas used or purchased for use in a stationary internal combustion engine that compresses natural gas.

Depending on the location of the natural gas compressor, different tax rates will apply. For example, if the compressor is located outside a processing plant and is used to move marketable gas from the gas processing plant to market or is outside of a storage facility, the tax is equal to $1.90 per 810.3 litres of fuel. If the compressor is located within a gas processing plant and is used to compress marketable gas, the tax is equal to $1.10 per 810.3 litres or fuel.

5.3.4 Carbon Tax

In BC, carbon tax was implemented on July 1, 2008 and is a broad-based tax that applies to the purchase or use of fuels such as gasoline, diesel, natural gas, heating fuel, propane, and coal. The carbon tax also applies to combustibles, such as peat and tires, when used to produce energy or heat. Although this carbon tax covers fuel use and purchases, it does not cover industrial process emissions, venting, or fugitive emissions. Consumers pay carbon tax on all natural gas that is combusted.

The carbon tax is a separate tax on fuel in addition to the motor fuel tax. The carbon tax rate for a type of fuel is the same throughout the province, regardless of where it is purchased or how it is used. The emitted carbon price began at $10 per tonne CO_2e in 2008 and has increased $5 per year. The last increase was July 1, 2012, which stabilized the tax at $30 per tonne, amounting to 6.67¢ per litre of fuel, and 5.70¢ per cubic metre (m^3) of natural gas.

The carbon tax rate for natural gas is based on the CO_2e emissions generated by combustion and has historically been discounted for naturally occurring CO_2 (formation CO_2) in a typical natural gas stream.

5.3.5 Venting Requirements

The BC Energy Plan: A Vision for Clean Energy Leadership (BC Ministry of Energy, Mines, and Petroleum Resources 2007) has set a goal to "eliminate all routine flaring at oil and gas producing wells and production facilities by 2016, with an interim goal to reduce routine flaring by 50% by 2011."

The Flaring and Venting Reduction Guideline (BC OGC 2013) provides regulatory requirements and guidance for flaring, incinerating, and venting in BC, as well as procedural information for the measuring and reporting of flared, incinerated, and vented gas. The guideline applies to the flaring, incineration, and venting of natural gas at well sites, facilities, and pipelines regulated under OGAA. This guideline focuses exclusively on requirements and processes associated with the BC OGC legislative authorities. This guideline has continued to evolve in order to achieve the Energy Plan's goals. The major 2013 changes to the flaring regulatory program applicable to this project include the requirement for flare meters at large compressor stations and the requirement to consider the use of incineration rather than flaring near populated areas.

5.3.6 Clean Energy Act

The *Clean Energy Act* (Government of British Columbia 2010) encourages the development of BC's clean and renewable resources and promotes energy self-sufficiency, independent power production and reductions in GHG emissions. The act provides a substantial revision of the governance framework for energy policy and the articulation of new and revised objectives for BC's energy policy. While these new objectives increase provincial commitments to conservation and clean energy, they also promote electricity exports and fuel-switching that could lead to significant increase in new electricity generation projects.

5.3.7 BC Natural Gas Strategy

On February 3, 2012, British Columbia released its natural gas and complementary strategy focusing specifically on the development of a brand-new liquefied natural gas (LNG) sector. The LNG Strategy is a strong message from the government that it will support proponents' LNG and pipeline projects in any way that it can, including working to minimize historical barriers – whether regulatory, administrative or socio-economic – to construction and operations. In particular, the LNG Strategy identifies specific actions such as coordinating and permitting approval processes among agencies and investing in critical infrastructure to power future LNG facilities and pipelines to support the development of the LNG sector. The Plan also describes actions to explore collaborative solutions for pipeline development to assist in making BC’s natural gas available to LNG facilities.

6.0 BASELINE CONDITIONS

6.1 PROVINCIAL AND NATIONAL GREENHOUSE GAS EMISSIONS

Emissions of GHGs resulting from proposed Project operations are placed in context with total emissions from British Columbia and Canada. Provincial and federal estimates of total GHG emissions were obtained from the British Columbia GHG Inventory and Environment Canada National Inventory Report (NIR), respectively. These emissions are compared to the estimated GHG emissions from the Project.

Total GHG emissions from British Columbia and Canada from 1990 to 2011 with projections for 2020 based on the Copenhagen Target, are shown in Table 6-1.

Table 6-1: GHG Emissions Released in British Columbia and Canada

	BC GHG Inventory Report[1]	National GHG Inventory Report[2]	
Year	British Columbia Total ($t\ CO_2e/y$)*	British Columbia Total ($t\ CO_2e/y$)*	Canada Total ($t\ CO_2e/y$)
2020	43,480,000**	53,120,000***	612,000,000**
2011	-	59,100,000	702,000,000
2010	61,993,000	59,900,000	701,000,000
2005	65,554,000	64,000,000	737,000,000
2000	65,754,000	61,900,000	718,000,000
1990	55,518,000	49,400,000	591,000,000

NOTE:

* The National Inventory Report 1990 to 2011, revised estimates for the energy sector and subsectors, thereby creating a discrepancy between provincial and national emission estimates.

** *The Greenhouse Gas Reduction Targets Act* of BC has set the provincial target to be 33% below 2007 levels by 2020. The 2020 emission levels presented above have been calculated based on this target.

*** The Copenhagen Target is to be 17% below the 2005 emission level by 2020. The 2020 emission levels presented above have been calculated based on this target

SOURCES:

[1] British Columbia Ministry of the Environment (June 2012) British Columbia Greenhouse Gas Inventory Report 2010.

[2] EC (2013), National Inventory Report 1990 to 2011.

Canada's most recent National Inventory Report (NIR) indicates that in 2011, Canada emitted about 702 Mt CO_2e, while BC generated 59.1 Mt CO_2e (EC 2013b). The NIR reported that overall national emissions from oil and gas transmission were 11 Mt CO_2e in both 2010 and 2011. In BC's 2010 GHG Inventory Report (BC MOE 2012) it was calculated that pipelines in the province emitted 0.836 Mt CO_2e in 2010.

6.2 INDUSTRY PROFILE

As of August 2013, there are 4 existing mainline transmission pipelines operating in British Columbia. As well, there are 6 pipelines currently being proposed other than the Coastal GasLink Project.

Table 6-2 presents the GHG data for existing pipelines in the province made available through the BC MOE GHG Reporting Regulation. The table contains a summary of pipeline specifications and GHG emissions reported based on 2011 activities. Table 6-3 presents pipeline specifications for pipelines proposed or currently in construction within BC.

Based on the data presented below, the typical annual emissions from a compressor station ranges from 25-53 kt of CO_2e/y. However, this value is directly related to the number of compressor units operating in each station. Pipeline, meter station and small compressor station emission profiles were typically aggregated together as per the BC GHG Reporting Regulation, thereby rendering these smaller sources less transparent.

Coastal GasLink did not conduct a comparison of pipeline emission intensities as these vary considerably because of many factors, such as:

- Terrain – Pipeline routes may cross different types of terrain. Terrain affects the operating characteristics of a pipeline, which directly affects fuel requirements to transport natural gas through the system.
- Pipe Diameter – The level of compression required to transport natural gas through a pipeline is dependent on the diameter of the pipe. This directly affects fuel requirements to achieve optimal system operation.
- Pipe Internal Coating – The presence or absence of internal pipeline coating can impact the flow efficiency of a pipeline, which directly affects fuel requirements to transport natural gas through the system.
- Station Locations and Pipeline Length – The hydraulic design of the system and the location of the compressor stations determine the compression required to transport natural gas through the pipeline.

As a result of these factors, an emission intensity based comparison between pipelines was not feasible.

Table 6-2: GHG Emissions – Existing Transmission Pipelines with Compression Stations in BC

Ownership	Start Location	End Location	Total Length (km)[1]	Capacity (Bscf/d)[1]	2011 GHG Emissions[2]		Notes and References
					Operation Description	CO_2e (t/y)	
Alliance Pipeline	Aiken Creek, BC	Guardian, IL	2,495	1.6	Compressor station	24,682	Products include natural gas and NGLs
					Pipeline and meter stations	989	www.alliancepipeline.com
Fortis Energy (Vancouver Island) Pipelines	Multiple pipelines on Vancouver Island		NA	NA	Compressor station	28,599	Products include natural gas
					Pipeline, meter stations, and a small compressor station	19,596	www.fortisbc.com
Fortis BC Pipelines	Multiple pipelines in southern BC (excluding Vancouver Island)		NA	NA	Pipeline, meter stations, and six small compressor stations	88,865	Products include natural gas www.fortisbc.com
Spectra Energy Transmission	Fort Nelson, BC	Sumas, WA	2,800	2.4	Pipeline, meter stations, and 13 small compressor stations	789,757	Products include natural gas
					Compressor station	25,224	—
					Compressor station	39,527	—
					Compressor station	45,934	—
					Compressor station	52,019	—
					Compressor station	42,426	http://www.spectraenergy.com/

NOTES:
N/A = Data not available
[1] Canadian Energy Pipeline Association (CEPA). Website accessed on 08/16/2013 (http://www.cepa.com/map/)
[2] British Columbia Ministry of the Environment. Website accessed on 08/16/2013 (http://www.env.gov.bc.ca/cas/mitigation/ggrcta/reporting-regulation/2011-emissions-reports-pdf.html)

Table 6-3: GHG Emissions – Proposed or Under Construction Transmission Pipelines with Compressor Stations in BC

Ownership	Start Location	End Location	Total Length (km)[1]	Capacity (Bscf/day)[1]	Notes and References
TransCanada – Prince Rupert Gas Transmission Project	Fort St. John, BC	Prince Rupert, BC	750	2	Products include natural gas
					www.transcanada.com
TransCanada – Alaska Pipeline Project	Beaver Creek, BC	Boundary Lake, BC	1,566	4.5	Products include natural gas
					www.transcanada.com
TransCanada – North Montney Mainline Project	Kahta, BC	Groundbirch, BC	305	2	Products include natural gas
					www.transcanada.com
TransCanada – Horn River – Northwest System Expansion	Ekwan, BC	75 km Northeast of Fort Nelson, BC	167	NA	Products include natural gas
					www.transcanada.com
Spectra	Cypress, BC	Prince Rupert, BC	850	4.2	Products include natural gas
					http://www.spectraenergy.com/
Pacific Trail Pipelines	Kitimat, BC	Summit Lake, BC	463	1	Products include natural gas
					http://www.spectraenergy.com/

NOTES:
N/A = Data not available
[1] Canadian Energy Pipeline Association (CEPA). Website accessed on 08/16/2013 (http://www.cepa.com/map/)

7.0 PROJECT GHG EMISSIONS

7.1 METHODOLOGY

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. The Protocol separates GHG producing activities according to the related scope:

- Scope 1 GHG emissions are produced directly from combustion, fugitive and vented sources that are within the Project boundary
- Scope 2 GHG emissions arise from generating purchased electricity, heat and steam
- Scope 3 GHG emissions refer to emissions related to the activities of the Project but arising outside the reporting boundary.

Scope 1 GHG emissions are of primary interest in this assessment as the proposed Project is not purchasing electricity, heat or steam from outside the LSA (Scope 2). Majority of Scope 3 emissions occur in the construction phase only and these sources are outside of the reporting boundaries of this assessment (i.e. the GHG emissions related to the extraction, production of fuel burned in the off/on road vehicles).

The potential Project activities and physical works which emit GHG emissions are described in the Application Information Requirements (available at the BC EAO site in 2013). The proposed Project activities and physical works affecting the GHG emission totals for construction and operations are assessed in Section 6.7. Minor activities that were not assessed in the GHG emission inventory include:

- construction and operation of camps during the Project construction phase
- maintenance activities at compressor and meter stations during the Project Operations phase
- decommissioning activities at the end of the Project.

The GHG emissions from these activities were considered to be intermittent, transient and minor in relation to the other Project activities and physical works.

7.2 CONSTRUCTION GHG EMISSIONS

GHG emissions from the construction of the pipeline, compressor stations, and meter stations are summarized in Table 7-1. The construction activities will involve grading, pipeline stringing and bending, welding, ditching, coating, lowering, backfilling, tie-ins, clean-up of eight different sections of the pipeline and construction of the compressor and meter stations. Construction of the pipeline sections makes up the majority of the GHG construction emissions (approximately 95%) while GHG emissions from construction of the compressor and meter stations are relatively small in comparison.

Construction is proposed to start in 2015-2016 with site clearing and preparation, moving to mainline construction for the next three to four years. The proposed Project is expected to be in service by the end of the decade.

Table 7-1: GHG Emissions for Construction

Construction Period	GHG Emissions (tonnes CO_2e)			
	Pipeline	Compressor Stations	Meter Stations	Total Construction
Construction Start	1,707,415	-	-	1,707,415
Mainline Construction	615,626	89,254	10,653	715,533
Total	2,323,041	88,254	10,653	2,422,948
Percent of Total	95.9	3.6	0.4	100

The methods used to calculate the construction emissions are summarized below and are described in further detail within Appendix C.

- U.S. EPA AP 42 emissions factors were used for the propane fired heaters.
- Off-road equipment emissions were calculated using equipment-specific emission factors determined using the U.S. EPA NONROAD (U.S. EPA 2010, 2004a, 2004b).
- U.S. EPA Motor Vehicle Emission Simulator (Mobile 6.2C) was used for on-road equipment.
- Open burning emissions were calculated based on biomass fuel loading values from the Canadian Journal of Forest Research (Amiro et al. 2001) and emission factors from Environment Canada's National GHG Inventory.
- Residual emissions expected from land clearing activities were calculated based on deforestation emissions provided by Ministry of Forests, Land and Natural Resources (Dymond 2013).

Table 7-2 presents GHG emissions released from the construction activities described above. Land clearing and biomass open burning make up the majority of the construction emissions (approximately 90%).

The removal of a carbon sink (forested area) was not quantified in this project as the cleared area will be returned to its original state after decommissioning of the pipeline; see Section 7.4.2 for more details. This assessment calculates the gross emission of GHGs from the Project; therefore, the net effect of removing then replenishing a carbon sink was not taken into account.

Table 7-2: GHG Emissions during Construction (by Activity)

Construction Activity	Emission Rates (tonnes)				Percent of Total
	CO_2	CH_4	N_2O	CO_2e	
Off-road construction equipment	174,114	10	72	196,614	8.1%
On-road construction equipment	61,702	0.6	0.5	61,878	2.6%
Propane-fired heaters	83	0.001	0.006	85	0.004%
Biomass open burning	437,420	1,674	351	581,391	24.0%
Land clearing residuals	-	-	-	1,578,535	65.3%
Totals	673,319	1,685	423	2,418,503	100%

The assessment includes two other scenarios in addition to the expansion scenario described above. The objective of the additional evaluation was to describe the magnitude of emissions expected during three possible scenarios:

- Scenario 1 includes the construction of the pipeline, one compressor station (Wilde Lake compressor station) with two natural gas turbine-driven compressors, and metering facilities at the beginning of the pipeline, using the same methodologies as described in the expansion scenario above.
- Scenario 2 includes the construction of the same infrastructure included in Scenario 1, with the addition of the Racoon Lake compressor station with two natural gas turbine-driven compressors, as well as one additional natural gas turbine-driven compressor unit installed at the Wilde Lake compressor station.
- Scenario 3 represents the GHG emissions expected during the construction of all the facilities in the expansion scenario.

Figure 7-1 shows the estimated GHG emissions for the three constructions scenarios.

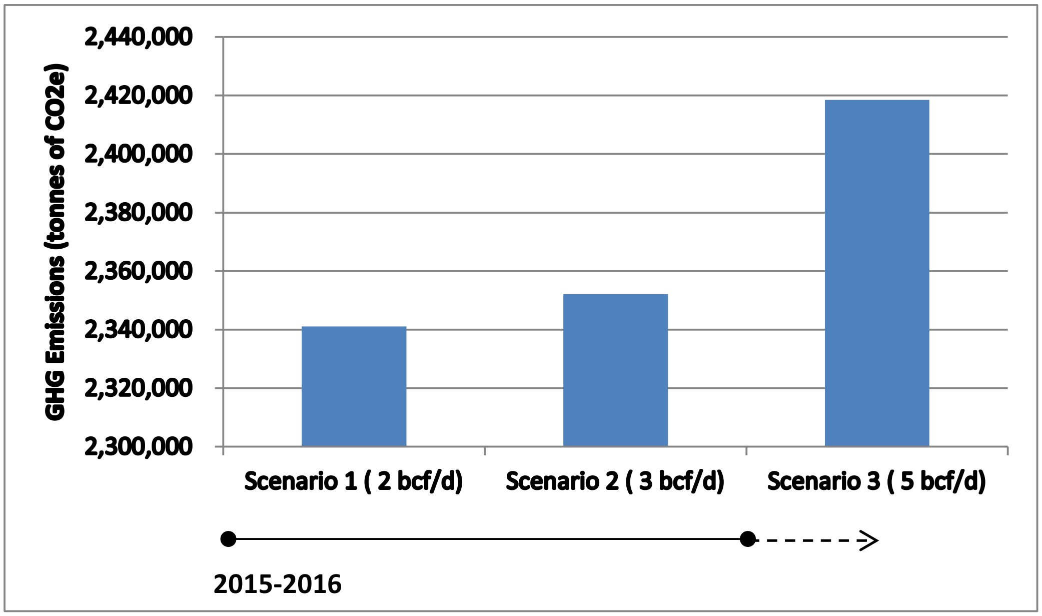

Figure 7-1: Estimated Emissions for Three Construction Scenarios

7.3 OPERATIONAL GHG EMISSIONS

GHG emissions related to the proposed Project operations will begin upon commissioning in late 2017. It is expected that the pipeline will be in service from 2018 to decommissioning in 2043.

GHG emissions for each compressor station, meter station, and the pipeline were calculated for inclusion in the assessment. Major emission sources include CO_2 emissions from combustion sources at the compressor stations such as boilers, generators, and compressors. Fugitive emissions which are comprised mostly of methane may be involuntarily released from components like compressor seals, valves and piping connectors and venting or purging emissions associated with standard practices, maintenance, or upset events. Other emissions from aerial patrols for routine maintenance to the pipeline are also included in the assessment. These emissions are summarized into four categories of GHG emissions: combustion, fugitive, venting, and aerial patrols and maintenance.

7.3.1 Combustion

CO_2 emission factors were based on equipment specific-data sheets which provide exhaust flow rates, CO_2 concentrations, and fuel combustion rates. Emissions of CH_4 and N_2O were calculated using Environment Canada emission factors for fuel combustion from Canada's National Inventory Report 1990 – 2011 (EC 2013b).

GHG emissions associated with the operation of stationary combustion equipment are summarized in Table 7-3. The total CO_2e emission rates are 3,382,094 t/y. Table 7-3 and illustrate that the Wilde Lake Compressor Station (KP 0) is the largest emitter of GHGs when compared to the other compressor stations. The pipeline and meter stations do not have combustions sources.

Table 7-3: Annual GHG Emissions from Stationary Combustion Equipment

Site	Emission Rate (t/y)				Percent of Total Combustion Emissions
	CO_2	CH_4	N_2O	CO_2e	
Wilde Lake compressor station (KP 0)	597,672	10.1	9.0	600,685	17.8
Sukunka Falls compressor station (KP83)	462,678	7.9	7.0	465,013	13.7
Mount Bracey compressor station (KP163)	309,998	5.3	4.7	311,563	9.2
Racoon Lake compressor station (KP 249)	462,678	7.9	7.0	465,013	13.7
Clear Creek compressor station (KP 329)	449,414	7.6	6.8	451,680	13.4
Segundo Lake compressor station (KP 417)	462,678	7.9	7.0	465,013	13.7
Goosly Falls compressor station (KP 492)	309,998	5.3	4.7	311,563	9.2
Titanium Peak compressor station (KP 573)	309,998	5.3	4.7	311,563	9.2
TOTAL	3,365,115	57	50.9	3,382,094	100

Carbon dioxide (CO_2) emissions from stationary combustion equipment were based on source specifications. However, the BC GHG Reporting Regulation requires CO_2 that emissions from stationary combustion equipment be quantified based on generic natural gas emission factors applicable to the entire province. As a reasonability check, CO_2 emissions were calculated using both methodologies. The comparison between the two approaches identified source-specific information to be 3% greater than BC GHG Reporting Regulation methods. This supports the fact that the assessment has been conducted in an accurate but conservative manner.

The assessment includes two other scenarios in addition to the expansion scenario described above. The objective of the additional evaluation was to describe the magnitude of emissions expected during three possible scenarios:

- Scenario 1 includes the operation of the pipeline, one compressor station (Wilde Lake compressor station) with two natural gas turbine-driven compressors, and metering facilities at the beginning of the pipeline, using the same methodologies as described in the expansion scenario above.

- Scenario 2 includes the operation of the same infrastructure included in Scenario 1, with the addition of the Racoon Lake compressor station with two natural gas turbine-driven compressors, as well as one additional natural gas turbine-driven compressor unit installed at the Wilde Lake compressor station.
- Scenario 3 represents the GHG emissions expected during the operation of all the facilities in the expansion scenario.

Figure 7-2 shows the estimated GHG emissions for the three operations scenarios.

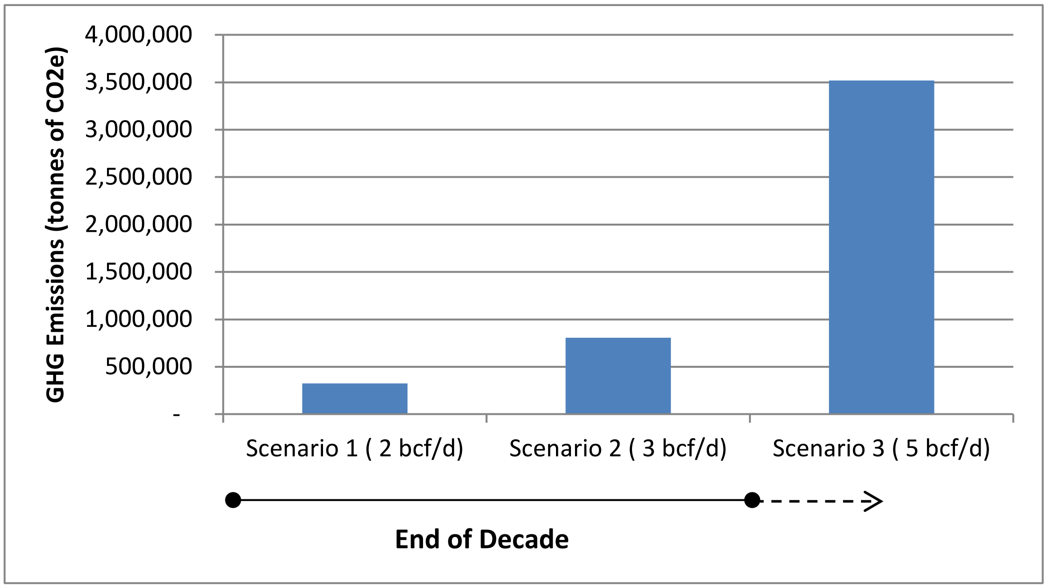

Figure 7-2: Estimated Emissions from Operations Scenarios

In addition to the evaluation of the three scenarios above, Coastal GasLink has conducted hydraulic modelling for the expansion scenario (Scenario 3) to quantify GHG emissions based on a more detailed pipeline hydraulic model that takes into account seasonal variations in power utilization at each compressor station. The basis of this detailed hydraulic model and the updated GHG emissions estimate are shown in Table 7-4 below.

Table 7-4: Average Summer and Winter Operating Loads

Description	Route	Total Volume (Bcf/d)	Total Stations	Total Running Units	Wilde Lake (KP 0)	Sukunka Falls (KP 83.3)	Mount Bracey (KP 162.9)	Racoon Lake (KP 249.3)	Clear Creek (KP 329.4)	Segundo Lake (KP 417.5)	Goosly Falls (KP 492.4)	Titanium Peak (KP 573.4)
Average summer conditions using summer capacity of 5.1 bcf/d East and 4.6 West	Rev D	5.1	8	22	**GHG Emissions (t CO2e/d)**							
					1604	1209	770	1166	1246	1230	759	799
					Power Utilization (%)							
					86%	87%	77%	79%	94%	91%	74%	85%
Average winter conditions using winter capacity of 5.2 bcf/d East and 4.6 West	Rev D	5.2	8	22	**GHG Emissions (t CO2e/d)**							
					1576	1209	770	1166	1230	1182	756	777
					Power Utilization (%)							
					82%	87%	77%	79%	91%	82%	73%	79%

Fugitive

GHG emissions associated with fugitive leaks from system components were calculated using the Interstate Natural Gas Association of America (INGAA 2005) document entitled "Greenhouse Gas Emission Estimation Guidelines for Natural Gas Transmission and Storage". This document provides emission factors determined in a 1990 collaborative study completed by the Gas Research Institute and U.S. EPA (GRI/U.S. EPA 1996). The emission factors were calculated per length of pipeline or number of compressor and meter stations. Furthermore, detailed equipment level emission factors for reciprocating and centrifugal compressors were also applied to the fugitive emission estimation.

Fugitive GHG emissions associated with the operation of the pipeline are presented in Table 7-5. The compressor stations contributed most of the fugitive emissions as they contain most of the components that may contribute to fugitive emissions. The total CO_2e emissions were estimated to be 110,397 t/y.

Table 7-5: Annual GHG Emissions from Fugitive Sources

Site	Emission Rate (t/y)				Percent of Total Fugitive Emissions
	CO_2	CH_4	N_2O	CO_2e	
Wilde Lake compressor station (KP 0)	49.0	909.9	-	19,156	17.4
Sukunka Falls compressor station (KP 83)	36.8	697.7	-	14,689	13.3
Mount Bracey compressor station (KP 163)	24.5	485.6	-	10,222	9.3
Racoon Lake compressor station (KP 249)	36.8	697.7	-	14,689	13.3
Clear Creek compressor station (KP 330)	36.8	697.7	-	14,689	13.3
Segundo Lake compressor station (KP 417)	36.8	697.7	-	14,689	13.3
Goosly Falls compressor station (KP 492)	24.5	485.6	-	10,222	9.3
Titanium Peak compressor station (KP 573)	24.5	485.6	-	10,222	9.3
Pipeline	0.41	2.82	-	59.6	0.1
Meter station 1	1.61	27.8	-	586	0.5
Meter station 2	1.61	27.8	-	586	0.5
Meter station 3	1.61	27.8	-	586	0.5
TOTAL	275	5,244	0.0	110,397	100

7.3.2 Venting

Methane emissions from venting differ from fugitive emissions in that emissions are typically voluntary actions associated with plant activities or produced when emergency situations require a rapid reduction of process pressure. Blowdowns are an example of these venting events. Emission factors used in this assessment are also from the 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.

GHG emissions associated with venting activities are presented in Table 7-6. The emission rates demonstrate that the vented emissions are typically considered to be consistent between the various compressor stations or meter stations. The total vented CO_2e emissions are calculated to be 24,684 t/y. The largest contributor of vented emissions are the pipelines.

Table 7-6: Annual GHG Emissions from Venting Activities

Site	Emission Rate Per Site (t/y/site)				Total Vented Emissions From All Sites (t/y)	Percent of Total Vented Emissions
	CO_2	CH_4	N_2O	CO_2e		
Compressor stations	-	101.5	-	2,131	17,051	23.2
Pipeline	-	323	-	6,780	6,781	73.7
Meter stations	-	13.5	-	284	852	3.1
TOTAL	0	438	0.0	9,195	24,684	100

7.3.3 Aerial Patrols and Maintenance

Patrol and routine maintenance of pipeline and compressor/meter stations will be performed by helicopter. Information regarding maintenance travel was obtained from TransCanada’s past experience. Helicopters (e.g., RH44) will be used for aerial patrols and operated quarterly with an average speed of 110 to 130 km/h. Helicopters (e.g. A-Star) will also be used for routine maintenance work, call-outs, valve works, and surveys. The helicopter emissions were based on the emissions and fuel consumption data generated by Emissions and Dispersion Modeling System (EDMS 5.1.3).

GHG emissions associated with aerial patrols and maintenance activities are presented in Table 7-7. This activity is only applicable to the pipeline, not the stations, and amounts to 300 CO_2e t/y.

Table 7-7: Annual GHG Emissions from Aerial Patrols and Maintenance (APM)

Site	Emission Rate (t/y)				Percent of Total APM Emissions
	CO_2	CH_4	N_2O	CO_2e	
Compressor station	-	-	-	-	-
Pipeline	290	0.03	0.03	300	100
Meter station	-	-	-	-	-
TOTAL	290	0	0	300	100

7.3.4 Summary of Operations Greenhouse Gases

For a summary of the total GHG emissions from project operations, see Table 7-8. Total CO_2e emission rates are 3,517,472 t/y. The largest GHG emitter is the Wilde Lake compressor station (KP 0) while the lowest emissions are associated with the meter stations.

Table 7-8: Project Operations GHG Emissions

Site	Emission Rate (t/y)				Percent of Total Project Emissions
	CO_2	CH_4	N_2O	CO_2e	
Wilde Lake compressor station (KP 0)	597,722	1021.5	9.0	621,973	17.7
Sukunka Falls compressor station (KP 83)	462,715	807.1	7.0	481,834	13.7
Mount Bracey compressor station (KP 163)	310,023	592.4	4.7	323,917	9.2
Racoon Lake compressor station (KP 249)	462,715	807.1	7.0	481,834	13.7
Clear Creek compressor station (KP 329)	449,451	806.8	6.8	468,500	13.3
Segundo Lake compressor station (KP 417)	462,715	807.1	7.0	481,834	13.7
Goosly Falls compressor station (KP 492)	310,023	592.4	4.7	323,917	9.2
Titanium Peak compressor station (KP 573)	310,023	592.4	4.7	323,917	9.2
Pipeline	290	326.00	0.03	7,138	0.20
Meter station 1	1.6	41.4	-	870	0.02
Meter station 2	1.6	41.4	-	870	0.02
Meter station 3	1.6	41.4	-	870	0.02
TOTAL	3,365,679	6,477	50.9	3,517,472	100

7.4 GHG EMISSION MANAGEMENT

Applicable jurisdictional policies, regulatory requirements, best management practices and technologies and mitigation intended to reduce the Project contribution to the provincial, national, and global emission totals are discussed in this section.

7.4.1 Jurisdictional Policies and Regulations

Coastal GasLink will comply with all prevailing provincial and federal GHG compliance programs. For this Project, the applicable GHG reporting programs include the British Columbia Reporting Regulation - *Greenhouse Gas Reduction (Cap and Trade) Act* and Environment Canada's GHG Reporting Regulation.

Coastal GasLink will assess all emission sources as per the applicable requirements and methodology of the British Columbia Reporting Regulation - *Greenhouse Gas Reduction (Cap and Trade) Act* and Environment Canada's GHG Reporting Regulation.

As it is expected that emissions from this project will be in excess of 50 kt CO_2e/y Coastal GasLink will report emissions to the BC MOE (10 kt CO_2e threshold) by March 31st of the following year and will have the report verified by an accredited 3rd party by March 31st as well (25 kt CO_2e threshold).

The annual emissions will also be reported to Environment Canada (50 kt CO_2e/y threshold).

7.4.2 Corporate GHG Emissions Management

During the design phase, route evaluations criteria were used to develop the shortest, most efficient pipeline, which also optimizes the pipe diameter, flow conditions, level of compression and choice of equipment. This evaluation process is intended to reduce operational costs and GHG emissions.

Mitigation and best achievable technologies (BATs) for GHG emission reductions have been considered for all phases of the Project, but will be focused particularly on avoiding GHGs from activities identified to contribute majority of the GHG emissions.

As discussed in Section 7, Aquatic Environment, these activities include:

- the use of fuel in on/off road vehicles during the construction phase
- land clearing during the construction phase
- stationary combustion source fuel consumption during operations

In addition to these activities, Coastal GasLink will implement efforts to reduce methane emissions during maintenance and upgrading activities, and will manage fugitive emissions through their leak detection and repair program.

TransCanada has demonstrated their commitment to implement waste heat recovery throughout their operations in North America and will continue to do so where practical.

Mobile Construction Equipment

Typical construction activities are clearing, topsoil salvage, grading, piling and mechanical construction. TGHG sources for construction include off-road and on-road equipment.

Construction vehicles, both on-road and off-road, are difficult GHG sources to control when it comes to selecting exact models and types to be used by all proponents in the construction phase of the project. Most of the equipment has already been procured by the Project and has specialized purposes in the construction of the pipeline and compressor stations. Therefore, selecting BATs for mobile sources were not possible. Instead, ensuring that industry best practices for maintaining these sources were completed as follows:

- Correct sizing of equipment. In many cases, the largest sized vehicle available is not necessary to complete a task. Coastal GasLink will assess the capacity of the equipment being considered and will use equipment meeting the minimum size requirements in the effort to reduce unnecessary fuel consumption.
- Planning ahead. During construction and operations, Coastal GasLink will devise a plan in advance of project activities to reduce the Project Footprint, and restrict activities to the designated work areas.
- Driver behaviour. Employees will be educated on how to effectively use equipment. The proper driving technique can help reduce fuel consumption and required maintenance activities. As well, speed restrictions will be implemented to reduce the load placed on the mobile equipment and improve site safety.
- Vehicle maintenance. On-road and off-road equipment will be diligently serviced and properly tuned on a regular bases to increase fuel consumption efficiency.
- Modernizing fleet and equipment. In addition to vehicle maintenance, newer and more efficient equipment will be considered in the attempt to modernize the fleet and reduce fuel consumption.
- Regulatory standards: Heavy and light duty equipment will adhere to and meet all relevant regulatory emission standards.
- Reduce idling. Employees will be encouraged to reduce idling times and turn off equipment when not in use or when safe to do so. As well, idling reduction

equipment will be implemented where practical (i.e., battery powered units, or automatic shutdown systems)

- Alternative fuels. The most common fuels used by mobile equipment are gasoline and diesel. However, in some instances propane or compressed natural gas might be used. The efficiency of the fuel will be assessed when selecting the type of equipment to use. As well, when considering the fuel type, effort will be made to combust fuel grades with low sulphur contents. Where practical, equipment capable of using renewable fuels (such as biofuels) will be introduced.

Land Clearing

Construction related GHG emissions occur during preparation of the pipeline RoW and from construction of the pipeline through to pipe installation and final reclamation. Clearing of the RoW and disposal of non-merchantable vegetation through burning is a major contributor of GHG emissions during pipeline construction. Timber will be salvaged where practical and either sold or donated to local regions. Provincially accepted guidelines will be followed in the event of burning biomass to maximize the combustion efficiency.

Coastal GasLink has committed to maintain clean-up and reclamation procedures which will be initiated immediately following construction. Reclamation will be completed once weather and soil conditions permit, likely in the year following construction. Garbage or debris remaining along the RoW will be removed regularly and disposed of in compliance with local regulations. The RoW contours will be returned to a stable and maintenance-free condition. In agricultural soils, compaction in subsoils will be relieved and the topsoil replaced. All disturbed upland areas will be seeded with an appropriate seed mix and specific land reclamation measures will be applied, as necessary. These activities will compensate for the temporary removal of forested areas currently acting as GHG sinks.

Within the station footprints, land clearing will remove small amounts of natural GHG sinks which cannot be reclaimed. Although minor, Coastal GasLink is exploring alternatives to counteract the removal of GHG sinks due to the land clearing within the station fence lines. All alternatives are still under review, but may be related in planting additional vegetation in the areas surrounding the stations to increase the capacity of the surrounding GHG sinks.

Upon decommissioning of this Project, the natural environment will be returned to its original state. Considering the limited timespan of this Project (in excess of 30 years) and the mitigation described above, the Project development was not considered to be a permanent deforestation activity.

Stationary Combustion Equipment

Carbon management is assessed in the context of the potential environmental effects of Project GHG emissions on the atmosphere by examining the technology to be used. The technology is reviewed to confirm that the best achievable is being proposed. BC MOE has advised that "Best Achievable Technology" is defined as technology that is normal (or better) for the specific industry, and is energy efficient and economically viable.

The operation of compressors at the stations will be responsible for more than 95% of GHG emissions originating from the operation of stations. Therefore, as per the IPCC 27 Good Practice Guidance (IPCC 2005) the compressors were identified to be key sources and have been assessed. Other stationary sources such as heaters were considered minor sources relative to the compressors and were not assessed.

The Rolls-Royce RB211 turbine has been chosen for purposes of this assessment. This unit meets the requirements of the Project and is representative of a turbine that will be used in the final design of the proposed Project. The turbine unit will be chosen based on best achievable technology factors, which may include:

- Meeting the high power output requirements with a high efficiency
- Low NO_x and CO_2 emissions
- Small footprint which allows for reduced station size
- Modular design for ease of transportation and construction
- Remote operation will reduce the visitation requirements and office space footprints.

These factors supported the decision that the Rolls-Royce RB-211 was both technically and financially practical while being a reliable solution to the design requirements of this project.

Reduction in Methane Emissions

In order to reduce the CO_2e release from blowdown operations, Coastal GasLink will determine when these operations are necessary and combine multiple repair projects into a single blowdown wherever practical. In these situations, a truck-mounted portable compressor will be used when practical to transfer gas from affected pipeline sections to adjoining pipeline sections, greatly reducing the amount of methane released to the atmosphere.

Hot tapping is an alternative procedure that makes a new pipeline connection while the pipeline remains in service, flowing natural gas under pressure. The hot tap procedure involves attaching a branch connection and valve on the outside of an operating pipeline, and then cutting out the pipe-line wall within the branch and removing the wall section through the valve. Hot tapping avoids product loss, methane emissions, and disruption of service to customers. While hot tapping is not a new practice, recent design improvements have reduced the complications and uncertainty operators might have experienced in the past. TransCanada uses hot tap procedures as often as possible on small jobs and perform larger taps (greater than 12 inches) only a handful of times per year. By performing hot taps, TransCanada is able to reduce methane loss and costs to shippers.

Leak Detection and Repair

TransCanada has rigorously managed fugitive emissions from its Canadian pipeline system over the past decade. Fugitive emissions are typically low-level leaks from above ground pipeline and equipment sources. In addition to continual monitoring of its facilities, the TransCanada Leak Detection and Repair (LDAR) program is a comprehensive program that identifies leaks on pipeline and compressor station components, such as valves, flanges and fittings, setting priorities and conducting repairs. Many years of experience conducting this program across its pipeline system has established TransCanada's influence in the development and implementation of leak detection technologies.

7.5 COMPARISON WITH PROVINCIAL AND FEDERAL EMISSIONS

GHG CO_2e emissions from operations activities of the Project based on the expansion scenario (3.517 Mt CO_2e/y) are minor when compared with Canadian emissions (702 Mt CO_2e/y) for 2011. Based on these 2011 provincial and federal GHG baselines, the Project will increase the emission totals by 6% provincially and 0.5% nationally.

Global emissions were determined to be 30,824 Mt CO_2e/y by the United Nations Statistics Division (UNSD 2010). These GHG emissions were based on data from 173 countries between 1994 and 2008. GHG CO_2e emissions from operations activities of the Project are only 0.012% of global emissions.

In the BC 2010 GHG Inventory Report (BC MOE 2012) it was calculated that natural gas pipelines in the province emitted 0.836 Mt CO_2e in 2010. Based on data reported to the BC MOE through the GHG Reporting Regulation, the emissions from the operation of BC pipelines amounted to 1.383 Mt CO_2e in 2011. Considering the 2011 provincial inventory, this Project will increase the emissions from the BC natural gas pipeline sector to more than 4.6 Mt CO_2e per year. These estimates are conservative since they assume that the Project will be operating at full capability all year long. The implementation of best GHG management practices throughout the operation of the Project will assist in reducing the GHG emissions.

In addition to the expansion scenario, two other scenarios were assessed as explained in Section 7.3 above:

- Scenario 1 includes the operation of the pipeline, one compressor station at Wilde Lake with two natural gas turbine-driven compressors, and metering facilities at the beginning of the pipeline, using the same methodologies as described in the expansion scenario.
- Scenario 2 includes the operation of the Racoon Lake compressor station with two natural gas turbine-driven compressors, as well as one additional natural gas turbine-driven compressor unit installed at the Wilde Lake compressor station.
- Scenario 3, the expansion scenario, represents the GHG emissions expected during the operation of all the facilities for the proposed Project.

A comparison estimating the operation emissions for each scenario and their respective contributions to provincial, national and global inventories is detailed in Table 7-9 below.

Table 7-9: Comparison of Estimated Emissions by Scenario and Relative Contributions to Provincial, National and Global Inventories

Scenario	Operation Emissions (Mt/y)	Compared to Provincial Emissions (59.1 MT CO2e/y)	Compared to National Emissions (702 MT CO2e/y)	Compared to Global Emissions (30,824MT CO2e/y)
Scenario 1 (2 bcf/d)	0.326	0.6%	0.05%	0.001%
Scenario 2 (3 bcf/d)	0.807	1.4%	0.1%	0.003%
Scenario 3 (5 bcf/d)	3.517	6%	0.5 %	0.012%

8.0 FOLLOW-UP AND MONITORING

8.1 REPORTING REQUIREMENTS

For the proposed Project, the applicable GHG reporting programs include the British Columbia Reporting Regulation - *Greenhouse Gas Reduction (Cap and Trade) Act* and Environment Canada's GHG Reporting Regulation. If the annual GHG emissions exceed the 10 kt CO_2e threshold, then reporting to BC MOE will be required. If the total linear facility operations emissions exceed 25 kt CO_2e then the emission report will be verified by an ISO 14065 accredited 3rd party.

If the annual emissions calculated from the proposed Project exceed 50 kt CO_2e, then reporting to Environment Canada will be required.

8.2 CARBON TAX

Coastal GasLink will be required to pay carbon tax on the fuel combusted by the proposed Project. As most of the GHG emissions released from the proposed Project originate from fuel combustion a large amount of taxes will be paid annually. By placing a price on carbon, Coastal GasLink is able to internalize the cost of releasing GHG emissions which can result in the deployment of GHG reduction technologies that would not normally be considered due to their financial and risk profile.

8.3 LEAK DETECTION AND REPAIR (LDAR)

TransCanada has rigorously managed fugitive emissions from its Canadian pipeline system over the past decade. The Coastal GasLink pipeline will be no different, and will be continually monitored and repaired, as discussed in Section 6.7.

8.4 RESEARCH AND DEVELOPMENT

TransCanada assesses new technologies and processes to improve energy efficiency or to reduce GHG emissions. These voluntary actions are part of TransCanada ongoing research and development efforts. An example of these efforts includes the evaluation of the effects of bleed valve modes of operation on unit performance. In 2011, engine performance was assessed from both efficiency and GHG emissions viewpoints. In 2012 the methodology was extended to other engine types and data were generated to quantify the effects of bleed valve opening on the unit and station performance with the aim of potentially operating in regimes where these losses can be reduced with lower impact on GHG emissions.

8.5 WASTE HEAT RECOVERY

Heat created from the operation of turbines at compressor stations can potentially be utilized to generate renewable electricity. Coastal GasLink will be evaluating the opportunities to utilize Waste Heat Recovery (WHR) systems throughout the compressor stations along this pipeline.

TransCanada has demonstrated their commitment to the implementation of WHR through the operation of 17 WHR facilities at compressor stations across North America. These facilities can generate more than 60 MW of clean electricity from waste heat.

TransCanada has continued to build on its demonstrated experience with waste heat recovery through the installation of a new WHR unit at a compressor station in the Crowsnest pass area in BC. The unit became operational in 2012 and has design capacity of 6.5 MW of clean power and an expected average output of 46 GWh/y, which is the equivalent to the electricity consumed by more than 4,000 homes. TransCanada will provide access to the waste heat while Mistral Power Inc. will own and operate the WHR facility while being commercially independent from TransCanada’s pipeline business. In addition, TransCanada is pursuing options for third-parties to develop, own and operate WHR units at three other compressor stations.

9.0 KEY RESULTS AND FINDINGS

To evaluate the GHG emission effects associated with the proposed Project, emissions of GHGs were calculated for construction and operations. Emissions of GHGs during operations were assessed by comparing the calculated emissions with provincial, national, and global emission totals.

Key assessment findings are that:

- Construction GHG emissions were estimated to amount to 2,419 kt CO_2e over the three construction years.
- Operations GHG emissions were estimated to be 3,517 kt CO_2e per year.
- Based on the 2011 provincial and national GHG baselines, the Coastal GasLink Project will only increase the emission totals by 6% provincially and 0.5% nationally.
- Based on data from 1994 to 2008, the Coast GasLink Project will only increase the global GHG emission totals by 0.012%.

The majority of emissions from the proposed Project will originate from the combustion of fuel, for which Coastal GasLink will be paying carbon taxes. Mitigation of GHG emissions is therefore realized by direct management and incentivized through participation in the BC Carbon tax System. Furthermore, best management practices of land clearing, mobile construction and BATs for stationary combustion equipment, as well as methane reduction strategies will be implemented, where practical. These practices, including the LDAR program, can potentially mitigate GHG emissions.

As Coastal GasLink advances its compressor station engineering plans, consideration is being given to the potential use of the General Electric PGT25+G4 turbine unit as an alternative to the Rolls-Royce RB211 turbine unit. The configuration of turbines, generators and heaters remains the same as the RB211 configuration. Appendix E provides details on the consideration of an alternative compressor driver in relation to the results of the assessment.

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Greenhouse Gas Emissions Technical Data Report

Appendices – Contents

Greenhouse Gas Emissions Technical Data Report

Appendix A
Abbreviations

Abbreviation	Definition
Units of Measurement	
Bcf	billion cubic feet
d	time in days
°C	degrees celsius
ha	hectare
K	degrees kelvin
km	kilometre = 1000 metres
m	metre
MW	mega watt
MMBtu/h	million British thermal units per hour
%	percent
$10^3m^3/d$	one thousand cubic meters per day
hr	time in hours
s	time in seconds
t	tonnes
Other Terms	
AIR	application information requirement
AP 42	Appendix 42, Fifth Edition, Compilation of Air Pollutant Emission Factors
BAT	best achievable technology
BC	British Columbia
BC EAO	British Columbia Environmental Assessment Office
BC EOR	British Columbia Emission Offsets Regulation
BC MOE	British Columbia Ministry of Environment
BC OGC	BC Oil and Gas Commission
BSFC	brake-specific fuel consumptions
CAS	Climate Action Secretariat
CEA	Canadian Environmental Assessment
CEAA	Canadian Environmental Assessment Agency
CEPA	Canadian Energy Pipeline Association
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
Coastal GasLink	Coastal GasLink Pipeline Ltd.
EA	environmental assessment
EIS	environmental impact statement
GGRTA	Greenhouse Gas Reduction Targets Act
GHG	greenhouse gas
GRI	Gas Research Institute

Abbreviation	Definition
H_2O	water
HFCs	hydrofluorocarbons
HHV	higher heating value
IPCC	Intergovernmental Panel on Climate Change
KI	key indicator
KP	kilometre post
LDAR	leak detection and repair
LNG	liquefied natural gas
LNG Canada	LNG Canada Development Inc.
N_2O	nitrous oxide
NA	not applicable
NEB	National Energy Board
NIR	national inventory report
NRCan-PFC	Natural Resources Canada-Pacific Forestry Centre
O_3	ozone
PCT	Pacific Carbon Trust
PFCs	perfluorocarbons
Project	Coastal GasLink Pipeline Project
ROW	right of way
SF_6	sulphur hexafluoride
SGER	Alberta's Specified Gas Emitters Regulation
SOI	substances of interest
TDR	Technical Data Report
US EPA	United States Environmental Protection Agency
VC	Valued Component
VVB	validation and verification bodies
WCI	Western Climate Initiative
WHR	waste heat recovery

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Appendix B Glossary

Term	Definition
Aboriginal	Being of the first or earliest known people present in a particular region. Aboriginal people in Canada comprise the First Nations, Inuit and Métis.
Anthropogenic	Man-made
Biogenic	Produced from the activity of living organisms.
blowdown	Block valve sometimes referred to as Mainline Block Valve (MLBV). A valve installed on the pipeline that allows the isolation of sections of the pipeline when two sequential valves are closed.
construction phase	The Project phase between internal Project execution approval and the beginning of transportation of natural gas consisting of pre-construction and construction activities.
cumulative effects	Changes to the biophysical, social, economic, and cultural environments caused by the combination of past, present and “reasonably foreseeable” future actions.
ecozone	An area of the earth's surface representative of a large and very generalized ecological unit characterized by interactive and adjusting abiotic and biotic factors.
hydrocarbon	An organic compound, such as natural gas or oil, consisting entirely of hydrogen and carbon; predominately used as a combustible fuel source.
Project	The Coastal GasLink Pipeline Project.
Right of Way (ROW)	The right of passage or of crossing over someone else’s land. Also, an easement on lands belonging to others that is obtained by agreement or lawful appropriation for public or private use.
Valued Component (VC)	Refers to both Value Environmental Component and Valued Socio-economic Component
Operations phase	The Project phase between beginning of transportation of natural gas and the decommissioning of the pipeline

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Appendix C
Construction Emissions Inventory

C.1 INTRODUCTION

Project construction activities will result in greenhouse gas (GHG) emissions. The equipment inventories provided in this appendix include only Project equipment that is expected to release GHG emissions (i.e., equipment with internal combustion engines). The equipment lists and operations schedules are based on the best available information at the time of this study.

The GHGs considered in the assessment include CO_2, CH_4, N_2O, PFCs, HFCs and SF_6; however, it is expected that negligible amounts of PFCs, HFCs and SF_6 will be emitted from this Project and therefore were not assessed further.

There are four main categories of emission sources resulting from Project construction, categorized as follows:

- off-road equipment
- on-road vehicles
- station heating
- land clearing and open burning.

In the following subsections, the methodology and assumptions used to estimate GHG emissions are summarized.

C.2 METHODOLOGY

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

Operating hours and emissions information provided by the NOVA Gas Transmission Ltd (NGTL) Northwest Mainline Expansion project (Stantec 2011) assessment was used as a basis to scale the respective pipeline section emissions to calculate a ratio of operating hour per 1 km of pipeline. The number of operating hours for most equipment was scaled linearly based on the ratio of the pipeline lengths. There is a different ratio of operation hour to 1 km of pipeline for every type of equipment. Each piece of equipment also has a different operating hour ratio depending on what sort of activity it is doing (clearing, dozing, etc.) The operating hour ratios were then applied to the lengths of Coastal GasLink pipeline. These are listed in Table C-1. The exception to this methodology is for equipment associated with directional drills and construction at water crossings. These activities were scaled based upon the number of water crossings and number of directional drills. Unfortunately the directional drill activity information was not available during the time of this study.

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

Table C-1: Pipeline Section Scaling Information

	Length (km)	Number of Water Crossings
Section 1	91.6	166
Section 2	80.2	150
Section 3	90.7	133
Section 4	73.5	102
Section 5	81.1	125
Section 6	79.3	90
Section 7	83.5	122
Section 8	85.6	182
NOTE: Information provided to Stantec by TransCanada.		

C.3 OFF-ROAD DIESEL EQUIPMENT

Estimated GHG emissions from off-road diesel equipment during pipeline, compressor stations and meter stations construction are provided in this section.

Construction equipment was assumed to be manufactured in 2005 or later. Some highly specialized equipment, such as pipe layers, benders, and ditching machines, may have been manufactured before 2005. However, it was assumed the emissions sources, such as equipment motors, have been replaced or retrofitted with more recent parts. The engine power specification associated with each piece of equipment has been sourced from manufacturer information.

The load factors considered in this assessment are a ratio of actual engine output relative to maximum rated output. The GHG emission factors and load factors used in the Horn River Mainline Assessment (RWDI 2010) were used to calculate Project GHG emissions. These emission factors were generated using the United States Environmental Protection Agency (US EPA) NONROAD model (US EPA 2010, 2004a, 2004b). This is the standard model used in Canada to estimate emissions from non-road equipment. US EPA NONROAD brake-specific fuel consumptions (BSFC) and load factors were also used.

Inventories of the off-road diesel equipment that will be used for the Project pipeline and station construction are provided in Table C-2 and Table C-3, respectively. The main types of equipment are tractors, loaders, backhoes, excavators, dozers, and cranes.

Table C-2: Off-Road Diesel Equipment List for Pipeline Construction

Equipment	Number of Equipment	Engine Power hp)	Load Factor (%)	BSFC (lb/hp*hr)
Clearing				
Backhoe, Cat 345CL	2	380	21.0	0.37
Mulcher	3	1,000	59.0	0.37
Dozer D6 (150 hp)	2	175	58.0	0.37
Delimber	3	153	58.0	0.37
Skidder	2	175	58.0	0.37
Line Locate				
Dozer, D6, Winch	1	150	58.0	0.37
Dozer, D7R (200 hp), Winch	1	200	58.0	0.37
Topsoil & Grade				
Grader 14H	2	220	58.0	0.37
Dozer, D6, LGP	3	200	58.0	0.37
Backhoe, 330DL	2	268	21.0	0.37
Backhoe, Cat 345CL	2	380	21.0	0.37
Dozer, D8N, Ripper	3	305	58.0	0.37
Dozer, D8N, Winch	3	305	58.0	0.37
Bending and Set-Up				
Sideboom, 583	6	310	59.0	0.37
Bending Machine 48-60 inch	2	142	59.0	0.37
Stringing				
Crane, Mobile 100 Ton	1	469	59.0	0.37
Sideboom, 583K	1	300	59.0	0.37
Bobcat	1	99.0	21.0	0.48
75kw (101 hp) Genset Engine	3	67.0	59.0	0.37
Welding - Auto Mainline				
Sideboom, 594	12	410	59.0	0.37
Welding - Back End				
Sideboom, 572	2	240	59.0	0.37
Sideboom, 583K	4	300	59.0	0.37
Sideboom, 594	2	410	59.0	0.37
Dozer, D6, LGP	1	200	58.0	0.37
Coating				
Sideboom, 561	4	110	59.0	0.37
Sideboom, 572G (180 hp)	3	180	59.0	0.37
Compressor 350 CFM	1	140	59.0	0.37
1600 CFM Compressor (475 hp)	1	300	59.0	0.37

Table C-2: Off-Road Diesel Equipment List for Pipeline Construction (cont'd)

Equipment	Number of Equipment	Engine Power hp)	Load Factor (%)	BSFC (lb/hp*hr)
Gensets	4	125	59.0	0.37
Ditch				
Backhoe, Cat 345CL	6	380	21.0	0.37
Dozer, D8N, Winch	2	305	58.0	0.37
Dozer, D8N, Ripper	3	305	58.0	0.37
Ditcher TA-77	1	160	58.0	0.37
Lower-in				
Crane, Mobile 100 Ton	1	305	59.0	0.37
Backhoe, Cat 330	2	268	59.0	0.37
Backhoe, Cat 345CL	2	380	21.0	0.37
Sideboom, 594	6	410	59.0	0.37
Screw Anchors (Wetlands)				
Dozer, D6R (200 hp), Winch	2	200	58.0	0.37
Backhoe, Cat 330	5	268	21.0	0.37
Backhoe, Cat 345CL	5	380	21.0	0.37
75kw (101 hp) Genset Engine	4	67.0	59.0	0.37
Backfill & Frost Packing				
Dozer, D8T, Winch	2	310	58.0	0.37
Backhoe, Cat 345CL	4	380	21.0	0.37
Tie-ins				
Sideboom, 594	6	410	59.0	0.37
Boring Crew				
Backhoe, Cat 345CL	2	380	21.0	0.37
Sideboom, 583	2	310	59.0	0.37
Sideboom, 594	2	410	59.0	0.37
Boring Machine, Cr., 12-48"	1	200	59.0	0.37
Dozer, D8N, Winch	1	305	58.0	0.37
Compressor 350 CFM	1	140	59.0	0.37
75kw (101 hp) Genset Engine	2	67.0	59.0	0.37
Testing & Support				
Dozer, D8N, Winch	7	305	58.0	0.37
Backhoe, 330	3	268	21.0	0.37
Sideboom, 583	3	310	59.0	0.37
Pump, Centrifugal, 4" G	4	300	59.0	0.37
75kw (101 hp) Genset Engine	2	67.0	59.0	0.37
Gen Set, 600 KW	2	804	59.0	0.37

Table C-2: Off-Road Diesel Equipment List for Pipeline Construction (cont'd)

Equipment	Number of Equipment	Engine Power hp)	Load Factor (%)	BSFC (lb/hp*hr)
Clean-Up				
Dozer, D6, LGP	5	200	58.0	0.37
Dozer, D8N, Winch	5	305	58.0	0.37
Backhoe, 330	3	268	21.0	0.37
Backhoe, 330 DDL	3	268	21.0	0.37
Grader 16H	1	265	58.0	0.37
Watercourse Crossings (Open-Cut/Isolated)				
Dozer, D8T, Winch	1	310	58.0	0.37
Backhoe, Cat 345CL	3	380	21.0	0.37
Sideboom, 583	2	310	59.0	0.37
Sideboom, 594	3	410	59.0	0.37
75kw (101 hp) Genset Engine	3	67.0	59.0	0.37
Pump, Ditch, 6"	4	12.0	59.0	0.41
HDDs				
HDD Rig	1	600	59.0	0.37
Ditch Pump (12 hp)	1	8	59.0	0.41
Mud Pump	1	1,000	59.0	0.37
Zoom Boom	1	110	21.0	0.43
75kw (101 hp) Genset Engine	1	67.0	59.0	0.37
Backhoe, 330	2	268	21.0	0.37
Maintenance				
Farm Tractor, 4 x 4	1	17.0	78.0	0.41
Challenger 65	1	282	78.0	0.37
Crane, Mobile 100 Ton	1	305	59.0	0.37
Front-End Loader (IT28 132 hp)	2	93.0	48.0	0.37
Generator	7	168	59.0	0.37
Zoom Boom	3	110	21.0	0.43
600kW (800 hp) Genset Engine	2	1,019	59.0	0.37
TOTAL	220	-	-	

Table C-3: Off-Road Diesel Equipment List for Compressor Stations and Meter Stations Construction

Equipment	**Number of Equipment**	**Engine Power** (hp)	**Load Factor** (%)	**BSFC** (lb/hp*hr)
Backhoe, Cat 345CL	2	380	21.0	0.37
Mulcher 700B	3	700	59.0	0.37
Backhoe, 225 w/clam	2	168	21.0	0.37
Dozer, D6, LGP	3	200	58.0	0.37
Grader 14H	2	220	58.0	0.37
Backhoe, 330DL	2	268	21.0	0.37
Backhoe, Cat 345CL	2	380	21.0	0.37
Dozer, D8N, Ripper	3	305	58.0	0.37
Roller Packer	2	174	58.0	0.37
Crane, Mobile 100 Ton	6	469	59.0	0.37
Compressor 350 CFM	4	140	58.0	0.37
Front-End Loader (IT28)	3	180	48.0	0.37
125kw Genset Engine	4	125	59.0	0.37
TOTAL	**38**	**-**	**-**	

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. For the Horn River Mainline Assessment (RWDI 2010), it was assumed that the majority of the equipment consisted of roughly 10% Tier 1 and 90% Tier 2 engines.

The US EPA NONROAD model accounts for the degradation of an engine performance over its lifetime due to normal use or misuse (i.e., tampering or negligence). Engine deterioration increases 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 as 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 Horn River Mainline Assessment (RWDI 2010) 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. Equipment specific emission factors for the Project are presented in Table C-4.

These emissions were determined using the following equation.

$$Emissions\ (t) = Operating\ Time\ (h) \times Maximum\ Engine\ Power\ (hp) \times Emission\ Factor\ \left(\frac{g}{hp\ h}\right) \times Unit\ Conversion\ \left(\frac{t}{10^6 g}\right)$$

Table C-4: Construction Off-Road Diesel Equipment Emission Factors

Equipment	Calculated Adjusted Emission Factor (g/hp*hr)		
	CO_2	CH_4	N_2O
Backhoe, 330DL	535	0.03	0.22
Backhoe, 330	535	0.03	0.22
Backhoe, Cat 345CL	536	0.03	0.22
Bending Machine	535	0.03	0.22
Boring Machine, Cr., 12-48"	530	0.03	0.22
Challenger 65	535	0.03	0.22
Crane, Mobile 100 Ton	530	0.03	0.22
Compressor 1600 CFM	530	0.03	0.22
Compressor 350 CFM	530	0.03	0.22
Dozer, D6, LGP	535	0.03	0.22
Dozer, D6R, Winch	535	0.03	0.22
Dozer, D6, Winch	535	0.03	0.22
Dozer, D8N, Ripper	536	0.03	0.22
Dozer, D8T, Winch	536	0.03	0.22
Dozer, D8N, Winch	536	0.03	0.22
Ditching Machine, Capital 900	536	0.03	0.22
Ditcher TA-77	535	0.03	0.22
Farm Tractor, 4x4	594	0.03	0.25
Grader 14H	535	0.03	0.22
Grader 16H	535	0.03	0.22
Gen Set, 125 KW	530	0.03	0.22
Gen Set, 400 kW	530	0.03	0.22
Gen Set, 600 KW	530	0.03	0.22
Gen Set, 75 KW	530	0.03	0.22
Backhoe/Loader, 446	624	0.04	0.26
F.E. Loader, IT28	535	0.03	0.22
Pump, Ditch, 3"	589	0.03	0.24
Pump, Ditch, 6"	589	0.03	0.24
Pump, 6X8 3200 GPM 2 St.	530	0.03	0.22
Quad Welder D6	530	0.03	0.22

Table C-4: Construction Off-Road Diesel Equipment Emission Factors (cont'd)

Equipment	Calculated Adjusted Emission Factor (g/hp*hr)		
	CO_2	CH_4	N_2O
Sideboom, 572G	530	0.03	0.22
Sideboom, 572	530	0.03	0.22
Sideboom, 583K	530	0.03	0.22
Sideboom, 583	530	0.03	0.22
Sideboom, 594	530	0.03	0.22
Sideboom, Auto Weld	530	0.03	0.22
Bobcat, CAT T870	694	0.04	0.29

The estimated GHGs from off-road diesel equipment during Project pipeline, compressor stations and meter stations construction are presented in Table C5, C-6 and C-7, respectively.

Table C-5: Summary of Off-Road Diesel Equipment Emissions for Pipeline Construction

	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Section 1	17,107	0.97	7.07	19,317
Section 2	28,554	1.61	11.79	32,244
Section 3	31,338	1.77	12.94	35,388
Section 4	13,203	0.75	5.45	14,909
Section 5	14,777	0.83	6.10	16,687
Section 6	13,908	0.79	5.74	15,705
Section 7	15,102	0.85	6.24	17,053
Section 8	31,047	1.75	12.82	35,059
Totals	165,035	9.32	68.17	186,362

Table C-6: Summary of Off-Road Diesel Equipment Emissions for Compressor Stations Construction

Compressor Stations	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Wilde Lake - KP 0	1,009	0.06	0.4	1,139
Sukunka Falls - KP 83	1,009	0.06	0.4	1,139
Mount Bracey - KP 163	1,009	0.06	0.4	1,139
Racoon Lake - KP 249	1,009	0.06	0.4	1,139
Clear Creek - KP 329	1,009	0.06	0.4	1,139
Segundo Lake - KP 417	1,009	0.06	0.4	1,139
Goosly Falls - KP 492	1,009	0.06	0.4	1,139
Titanium Peak - KP 573	1,009	0.06	0.4	1,139
Totals	8,070	0.46	3.3	9,113

Table C-7: Summary of Off-Road Diesel Equipment Emissions for Meter Stations Construction

Meter Stations	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Meter Station - Wilde Lake	336	0.02	0.1	380
Meter Station - Vanderhoof	336	0.02	0.1	380
Meter Station - Kitimat	336	0.02	0.1	380
Totals	1,009	0.06	0.4	1,139

C.4 ON-ROAD DIESEL EQUIPMENT

During the construction phase, 27 different types of on-road (defined as highway-legal) vehicles will be used. The majority of on-road vehicles used during the construction phase will be trucks. The average speed of on-road vehicles was assumed to be 50 km/h, which includes driving to the site and around the site. This average speed was used to convert the total operating hours to the total distance travelled for each vehicle.

The emission factors for on-road vehicles were determined using the MOBILE6.2C model, which is the Canadian version of the US EPA MOBILE6 model, developed by Environment Canada. It is the standard model used in Canada to estimate emissions from on-road vehicles. 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 Horn River Mainline Assessment (RWDI 2010) were applied to calculate emissions for the Project. The emission factors were estimated assuming the vehicles were between the 2005 to 2010 model years and the age distribution of the vehicles was 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 deterioration in engine performance with age and the effects of climate on exhaust and non-exhaust emissions.

Each Project vehicle was classified corresponding to the MOBILE6.2C vehicle classifications. The emission factors for GHG from on-road diesel equipment for construction are presented in Table C-8. The estimated GHGs from on-road diesel equipment during Project pipeline, compressor stations and meter stations construction were calculated using the following equation:

$$Emissions\ (t) = Emission\ Factor\ \left(\frac{g}{mile}\right) \times Total\ Distance\ Travelled\ (mile) \times Unit\ Conversion\ \left(\frac{t}{10^6 g}\right)$$

Table C-8: On-Road Diesel Construction Equipment Emission Factors

Equipment	Number of Each Vehicle Type	Vehicle Type [a]	GVWR (lb)	Emission Factors (g/mile)		
				CO_2	CH_4	N_2O
Ambulance 4x4	2	LDDT34	7,400	1,614	0.02	0.01
Bus, 24 Pass. 4x2	17	HDDBS	14,050	1,614	0.02	0.01
Bus, 36 Pass. 4x2	19	HDDBS	14,050	1,614	0.02	0.01
Truck, Crew Cab 4x4	12	HDDV2b	9,200	785	0.007	0.007
Truck, Flat Bed 3 Ton	18	HDDV7	31,000-33,000	1,351	0.02	0.01
Truck, Flat Bed 1 Ton	10	HDDV3	13,000	872	0.008	0.007
Truck, Mech. Rig	5	HDDV7	31,000-33,000	1,351	0.02	0.01
Truck, Pickup 4x4	56	HDDV2b	9,200	785	0.007	0.007
Truck, Tandem Skid	1	HDDV5	12,000-20,000	1,030	0.010	0.009
Truck, TA Picker	7	HDDV5	12,000-20,000	1,030	0.010	0.009
Truck, Tandem Crane	3	HDDV5	12,000-20,000	1,030	0.010	0.009
Truck, Tandem Dump	5	HDDV8a	33,000-66,000	1,543	0.02	0.01
Truck, Tandem Fuel	4	HDDV5	12,000-20,000	1,030	0.010	0.009
Truck, Tandem Service	2	HDDV7	31,000-33,000	1,351	0.02	0.01
Truck, Tandem Tractor	7	HDDV5	12,000-20,000	1,030	0.010	0.009
Truck, Utility Weld R.	3	HDDV5	16,000–19,000	1,030	0.010	0.009
Truck, Vacuum Truck	2	HDDV5	16,000–19,000	1,030	0.010	0.009
Truck, Weld Rig	23	HDDV5	16,000–19,000	1,030	0.010	0.009
Truck, Tandem Water	5	HDDV7	31,000-33,000	1,351	0.02	0.01
Minibus	6	HDDBS	9,900-11,500	1,614	0.02	0.01
Truck, Sandblast	1	HDDV5	31,000-33,000	1,030	0.010	0.009
Truck, Hydrovac	8	HDDV7	31,000-33,000	1,351	0.02	0.01
Ambulance 4x4	5	LDDT34	7,400	1,614	0.02	0.01

Table C-8: On-Road Diesel Construction Equipment Emission Factors (cont'd)

Equipment	Number of Each Vehicle Type	Vehicle Type [a]	GVWR (lb)	Emission Factors (g/mile)		
				CO_2	CH_4	N_2O
Ambulance 4x4	5	LDDT34	7,400	1,614	0.02	0.01
Truck, Crew Cab 4x4	27	HDDV2b	9,200	785	0.007	0.007
Truck, Tandem Tractor	5	HDDV5	12,000-20,000	1,030	0.010	0.009
Truck, Weld Rig	9	HDDV5	12,000-20,000	1,030	0.010	0.009

The estimated GHGs from on-road diesel equipment during Project pipeline, compressor stations and meter stations construction are presented in Table C-9, C-10 and C-11, respectively.

Table C-9: On-Road Diesel Equipment Emissions for Pipeline Construction

	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Section 1	4,491	0.05	0.04	4,504
Section 2	11,913	0.12	0.10	11,947
Section 3	12,554	0.13	0.11	12,590
Section 4	3,343	0.03	0.03	3,352
Section 5	3,793	0.04	0.03	3,803
Section 6	3,439	0.04	0.03	3,449
Section 7	3,849	0.04	0.03	3,860
Section 8	13,265	0.14	0.11	13,303
Totals	56,646	0.58	0.48	56,808

Table C-10: On-Road Diesel Equipment Emissions for Compressor Stations Construction

Compressor Stations	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Wilde Lake - KP 0	562	0.01	0.005	563
Sukunka Falls - KP 83	563	0.01	0.005	564
Mount Bracey - KP 163	564	0.01	0.005	565
Racoon Lake - KP 249	565	0.01	0.005	566
Clear Creek - KP 329	566	0.01	0.005	567
Segundo Lake - KP 417	567	0.01	0.005	568
Goosly Falls - KP 492	568	0.01	0.005	569
Titanium Peak - KP 573	569	0.01	0.005	570
Totals	4,522	0.05	0.04	4,535

Table C-11: On-Road Diesel Equipment Emissions for Meter Stations Construction

Meter Stations	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Meter Station - Wilde Lake	187	0.002	0.002	188
Meter Station - Vanderhoof	188	0.002	0.002	189
Meter Station - Kitimat	189	0.002	0.002	190
Totals	565	0.006	0.005	566

C.5 LAND CLEARING

Land clearing required to create the pipeline right-of-way will involve the removal of trees and other vegetation. Since the amount of biomass that will be used for other purposes is unknown, it was assumed that all land-clearing debris will be disposed of through open burning, which will result in a worst-case emission estimate.

Open burning emissions were calculated as follows:

$$Emissions\ (t) = Area\ Burned\ (ha) \times Fuel\ Loading\ \left(\frac{t\ burned}{ha}\right) \times Emission\ Factor\ \left(\frac{kg\ emitted}{t\ burned}\right) \times Unit\ Conversion\ \left(\frac{t}{10^3 kg}\right)$$

The GHG emissions generated from open burning were estimated for each Project section, compressor station and meter station. The biomass fuel loading values from the Canadian Journal of Forest Research (Amiro, B.D. 2001) were used in this assessment. Based upon the Canadian Forest Service Forest Fire Behavior Prediction System analysis of forest fires that occurred from 1959 to 1999, fuel loading factors were determined for each ecozone. The pipeline was determined to cross the Pacific Maritime, Montane Cordillera, and Boreal Plains ecozones. Therefore, the largest biomass fuel loading factor from these three zones was used in this assessment (39 t/ha).

Emission factors from Environment Canada’s National GHG Inventory (EC 2004) were used to convert fuel loading to mass released to air (Table C-12).

Table C-12: Open Burning Emission Factors

Substance	CO_2	CH_4	N_2O
Emission Factor (kg emitted to air / t biomass burned)	1,620	6.20	1.30

Residual emissions expected from land clearing activities were calculated based on a deforestation emission factor of 228 t CO_2e per hectare provided by the Ministry of Forest, Land and Natural Resources Operations. IPCC Tier 1 assumptions for addressing the release of residual emissions were applied to this calculation (IPCC 2006). This assumption suggests all residual emissions will be released within the year the land clearing activity takes place.

The total area to be cleared for each project section and the estimated emissions of GHGs due to land clearing during pipeline, compressor stations and meter stations construction are shown in Table C-13, C-14 and C-15, respectively.

Table C-13: Biomass Burning and Land Clearing Emissions from Pipeline Construction

Land Clearing	Area (ha)	Biomass Burning Emissions (t)				Residual Emissions (t)
		CO_2	CH_4	N_2O	CO_2e	CO_2e
Section 1	916	57,873	221.49	46.44	76,921	208,848
Section 2	802	50,670	193.92	40.66	67,348	182,856
Section 3	907	57,304	219.31	45.98	76,165	206,796
Section 4	735	46,437	177.72	37.26	61,721	167,580
Section 5	811	51,239	196.10	41.12	68,104	184,908
Section 6	793	50,102	191.75	40.21	66,592	180,804
Section 7	835	52,755	201.90	42.33	70,119	190,380
Section 8	856	54,082	206.98	43.40	71,882	195,168
Totals	6,655	420,463	1,609	337	558,852	1,517,340

Table C-14: Construction Land Clearing Emissions for Compressor Stations

Compressor Stations	Area (ha)	Biomass Burning Emissions (t)				Residual Emissions (t)
		CO_2	CH_4	N_2O	CO_2e	CO_2e
Wilde Lake - KP 0	30	1,895	7.3	1.5	2,519	6,840
Sukunka Falls - KP 83	30	1,896	7.3	1.5	2,520	6,840
Mount Bracey - KP 163	30	1,897	7.3	1.5	2,521	6,840
Racoon Lake - KP 249	30	1,898	7.3	1.5	2,522	6,840
Clear Creek - KP 329	30	1,899	7.3	1.5	2,523	6,840
Segundo Lake - KP 417	30	1,900	7.3	1.5	2,524	6,840
Goosly Falls - KP 492	30	1,901	7.3	1.5	2,525	6,840
Titanium Peak - KP 573	30	1,902	7.3	1.5	2,526	6,840
Totals	240	15,191	58.0	12.2	20,182	54,720

Table C-15: Construction Land Clearing Emissions for Meter Stations

Meter Stations	Area (ha)	Biomass Burning Emission Rates (tonnes)				Residual Emissions (tonnes)
		CO_2	CH_4	N_2O	CO_2e	CO_2e
Meter Station - Wilde Lake	6	354	1.4	0.3	470	1,277
Meter Station - Vanderhoof	11	720	2.8	0.6	957	2,599
Meter Station - Kitimat	11	721	2.8	0.6	958	2,599
Totals	28	1,795	6.9	1.4	2,386	6,475

C.6 HEATING

During the construction phase of the pipeline segments, there will be office trailers on site which will be heated. The current construction schedule indicates that multiple heated office trailers could be on site concurrently. Alternatively, it is possible that one trailer will be used and moved to the different sites. The total office trailer heating hours associated with the construction phase has been estimated to be 3,600 hours for each section and compressor station and 1,200 hours for each meter station. These values were estimated based on historical information for similar projects.

The heater emissions were estimated using US EPA AP-42 emission factors (US EPA 1995) as shown in Table C-16. The emission factors for liquefied petroleum gas combustion, specifically for propane fired heaters, were used for GHG emissions. Estimated GHG emissions from heaters used during pipeline, compressor stations and meter stations construction are presented in Table C-17, C-18 and C-19 respectively.

$$Emissions\ (t) = Emission\ Factor\ \left(\frac{lb}{MMBtu}\right) \times Engine\ Power\ \left(\frac{Btu}{hr}\right) \times Operating\ Hours \times Unit\ Conversion\ \left(\frac{MMBtu}{10^6 Btu}\right) \times \left(\frac{t}{2{,}204.6\ lb}\right)$$

Table C-16: Propane Heater Emission Factors

Substance	CO_2	CH_4	N_2O
Emission Factor (lb/MMbtu) [a]	137	0.002	0.01

NOTES:
[a] AP-42 emission factors for propane-fired heater, Section 1.5 of US EPA AP-42. Heating Value for Propane is 91.5 MMBtu/1000 gallon (US) propane.

Table C-17: Propane Heater Emissions for Pipeline Construction

	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Section 1	4.9	0.0001	0.0004	5.0
Section 2	4.9	0.0001	0.0004	5.0
Section 3	4.9	0.0001	0.0004	5.0
Section 4	4.9	0.0001	0.0004	5.0
Section 5	4.9	0.0001	0.0004	5.0
Section 6	4.9	0.0001	0.0004	5.0
Section 7	4.9	0.0001	0.0004	5.0
Section 8	4.9	0.0001	0.0004	5.0
Totals	39.3	0.0006	0.003	40.1

Table C-18: Propane Heater Emissions for Compressor Stations Construction

Compressor Stations	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Wilde Lake - KP 0	4.9	0.0001	0.0004	5.0
Sukunka Falls - KP 83	5.9	0.0001	0.0004	6.0
Mount Bracey - KP 163	6.9	0.0001	0.0004	7.0
Racoon Lake - KP 249	7.9	0.0001	0.0004	8.0
Clear Creek - KP 329	8.9	0.0001	0.0004	9.0
Segundo Lake - KP 417	9.9	0.0001	0.0004	10.0
Goosly Falls - KP 492	10.9	0.0001	0.0004	11.0
Titanium Peak - KP 573	11.9	0.0001	0.0004	12.0
Totals	67.3	0.001	0.003	68.1

Table C-19: Propane Heater Emissions for Meter Stations Construction

Meter Stations	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Meter Station - Wilde Lake	1.6	0.00003	0.0001	1.7
Meter Station - Vanderhoof	2.6	0.00003	0.0001	2.7
Meter Station - Kitimat	3.6	0.00003	0.0001	3.7
Totals	7.9	0.0001	0.0004	8.0

C.7 SUMMARY

GHG emissions from the construction of the pipeline, compressor stations and meter stations are presented in Table C-20.

Table C-20: Total GHG Emissions during Construction

Construction Activity	Emission Rates (tonnes)				Percentage of Total
	CO_2	CH_4	N_2O	CO_2e	
Off-road construction equipment	174,114	10	72	196,614	8.1%
On-road construction equipment	61,702	0.6	0.5	61,878	2.6%
Propane-fired heaters	83	0.001	0.006	85	0.004%
Biomass open burning	437,420	1,674	351	581,391	24%
Land clearing residuals	-	-	-	1,578,535	65.3%
Totals	673,319	1,685	423	2,418,503	100%

C.8 REFERENCES

C.8.1 Literature Cited

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Greenhouse Gas Emissions Technical Data Report

Appendix D
Operations Emissions Inventory

D.1 INTRODUCTION

Project and other related operations are scheduled to commence once the Project facilities are constructed and should continue in excess of 30 years. During the operations phase, there are four components that contribute to the GHG emissions:

- Combustion exhaust
- Fugitive sources
- Natural gas venting
- Aerial patrols and pipeline maintenance.

Methodologies for calculating emissions from above sources are described in the following sections.

D.2 COMBUSTION

Combustion sources are mainly from compressor stations. Meter stations are used to monitor the amount of gas in the pipeline and do not contain any combustion sources. The combustion sources from compressor station include gas turbine compressor engines, generator engines, and boilers. CO_2 emission factors were based on equipment specific-data sheets which provide exhaust flow rates, CO_2 concentrations, and fuel combustion rates. Emissions of CH_4 and N_2O were calculated using Environment Canada emission factors for fuel combustion from Canada's National Inventory Report 1990–2011 (EC 2013a). These emission factors are listed in Table D-1. The stack parameters and emission rates associated with typical boiler, generator engine and compressor engine are summarized in Table D-2. The GHG emissions associated with the operation of stationary combustion equipment for each compressor station are summarized in Table D-3.

The following equation was used to estimate the emissions from CO_2 from gas turbine compressors

$$Emissions\ (t/y) = Exhaust\ Flowrate\ \left(\frac{kg}{s}\right) \times Exhaust\ CO_2\ Concentration\ (\ wt\ fraction) \times Unit\ Conversion \left(\frac{1\ t}{1000kg} \times \frac{3600\ s}{hr} \times \frac{24hr}{d} \times \frac{365\ d}{yr}\right)$$

The following equation was used to estimate the emissions from CO_2 from boilers and generators

$$Emissions\ (t/y) = Emission\ Factor\ \left(\frac{g}{bhp - hr}\right) \times Power\ Rating\ (KW) \times Unit\ Conversion \left(\frac{1.341022hp}{KW} \times \frac{24hr}{d} \times \frac{365\ d}{y} \times \frac{t}{10^6 g}\right)$$

The same equation was used to estimate the emissions from CH_4 and N_2O from turbine compressors, boilers, and generators

$$Emissions\ (t/y) = Emission\ Factor\ \left(\frac{g}{m^3}\right) \times Fuel\ Consumption \left(\frac{10^3 m^3}{d}\right) \times Unit\ Conversion \left(\frac{365\ d}{y} \times \frac{t}{10^6 g}\right)$$

Table D-1: Methane (CH4) and Nitrous Oxide (N2O) Emission Factors for Natural Gas

Emission Factors (g/m^3)	
CH_4	N_2O
0.037	0.033

Table D-2: Stack Parameters and Emission Rates Associated with a Typical Compressor Station

Source Identification (ID)		**STB1a**	**STG1**	**STA1**
Unit Description		Boiler [a]	Power Generator	Compressor
Temporal Variation		Continuous	Continuous	Continuous
Source Type		Point	Point	Point
Capacity (Heat Input) [a]	MMBtu/h	2.4	-	-
Capacity (Heat Input)	MW	-	-	81.2
Power Output	kW	-	776	-
Efficiency	%	75.0	30.6	39.3
Fuel Type		Fuel Gas	Fuel Gas	Fuel Gas
Fuel Consumption at STP (T = 0°C and 1 Atm)	10^3 Nm^3/d	1.46	5.81	186
Stack Dimensions				
Height	m	5.17	5.17	15.8
Inside Tip Diameter	m	0.457	0.254	4.46
Exhaust Parameters				
Exit Velocity	m/s	2.06	45.6	12.9
Exit Temperature	°C	125	616	465
	K	398	889	739
Emission Rate				
CO_2	t/d	3.18	12.1	406
CH_4	t/d	0.0000539	0.000215	0.00688
N_2O	t/d	0.0000481	0.000192	0.00614
CO_2e	t/d	3.19	12.2	408
[a] Based on Higher Heating Value				

Table D-3: Annual GHG Emissions from Stationary Combustion Equipment

Site	Emission Rate (t/y)			
	CO_2	CH_4	N_2O	CO_2e
Wilde Lake Compressor Station	597,672	10.1	9.0	600,685
Sukunka Falls Compressor Station	462,678	7.9	7.0	465,013
Mount Bracey Compressor Station	309,998	5.3	4.7	311,563
Racoon Lake Compressor Station	462,678	7.9	7.0	465,013
Clear Creek Compressor Station	449,414	7.6	6.8	451,680
Segundo Lake Compressor Station	462,678	7.9	7.0	465,013
Goosly Falls Compressor Station	309,998	5.3	4.7	311,563
Titanium Peak Compressor Station	309,998	5.3	4.7	311,563
TOTAL	3,365,115	57	50.9	3,382,094

D.3 FUGITIVE

Fugitive GHG emissions are methane and carbon dioxide leaks from pipeline and system components such as seals, valves and connectors. They were calculated using the Interstate Natural Gas Association of America (INGAA) document entitled “Greenhouse Gas Emission Estimation Guidelines for Natural Gas Transmission and Storage”(2005). This document provides emission factors determined in a 1990 collaborative study completed by the Gas Research Institute and US EPA (GRI/US EPA 1996). The emission factors were calculated per length of pipeline or number of compressor and meter stations. Furthermore, detailed equipment level emission factors for reciprocating and centrifugal compressors were also applied to the fugitive emission estimation. The emission factors are shown in Table D-4, and the fugitive GHG emissions associated with the operation of the pipeline are presented in Table D-5.

Table D-4: Emissions Factors for Fugitive Emissions

Activity Data	Substance	EF	EF Units
Compressor station count	CH_4	135,260	lb CH_4 /station-yr
Compressor station count	CO_2	7,813	lb CO_2 /station-yr
Centrifugal compressor count	CH_4	467,660	lb CH_4 /comp.- yr
Centrifugal compressor count	CO_2	27,014	lb CO_2 /comp.- yr
Meter/Regulator station count	CH_4	61,390	lb CH_4 /station-yr
Meter/Regulator station count	CO_2	3,546	lb CO_2 /station- yr
Protected steel pipeline length	CH_4	15.10	lb CH_4 /mile-yr
Protected steel pipeline length	CO_2	2.20	lb CO_2 /mile-yr

Table D-5: Annual GHG Fugitive Emissions

Site	Emission Rate (t/y)			
	CO_2	CH_4	N_2O	CO_2e
Wilde Lake Compressor Station	49.0	909.9	-	19,156
Sukunka Falls Compressor Station	36.8	697.7	-	14,689
Mount Bracey Compressor Station	24.5	485.6	-	10,222
Racoon Lake Compressor Station	36.8	697.7	-	14,689
Clear Creek Compressor Station	36.8	697.7	-	14,689
Segundo Lake Compressor Station	36.8	697.7	-	14,689
Goosly Falls Compressor Station	24.5	485.6	-	10,222
Titanium Peak Compressor Station	24.5	485.6	-	10,222
Pipeline	0.41	2.82	-	59.6
Meter Station – Wilde Lake	1.61	27.8	-	586
Meter Station - Vanderhoof	1.61	27.8	-	586
Meter Station - Kitimat	1.61	27.8	-	586
TOTAL	275	5,244	0.0	110,397

D.4 VENTING

Vented methane emissions come from a variety of process equipment and operations practices (e.g. blowdown). They are different from fugitive emissions in that emissions are typically voluntary actions associated with plant activities or produced when emergency situations require a rapid reduction of process pressure. Blowdowns are an example of these venting events. Emission factors used in this assessment are also from the INGAA (2005) guideline document. 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. The emission factors are shown in Table D-6. The GHG emissions associated with venting activities are presented in Table D-7.

Table D-6: Emissions Factors for Blowdown and Equipment Venting Events

Activity Data	Emission Source	Substance	EF	EF Units
Compressor Station Count	Blowdown & Venting	CH_4	223,758	lb/station-yr
Pipeline Length	Pipeline Blowdown	CH_4	1,729	lb/mile-yr
M&R Station Count	Blowdown & Venting	CH_4	29,817	lb/station-yr

Table D-7: Annual GHG Emissions from Venting

Site	Emission Rate Per Site (t/y/site)				Total CO_2e Vented Emissions From All Sites (t/y)
	CO_2	CH_4	N_2O	CO_2e	
Compressor stations	-	101.5	-	2,131	17,051
Pipeline	-	323	-	6,780	6,781
Meter stations	-	13.5	-	284	852
TOTAL	0	438	0.0	9,195	24,684

D.5 Aerial Patrols, Surveys and Maintenance Activities

Patrols, surveys, and routine maintenance of the pipeline will be performed by helicopter. While there is a small possibility that a maintenance trip could be done by on-road vehicles when weather does not permit flying, this would be an exception and an option avoided if at all possible due to the increased time involved. Due to the expected infrequency of such an event, the vehicle emissions associated with a maintenance trip of this type were not included in the assessment.

Past TransCanada experience with aerial patrols performed in the northwest section of BC were assumed. These helicopter movements were considered to be the most representative information given that it is the closest area to the Project where TransCanada currently has pipelines. The information regarding maintenance travel was obtained from TransCanada's past experience.

Emissions were calculated as follows:

$$Emissions\ (t) = Emission\ Factor\ \left(\frac{kg\ emitted}{kg\ of\ fuel}\right) \times Annual\ Fuel\ Combusted\ (kg) \times Unit\ Conversion\ \left(\frac{t}{1000kg}\right)$$

Assumptions for helicopter movements are summarized in Table D-8. RH44 helicopters will be used for aerial patrols and operated quarterly with an average speed of 110 to 130 km/hr. A-start helicopters will be used for routine maintenance work, call-outs, valve works, and surveys. To cover each pipeline section in the RSA, the approximate duration of each flight is four hours. Routine maintenance work is scheduled to occur on a monthly basis, call-outs are expected three times annually, and both valve work and surveys are expected to occur on an annual basis.

The GHG emission factors were derived from the Federal Aviation Administration Emissions and Dispersion Modeling System. This model is the industry standard for estimating aircraft emissions. The Dispersion Modeling System contains a database of aircraft specific emission factors and is designed to calculate emissions for take-off, landing, approach, and climb. The model accounts for number of aircrafts, types of aircraft, and climate effects.

The total annual estimated GHG emissions from helicopters during the Project Operations phase are presented in Table D-9.

Table D-8: Operations Helicopter Input Information

Description	Aircraft Type	Surrogate Craft	Aviation Fuel Type	Number of Patrols per Year[a]	Fuel Consumption (l/hr)	cruise speed (km/hr)	Assumed Cruise Time Per Flight (hours)
Aerial Patrols	RH44 helicopter	Robinson R44 Raven	av gas	4	75	120	4
Routine Maintenance Work	A-star helicopter	Hughes 500D	jetb/jeta gas	12	180	120	4
Call-outs and special PM	A-star helicopter	Hughes 500D	jetb/jeta gas	3	180	120	4
Valve work	A-star helicopter	Hughes 500D	jetb/jeta gas	1	180	120	4
CP surveys	A-star helicopter	Hughes 500D	jetb/jeta gas	1	180	120	4

NOTES:
[a] Stantec assumed that the number of flights estimated by TransCanada is for each pipeline segment.

Table D-9: Annual Helicopter GHG Emissions

	Emissions (t)			
	CO_2	CH_4	N_2O	CO_2e
Section 1	36	0.004	0.003	37
Section 2	37	0.004	0.003	38
Section 3	38	0.004	0.003	39
Section 4	39	0.004	0.003	40
Section 5	40	0.004	0.003	41
Section 6	41	0.004	0.003	42
Section 7	42	0.004	0.003	43
Section 8	43	0.004	0.003	44
TOTAL	317	0.03	0.03	326

D.6 SUMMARY

GHG emissions from the operation of the pipeline, compressor stations and meter stations are presented in Table D-10. Total CO_2e emission rates are 3,517,472 t/y. The largest GHG emitter is the Wilde Lake compressor station while the lowest emissions are associated with the meter stations.

Table D-10: Total GHG Emissions from Operations

Site	Emission Rate (t/y)				Percent of Total Project Emissions
	CO_2	CH_4	N_2O	CO_2e	
Wilde Lake compressor station	597,722	1021.5	9.0	621,973	17.7
Sukunka Falls compressor station	462,715	807.1	7.0	481,834	13.7
Mount Bracey compressor station	310,023	592.4	4.7	323,917	9.2
Racoon Lake compressor station	462,715	807.1	7.0	481,834	13.7
Clear Creek compressor station	449,451	806.8	6.8	468,500	13.3
Segundo Lake compressor station	462,715	807.1	7.0	481,834	13.7
Goosly Falls compressor station	310,023	592.4	4.7	323,917	9.2
Titanium Peak compressor station	310,023	592.4	4.7	323,917	9.2
Pipeline	290	326.00	0.03	7,138	0.20
Meter station 1	1.6	41.4	-	870	0.02
Meter station 2	1.6	41.4	-	870	0.02
Meter station 3	1.6	41.4	-	870	0.02
TOTAL	3,365,679	6,477	50.9	3,517,472	100

D.7 REFERENCES

D.7.1 Literature Cited

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Interstate Natural Gas Association of America (INGAA) Guideline. 2005. Greenhouse Gas Emission Estimation Guidelines for Natural Gas Transmission and Storage.

D.7.2 Internet Sites

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Appendix E
Discussion of Alternate Turbine Compressor Equipment for the Coastal GasLink Pipeline Project

E.1 DISCUSSION OF ALTERNATE TURBINE COMPRESSOR EQUIPMENT FOR THE COASTAL GASLINK PIPELINE PROJECT

As Coastal GasLink advances its compressor station engineering plans, consideration is being given to the potential use of General Electric (GE) PGT25+G4 turbine units as an alternative to the Rolls-Royce RB211 turbine units. The configuration of turbines, generators and heaters remains the same as the RB211 configuration. The same methodology described in Section 6 was used to consider whether using an alternative compressor driver would affect the results of the assessment as presented in the Application. This appendix contains the discussion and findings comparing the alternative equipment to the assessment of the Rolls-Royce RB211 turbine units.

E.2 DISCUSSION

The Application includes the assessment of effects of the proposed Project on the atmospheric environment. These effects include the effects on the acoustic environment, air quality and greenhouse gas (GHG) emissions.

E.3 GENERAL ELECTRIC TURBINE CHARACTERISTICS

The GE PGT25+64 sales brochure lists the following key characteristics:

- high reliability and availability traced to previous designs
- high fuel flexibility including natural gas, ethane, synthetic gas, medium BTU gas, liquid fuel, dual fuel (natural gas or liquid)
- dry low emissions from both natural gas and dual fuelling

Turbine specifications of interest include the following:

- Output power from natural gas fueling is 34 MW.
- Dry low emission (DLE) system efficiency at ISO conditions is 41%.
- Emissions control from natural gas combustion includes 25 ppm NO_x concentrations.

E.4 TURBINE CHARACTERISTIC COMPARISONS

An inventory of the operational characteristics of both the General Electric PGT25+G4 turbine unit and the Rolls-Royce RB211 turbine unit is found in Table 6A-1. Where possible, the source of the information is listed. A percentage comparison of the operational values is found in the last column.

Table 6E-1: Comparison of Rolls-Royce RB211 and General Electric PGT25+G4 Characteristics

Model Parameter		Rolls-Royce RB211	RB211 Comments	General Electric PGT25+G4	PGT25+G4 Comments	Value % diff
Load Factor	%	90		90	Assumed equivalent operational load	
Capacity Heat Input	MW equivalent	81.2		74.6	Based on output power and turbine efficiency	-8%
	GJ/h	292.3	Calculated based on MW	268.7	One watt equals 3600 joules per hour	-8%
Power Output	MW	31.9		30.6	Output at 90 % load	-4%
Efficiency (%)		39.3	Provided by Client	41.0	Manufacturer specification	
Fuel Consumption	$10^3 m^3/d$	186.0	Assumed a heating value of 37.7 MJ/m^3	171.0	Assumed a heating value of 37.7 MJ/m^3	-8%
Exhaust Flow Rate	kg/s	94.8		86.7	Manufacturer specification	-8%
	m^3/s	201.1	Calculated based on exhaust gas composition	200.7	Assumed exhaust air density of 0.44 kg/m^3	-6%
		Rolls-Royce RB211	**RB211 Comments**	**General Electric PGT25+G4**	**PGT25+G4 Comments**	**Value % Diff**
Emission Rates (tonnes/day) a)						
CACs	SO_2	0.000995		0.000908	Based on a H_2S composition of 2 ppm and 98% conversion	-9%
	NO_x	0.302		0.310	Manufacturer specification	1%
	CO	0.413		0.189	Manufacturer specification	-54%
	TSP	0.022	Assume TSP equal to $PM_{2.5}$	0.018	Base on AP-42 emission factors	-18%
	PM_{10}	0.022	Assume PM_{10} equal to $PM_{2.5}$	0.018	Same as TSP	-18%
	$PM_{2.5}$	0.022		0.018	Same as PM_{10}	-18%
	VOCs	0.0269		0.0058	Base on AP-42 emission factors	-78%

Table 6E-1: Comparison of Rolls-Royce RB211 and General Electric PGT25+G4 Characteristics (cont'd)

		Rolls-Royce RB211	**RB211 Comments**	**General Electric PGT25+G4**	**PGT25+G4 Comments**	**Value % Diff**
Emission Rates (tonnes/day) [a]						
GHGs	CO_2	406.2	Manufacturer specification and exhaust gas composition	406.88	Manufacturer specification and exhaust gas composition	-2%
	CH_4	0.0069	Based on Environment Canada emission factors	0.0063	Based on Environment Canada emission factors	-8%
	N_2O	0.0061		0.0056		-8%
	CO_2e	408.2	Global warming potential: CO2 =1; CH4=21, N2O=310	369.6	Global warming potential: CO2 =1; CH4=21, N2O=310	-2%

Notes:
a) Assumes compressor inlet temperature of 0°C. Manufacturer specification found: PGT25+G4 Technical Description Gas Turbine, GE Oil and Gas.

Noise emissions at compressor stations are primarily driven by the amount of gas compression that is required. The required compression drives the power rating (and size) of gas turbines as well as the amount of cooling required for the facility. The noise assessment presented in the Application was performed assuming that the compressors would be driven by Rolls-Royce RB211-G62 DLE gas turbines. RB211-G62 has shaft power rating of 30 MW. The slight increase in the power rating of compression packages is not sufficient to alter the potential adverse noise effects originally predicted for Project study areas.

The most dominant noise sources associated with the assessment of compressor stations in the current Project are the aerial coolers. A small increase in the power rating of the compression packages (4 MW per package) will not alter the preliminary estimates of the cooling air flow requirement on which cooler noise emission estimates have been based. Therefore, the proposed changes to gas turbines will not alter the assumptions regarding the aerial coolers and the corresponding noise emissions from those used in the assessment.

Other main sources of noise include gas turbine combustion air inlets, compressor building ventilation systems and lube oil coolers. The noise emissions for this equipment associated with the PGT25+G4-based compression may result in a marginal increase of 0.5 dB as compared to those for the RB211-G62-based compression. Any future changes in equipment noise emissions from those established in the effects assessment presented in the Application will be addressed through final noise mitigation designs and subject to review by the BC Oil and Gas

Commission. If required at that time, the acoustic performance of selected noise control will be enhanced to maintain compliance of all Project facilities.

E.5 FINDINGS

The atmospheric resources assessment documents the potential adverse effects of the proposed Project on the acoustic environment, air quality and GHG emissions. The following summarizes the review of the alternate compressor equipment:

- Noise: The noise generated for each of the turbine and cooler equipment packages is similar. The conclusion “no long-term residual adverse effect” found in Section 6.5 of the Application will remain the same.
- Air quality: The emission estimates for NO_x emissions are similar. For the other CACs, each turbine will be emitting less so the alternate turbine equipment is expected to reduce potential adverse effects on the environment. The characterizations of the residual adverse environmental effects described in Section 6.6 of the Application will remain the same.
- GHG emissions: Each turbine will be emitting approximately 2% less GHGs. The characterizations of the residual adverse environmental effects described in Section 6.7 of the Application will remain the same.

In conclusion, the alternative equipment, General Electric PGT25+G4, when compared to the Rolls-Royce RB211, does not change the conclusions in the atmospheric environment assessment. Therefore, the findings documented in Section 6 of the Application are unchanged.