Greenhouse Gas Management Technical Data Report

LNG Canada Export Terminal

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LNG CANADA
Opportunity for British Columbia. Energy for the world

Joint venture companies

Mitsubishi Corporation

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EXECUTIVE SUMMARY

LNG Canada Development Inc. is proposing to construct and operate a liquefied natural gas (LNG) facility (including an LNG processing and storage site and marine terminal) in the District of Kitimat, British Columbia, and to export LNG from the facility by shipping. This proposed project is called the LNG Canada Export Terminal (the Project).

This technical data report presents the greenhouse gas (GHG) emissions inventory for the Project. The boundaries, methods, and assumptions used to estimate GHG emissions are presented. Sources of GHG emissions arising from activities during construction and operation include:

Construction

- land clearing and decay
- site preparation
- instrumental, mechanical, and electrical installation
- construction of the marine terminal
- on-road transportation, and
- shipping activities (marine vessels and tug boats).

Operation

- eight natural gas fuelled turbines
- four acid gas incinerators
- five flares
- fugitive sources, and
- shipping activities (marine vessels and tug boats).

The GHG emissions arising from activities during decommissioning are only assessed qualitatively because a quantitative assessment is not feasible at this time. Emissions are expected to be small and comparable to construction emissions.

The GHGs released during construction activities for full build-out are estimated to be 255,742 tonnes of carbon dioxide equivalent (CO_2e). The primary source of GHGs during construction originates from land clearing (65% of total construction emissions).

The GHGs released during operation of the Project are estimated to be 4.0 million tonnes (Mt) CO_2e per year on average for at least 25 years. Most GHG emissions (95.2%) originate from stationary combustion (the operation of natural gas-fuelled turbines and the acid gas incinerators).

ACRONYMS AND ABBREVIATIONS

AIR .... Application Information Requirements

BC .... British Columbia

BSFC .... brake specific fuel consumption

CAPP .... Canadian Association of Petroleum Producers

CH_4 .... methane

CO_2 .... carbon dioxide

CO_2e .... carbon dioxide equivalent

EC .... Environment Canada

g .... gram

GHG .... greenhouse gas

GJ .... gigajoule

GWP .... global warming potential

h .... hour

ha .... hectare

HFC .... hydrofluorocarbon

HHV .... higher heating value

hp .... horsepower

IPCC .... Intergovernmental Panel on Climate Change

km .... kilometre

kW .... kilowatt

L .... litre

lb .... pound

LNG .... liquefied natural gas

LNG Canada .... LNG Canada Development Inc.

m^3 .... cubic metres

mol .... mole

Mt .... million tonnes

mtpa .... million tonnes per annum

N/A .... not applicable

N_2O .... nitrous oxide

PFC .... perfluorocarbon

Project .... LNG Canada Export Terminal Project

SF_6 .... sulphur hexafluoride

U.S. EPA .... United States Environmental Protection Agency

TDR .... technical data report

THC .... total hydrocarbons

WCI .... Western Climate Initiative

y .... year

TABLE OF CONTENTS

List of Tables

1 INTRODUCTION

LNG Canada Development Inc. (LNG Canada) is proposing to construct and operate a liquefied natural gas (LNG) facility (including an LNG processing and storage site and marine terminal) in the District of Kitimat, British Columbia (BC), and to export LNG from the facility by shipping. This proposed project is called the LNG Canada Export Terminal (the Project).

The Project will consist of a LNG facility (including a LNG processing and storage site), a marine terminal able to accommodate two LNG carriers, and supporting infrastructure and facilities. At full build-out, the LNG facility will consist of four liquefaction trains, each containing purifying and cooling equipment. The facility will bring in about 119 million cubic metres (m^3) of natural gas per day, of which some will be used for fuel and the rest will be processed into 26 million tonnes per annum (mtpa) of LNG. The Project is expected to operate for a minimum of 25 years.

Project activities and physical works included in the construction and operation inventories are described in the final AIR (BCEAO 2014). These include operation of heavy mobile equipment, vehicles, and marine vessels during construction, as well as combustion sources, production equipment and loading activities during operation. These activities are expected to release GHGs to the atmosphere.

The GHGs are identified as a valued component due to their potential effects on climate change and concerns raised by stakeholders, First Nations, and government agencies. A GHG can be any atmospheric gas that absorbs and re-emits infrared radiation, thereby acting as a thermal blanket for the planet and warming the lower levels of the atmosphere. GHGs are emitted to the atmosphere from a number of natural and anthropogenic (human activity) sources.

This GHG management TDR presents background information, methods, and results of the potential-effects studies conducted for the Project. Professional judgment of the study team and input from consultation with regulators, Aboriginal groups, and the public guided the scope of the study.

2 STUDY AREAS

2.1 Spatial Boundaries

The GHG emissions from Project physical works and activities related to construction and operation are estimated and assessed. Recognizing that GHGs mix well in the atmosphere and disperse from the source, spatial boundaries are assessed at the global level. Further, applicable provincial and federal GHG jurisdictional boundaries and legislation are considered.

2.2 Temporal Boundaries

Based on the current Project schedule, the temporal boundaries are:

- construction: Phase 1 (trains 1 and 2) to be completed approximately five to six years following issuance of permits; subsequent phases (trains 3 and 4) to be determined based on market demand
- operation: minimum of 25 years after commissioning, and
- decommissioning: approximately two years at the end of the Project life.

All project phases from construction to decommissioning are addressed in this GHG management assessment. However, GHG emissions from decommissioning are not quantified because no reasonable estimate of emissions can be determined at this time.

2.3 Administrative and Technical Boundaries

Administrative boundaries for GHG management are those defined by government jurisdictional policies. GHG emissions from the LNG facility and Project shipping (from the pilotage point to the port) are compared with provincial, federal, and global GHG jurisdictional boundaries and, where possible, with reduction targets.

Technical boundaries for the assessment include inherent uncertainty in estimating emission rates from the Project at a preliminary stage of engineering design and preliminary data. This inherent uncertainty, however, does not impede the effects assessment. The emissions estimates used in the assessment are conservatively high to capture worst-case, full build-out conditions.

3 METHODS

The GHG assessment for the Project is based on accounting and reporting principles of the GHG protocol developed by the World Resource Institute and the World Business Council for Sustainable Development (2004). This protocol is an internationally accepted accounting and reporting standard for quantifying and reporting GHG emissions. The guiding principles of the protocol for compiling an inventory of GHG data are relevance, completeness, consistency, transparency, and accuracy.

The total quantities of GHGs released to the atmosphere are normally reported as CO_2e in order to express the effects of different GHGs as a single number. Multiplying each GHG by its global warming potential (GWP) converts various gases into equivalent amounts of CO_2. The GWP of the main GHGs are: carbon dioxide (CO_2) = 1.0; methane (CH_4) = 25; nitrous oxide (N_2O) = 298; and sulphur hexafluoride (SF_6) = 23,900. Hydrofluorocarbon (HFC) gases range from 140 to 11,700, and perfluorocarbon (PFC) gases range from 6,500 to 9,200 (IPCC 2007)[1].

The following GHGs are excluded from the GHG assessment:

- SF_6 - In Canada, SF_6 is most commonly used in industrial processes as a cover gas or insulating gas. Insulating gas used in the electric breakers for the Project may contain SF_6; however, these systems are designed not to leak, and therefore SF_6 was not considered further in the assessment.
- HFCs - The main sources of HFCs are refrigerant fluids in industrial processes. HFCs are not included in the assessment because the Project is designed to prevent releases (if any).
- PFCs - This substance is primarily used in the manufacturing industry and is found in consumer products. These products might be used by the oil and gas industry in small quantities; however, the facility is not expected to release measurable amounts of PFCs.

The following GHGs are included in the GHG assessment:

- CO_2
- CH_4
- N_2O

On this basis, CO_2e emissions for the Project are calculated as:

$$CO_2e = (\text{mass } CO_2 \text{ x } 1.0) + (\text{mass } CH_4 \text{ x } 25) + (\text{mass } N_2O \text{ x } 298)$$

[1] Using GWP from the 4th Intergovernmental Panel on Climate Change (IPCC) assessment report is in line with the Environment Canada (EC) guidance.

The GHG assessment focusses on the Project's main GHG-producing activities, which occur during the construction and operation phases (Table 3.0–1). GHG emissions from decommissioning are not quantified because a reasonable estimate of emissions cannot be determined at this time. This approach aligns with the Canadian Environmental Assessment Agency (2003) guideline, which suggests assessing only relevant GHG emissions that are potentially important and reasonably foreseeable.

Table 3.0-1: List of Activities Used for Greenhouse Gas Estimates

Phase	Main Activities
Construction	▪ Land clearing ▪ Site preparation ▪ Instrumental, mechanical, and electrical installation ▪ Marine terminal construction ▪ On road transportation ▪ Shipping activities along the channel
Operation	▪ Gas turbines ▪ Incinerators ▪ Flaring ▪ Fugitive emissions ▪ Shipping activities along the channel
Decommissioning	▪ Only assessed qualitatively

Most GHGs are quantified using methods presented in the Western Climate Initiative (WCI) *Final Essential Requirements of Mandatory Reporting* (WCI 2011). Methods for estimating emissions from shipping activities (from pilotage point to the port) are guided by those used for port-related emission inventories (ICF Consulting 2009). Land-clearing emissions are based on emission factors from Dymond (2013); construction emissions related with the installation and site preparation are based on emission factors from the United States Environmental Protection Agency (U.S. EPA) NONROAD 2008a model (U.S. EPA 2009, 2010), as well as on emission factors from EC's *National Inventory Report* (EC 2014). On road transportation related emissions are based on the Canadian Mobile6.2c version of the U.S. EPA Mobile6.2 Vehicle Emission Model (U.S. EPA 2004).

An operating average of 344.5 onstream days a year is considered in the emission inventory. Further, the CO_2 content of the feed gas is assumed to be 0.8 mol%, which is based on a three year average of the two closest receipt points (Saddle Hills and Pipestone) on the TransCanada PipeLines Limited Nova Gas Transmission System (Table 3.0-2). Gas compositions presented in Table 3.0-2 represent best knowledge of LNG Canada at the point of this assessment.

Table 3.0-2: Gas Analysis

Gas Analysis	Acid Gas to Incinerator	Fuel Gas for Incinerator	Pilot Gas	Fuel Gas for Turbine	Feed Gas
	Mol fraction in gas stream				
Helium (He)	-	-	-	-	0.0002
Nitrogen (N)	-	0.1500	0.0031	0.0402	0.0055
Carbon dioxide (CO_2)	0.8749	-	0.0200	0.0008	0.0081
Hydrogen sulfide (H_2S)	0.0005	-	-	-	-
Methane (CH_4)	0.0544	0.8500	0.9235	0.9526	0.9215
Ethane (C_2H_6)	0.0322	-	0.0398	0.0044	0.0443
Propane (C_3H_8)	0.0033	-	0.0094	0.0013	0.0134
Iso-butane (C_4H_{10})	0.0023	-	0.0014	0.0002	0.0021
Normal-butane (C_4H_{10})	0.0012	-	0.0015	0.0003	0.0029
Iso-pentane (C_5H_{12})	0.0007	-	0.0004	0.0001	0.0007
Normal-pentane (C_5H_{12})	0.0007	-	0.0004	0.0001	0.0006
Hexane (C_6H_{14})	0.0009	-	0.0003	0.0001	0.0005
Heptane (C_7H_{16})	0.0008	-	0.0002	-	-
Benzene (C_6H_6)	0.0007	-	-	-	-
Toluene ($C_7H_8(C_6H_5CH_3)$)	0.0012	-	-	-	-

NOTE:
- denotes concentration is below detection level or negligible.

GHG emissions are estimated for the full build-out scenario, which includes four trains and two berths at the marine terminal (Phase 1: two trains, subsequent phases: two additional trains). Where estimates are only available for Phase 1, emissions are conservatively doubled to capture the full build-out scenario.

4 GHG EMISSIONS DURING CONSTRUCTION

Project activities during construction listed in Table 3.0-1 will result in releases of GHGs to the atmosphere. The equipment inventories provided in this Section are commonly associated with these activities and are those expected to release GHG emissions (i.e., equipment with internal combustion engines). The list of equipment is a preliminary estimate only and is not based on actual equipment planned.

Detailed estimates of the type, number, and total operating hours of off-road and on-road construction and transportation equipment, and marine activity are based on equipment specifications, historical data, equipment rates developed for similar projects, and input from LNG Canada. The equipment lists and operational schedules are based on the best available information at the time of this assessment. Construction emission estimates consider the full build-out scenario. To capture emissions for the full build-out scenario (four trains), emissions related to instrumental, mechanical, and electrical installations, as well as marine construction have been doubled because the preliminary equipment use estimates are only available for Phase 1. Hence, it is conservatively assumed that subsequent phases will emit the same amount as Phase 1.

4.1 Land Clearing

Site clearing will involve removal of trees, other vegetation, and topsoil. Land clearing, as well as subsequent decay, will release GHGs to the atmosphere. Timber salvage will be maximized in accordance with a timber harvest plan. Timber that cannot be salvaged will be donated to local communities.

To estimate CO_2e emissions related to land clearing, emission and decay factors for the Skeena ecoregion from Dymond (2013) are used (Table 4.1-1). Areas of the Project footprint with salvageable timber have a reduced average CO_2e emission factor because it has been assumed that 25% of the total stored carbon will be retained in the post-processed wood (not emitted). The remaining biomass (including debris, stumps, and unused portions of the salvaged timber) has been assumed to be burned offsite; therefore, the uproot and burn emission factor is applied, with 25% of carbon assumed stored. In areas where little to no salvageable timber has been identified, it is assumed that all stored carbon within the biomass is emitted and therefore the uproot and burn emission factor is applied. It should be noted that open burning of debris and stumps will be avoided onsite.

Table 4.1-1: Open Burning and Decay Emission Factors for Ecoregion and Process

Ecoregion	Average tonnes CO_2e/ha	Process
Skeena	342	Uproot and burn[a] (all harvested carbon assumed emitted)
	309	Uproot and burn[a] (25% of harvested carbon assumed stored)
	228	Decay for the following 19 years

NOTE:

[a] Even though no open burning will occur at the Project site, the uproot and burn emission factors have been applied instead of the uproot and decay emission factors because the biomass will be cleared from the site and not left onsite to decay. According to methods in Dymond (2013), the uproot and burn emission factors are applicable in this scenario.

SOURCE: Dymond (2013)

Based on the terrestrial ecosystem mapping (see Vegetation TDR for information on the sources and limitations of the mapping) (Stantec Consulting Ltd. 2014a), the total footprint of the LNG facility is 421.3 hectare (ha), which includes developed areas, areas covered by water, vegetated areas and potential tree clearing areas. 71% (297.9 ha) of the total footprint is currently vegetated (mature, young, and immature forests, as well as woody shrubs and low-lying vegetation). Of the vegetated area, 87.8 ha are considered to contain merchantable timber, and 210.1 ha are considered to contain non-merchantable timber (young and immature forest as well as herb and low-lying vegetation) (Table 4.1-2). Since land clearing in the potential tree clearing area will be selective, it is assumed that immature forest and shrub (1.1 ha) will not be cleared. The uproot and burn emission factor that assumes 25% of harvested carbon is stored is applied to the merchantable timber (87.8 ha). The uproot and burn emission factor that assumes all harvested carbon is emitted is applied to the non-merchantable timber area (209 ha, this excludes 1.1 ha of immature forest and shrub). The decay emission factor, which accounts for 19 years of decay, is applied to the entire cleared vegetated area (296.8 ha). As per the Tier 1 approach in the Intergovernmental Panel on Climate Change *Guidelines for National GHG Inventories* and *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC 2003, 2006), it is assumed that decay emissions occur during the construction phase (i.e., the year of the disturbance) and will not occur during the operation phase.

Table 4.1-2: Vegetated Area in the Project Facility Footprint

Category	Facility Footprint(ha])	Potential Tree Clearing Area (ha)	Project Footprint Sum (ha)	Proportion of Total Footprint (%)
Merchantable timber (approximately >80 years old)	77.2	10.6	87.8	21%
Young forest (approximately 50 to 80 years old)	112.9	9.5	122.5	29%
Immature forest and shrub (<50 years old)	61.1	1.1	62.2	15%
Herb and low-lying vegetation	25.5	0.0	25.5	6%
Total vegetated	276.7	21.2	297.9	71%
Total unvegetated[a]	122.9	0.6	123.5	29%
Total Footprint	**399.5**	**21.8**	**421.3**	**100%**

NOTE:
[a] Non-vegetated area of footprint includes sedge/herb-dominated climax communities, anthropogenic areas, and water (river, pond, ocean).
Values may not sum to totals shown because of rounding.
SOURCE: Based on terrestrial ecosystem mapping

Emissions related to land clearing are estimated using the following equation:

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

Land-clearing activities during the construction phase are estimated to emit 166,137 tonnes CO_2e (Table 4.1-3).

Table 4.1-3: GHG Emissions from Land Clearing and Residual Decay – Construction

Process	Emissions (tonnes CO_2e)
Land clearing emissions (year 0)	98,482
Residual decay (for 19 years after)	67,654
Total	**166,137**

4.2 Site Preparation

All the off-road equipment is assumed to be powered with diesel fuel. The engine type, number of units, power rating, and total operating hours of the equipment is based on manufacturer specifications, experience with similar projects, and input from LNG Canada. The equipment is assumed to be manufactured in 2008 or later. Some highly specialized equipment, such as cranes, might have been manufactured before 2008. However, it is assumed the emissions sources, such as equipment motors, have been replaced or retrofitted with more recent parts.

Emission standards for off-road engines vary with model year because of changing regulations. Canada has adopted the U.S. 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 (hp) rating in 1996. Tier 2 standards began in 2001, and Tier 3 standards began in 2006. For this assessment, it is assumed that most of the equipment has Tier 3 engines.

The load factors considered in this assessment are a ratio of actual engine output relative to maximum rated output. The load factors used in this study are based on the U.S. EPA NONROAD 2008a model (U.S. EPA 2009, 2010). This is the standard model used in Canada to estimate emissions from non-road equipment.

Each section lists the off-road diesel equipment that is assumed to be used for Project construction. Emission factors developed using the U.S. EPA NONROAD 2008a model are matched to construction equipment for the Project. For some equipment, exact matches are not available, so emission factors are selected for similar equipment with similar-sized engines and similar function.

The U.S. EPA NONROAD 2008a model accounts for the degradation of an engine performance over its lifetime resulting from 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 resulting from transient operation of the engines. While developing emission factors, non-road engines are primarily tested with steady-state tests, which may not represent real-world conditions. A transient adjustment factor is included in the model because actual emissions might be greater because of differences in load, engine speed, and other differences attributable to transient demand. The methods used to reach the adjusted CO_2 emission factor and the adjusted brake specific fuel consumption (BSFC) are identical to the air quality assessment and can be found in the Air Quality TDR (Stantec Consulting Ltd. 2014b). Emission factors for CH_4 and N_2O emissions are from EC's *National Inventory Report* (EC 2014) (Table 4.2-1)

Table 4.2-1: CH_4 and N_2O Emission Factors

Mode	Emission Factor (g/L fuel)	
	CH_4	N_2O
Off-road diesel	0.15	1.1

SOURCE: EC (2014)

Site preparation equipment includes compactors, dozers, excavators, and graders (Table 4.2-2). CO_2, N_2O, and CH_4 emissions associated with use of this equipment are calculated based on the following equations:

$$CO_2\ Emissions\ (tonnes) = Total\ Operating\ Time\ (h) \times Engine\ Power\ (hp) \times Load\ Factor \times Adjusted\ Emission\ Factor\ \left(\frac{g}{hp\ h}\right) \times Unit\ Conversion\ \left(\frac{tonnes}{10^6 g}\right)$$

$$N_2O\ and\ CH_4\ Emissions\ (tonnes) = Total\ Operating\ Time\ (h) \times Engine\ Power\ (hp) \times Load\ Factor\ \times BFSC\ \left(\frac{lb}{hp \times h}\right) \times Unit\ Converstion\ \left(\frac{453.6\ g}{lb}\right) \times Emission\ Factor\ \left(\frac{g}{l}\right) \times Unit\ Conversion\ \left(\frac{Diesel\ Density}{850\ \ g/l}\right) \times Unit\ Conversion\ \left(\frac{tonnes}{10^6 g}\right)$$

Table 4.2-2: Off-Road Equipment List for Site Preparation

Equipment	Number of Equipment	Total Operation Hours	Engine Power (hp)	Load Factor (%)	Adjusted BSFC (lb/hp*h)	Adjusted CO_2 Emission Factor (g/hp*h)
Compactor	5	30,600	100	43	0.408	589.7781
Dozer – 450 kW Class	5	30,600	600	59	0.371	535.7854
Loader (6 m^3)	6	36,720	275	59	0.433	625.2535
Grader 24M	3	18,360	530	59	0.371	535.7847
Excavator	6	36,720	335	59	0.371	535.7834
Track drill	4	24,480	425	43	0.367	530.5074
Pick-up truck	5	30,600	225	59	0.371	535.7220
Dump truck (10 m^3)	10	61,200	325	59	0.371	535.7794
Dump truck (20 m^3)	12	73,440	511	59	0.371	535.7794
Water truck	2	288	750	59	0.371	535.7794

Estimated GHG emissions from site preparation during construction are listed in Table 4.2-3.

Table 4.2-3: GHG Emissions from Site Preparation during Construction

Source	Emissions (tonnes)			
	CO_2	CH_4	N_2O	CO_2e
Site preparation	20,190	1.12	8.20	22,661

4.3 Instrumental, Mechanical, and Electrical Installation

Methods and assumptions regarding off-road equipment used during the installation phase are the same as outlined in Section 4.2 for site preparation. The engine type, number of units, power rating, and total operating hours of the equipment is based on manufacturer specifications, experience with similar projects, and input from LNG Canada. See Table 4.3-1 for the inventory list of equipment used during installation.

Table 4.3-1: Off-Road Equipment List for Instrumental, Mechanical, and Electrical Installation

Equipment	Number of Equipment	Total Operation Hours	Engine Power (hp)	Load Factor (%)	Adjusted BSFC (lb/hp*h)	Adjusted CO_2 Emission Factor (g/hp*h)
Welding rig	12	142,157	40	21	0.481	694.5748
Gene boom manlift	6	71,078	60	21	0.481	693.9435
Crane, 120 tonnes	1	11,846	469	43	0.367	530.5037
Crane, 90 tonnes	1	11,846	339	43	0.367	530.5037
Crane, 60 tonnes	1	11,846	229	43	0.367	530.4459
Crane, 30 tonnes	1	11,846	179	43	0.367	530.4459
Compressor	2	23,693	475	43	0.367	530.5050
Filter trucks	5	720	202	59	0.371	535.7220
Aggregate haul trucks	10	1,440	375	59	0.371	535.7794
Cement trucks	10	1,440	350	59	0.371	535.7794
X-ray truck	1	144	325	59	0.371	535.7794

Estimated GHG emissions from installation activities during construction are listed in Table 4.3-2. In order to capture full build out emissions, the estimates are doubled since the equipment information provided by LNG Canada only applied to Phase 1.

Table 4.3-2: GHG Emissions from Installation during Construction

Source	Emissions (tonnes)			
	CO_2	CH_4	N_2O	CO_2e
Instrumental, mechanical, and electrical installation (Phase 1)	7,695	0.43	3.13	8,637
Instrumental, mechanical, and electrical installation (subsequent phases)	7,695	0.43	3.13	8,637
Total	**15,390**	**0.85**	**6.25**	**17,274**

NOTE:
Values may not sum to totals shown because of rounding.

4.4 Marine Terminal Construction

The approach to estimating emissions of onshore off-road equipment (Table 4.4-1) used during construction of the marine terminal is the same as that used for off-road equipment used for site preparation and installation.

Table 4.4-1: Onshore Off-Road Equipment List for the Marine Terminal Construction

Equipment	Number of Equipment	Total Operation Hours	Engine Power (hp)	Load Factor (%)	Adjusted BSFC (lb/hp*h)	Adjusted CO_2 Emission Factor (g/hp*h)
Piling driver	2	2,400	235	43.0	0.367	530.4520
Dozer – 200 kW Class	3	7,200	275	59.0	0.371	535.7235
Medium crane (22 tonnes)	3	7,200	160	43.0	0.367	530.4459
Drill rig (12.5 tonnes)	3	7,200	196	43.0	0.367	530.4520
Large crane (100 tonnes)	2	4,800	390	43.0	0.367	530.5037

Methods used to estimate emissions of offshore equipment used during construction of the marine terminal follow those of ICF Consulting (2009). GHG emissions from offshore equipment (Table 4.4-2) are estimated using the following equation:

$$Emissions\ (tonnes) = Total\ Operating\ Time\ (h) \times Engine\ Power\ (kW) \times Load\ Factor \times Emission\ Factor\ \left(\frac{g}{kW\ h}\right) \times Unit\ Conversion\ \left(\frac{tonnes}{10^6 g}\right)$$

Table 4.4-2: Offshore Equipment List for the Marine Terminal Construction

Equipment	Number of Equipment	Total Operation Hours	Engine Power (kW)	Load Factor (%)	Emission Factor (g/kW*h)		
					CO_2	CH_4	N_2O
Dredge vessel Jan De Nul (2,461 tonnes)	1	2,400	1,909	69	690	0.09	0.02
Tug boat with material barge Hornbeck Offshore	2	4,800	746	31	690	0.09	0.02

Estimated total GHG emissions from onshore and offshore construction activities for the marine terminal are listed in Table 4.4-3.

Table 4.4-3: GHG Emissions from Marine Terminal Construction

Source	Emissions (tonnes)			
	CO_2	CH_4	N_2O	CO_2e
Onshore construction (Phase 1)	2,107	0.12	0.86	2,365
Onshore construction (subsequent phases)	2,107	0.12	0.86	2,365
Offshore construction (Phase 1)	2,947	0.38	0.09	2,981
Offshore construction (subsequent phases)	2,947	0.38	0.09	2,981
Total	**10,108**	**1**	**1,88**	**10,694**

NOTE:
Values may not sum to totals shown because of rounding. In order to capture full build out emissions, the estimates are conservatively doubled since the equipment information provided by LNG Canada only applied to Phase 1

4.5 Shipping Activities

Module carriers and break bulk carriers, as well as assisting tug boats, are used to transport construction equipment and material to the site. U.S. EPA methodologies for preparing mobile source port-related emission inventories (ICF Consulting 2009) are used to estimate marine construction emissions. The estimates represent the emissions of the vessels while in port and while travelling at 12 knots (22.2 kilometer (km)/h) along the channel between the Kitimat Harbour Terminal and the pilot boarding location at or near Triple Island. A total of 200 vessels and 500 barges are assumed to be used during construction to reach full build-out conditions. In addition, 500 tug boats are expected to assist during maneuvering time. Module carriers are assumed to stay in port for a week (loading time per carrier: 168 hours), and break bulk carriers only stay in port for 3 days (72 hours) (Table 4.5-1).

Table 4.5-1: Marine Vessel Characteristics

Feature	Carrier Type		Tug Boat with Material Barge
	Break Bulk Carriers	Module Carriers	
Manufacturer/Model	Austral Asia Line/A-Class	Bigroll/MC Class	Seaspan/Cavalier
Main engine power rating (kW)	11,620	8,775	1,268
Auxiliary engine power rating (kW)	975	1,000	N/A
Number of visit during construction phases	130	70	500 tugs in total
Total time of maneuvering per visit (h)	2	3	2–3
Total time of loading per visit (h)	72	168	N/A
Fuel type	Marine gas oil	Marine gas oil	Diesel
Distance travelled along Douglas Channel (km) (one way)	289.7		289.7
Shipping speed along the channel (km/h)	22.2 (12 knots)		22.2 (12 knots)
Shipping time along the Channel (h) (one way)	13		13

The emission factors, load factors and the adjustment factors for the CO_2 emission factor for the main engine emissions follow the ICF Consulting method (2009). Starting January 2015, vessels travelling within the North American Emission Control Area will be required to use fuel with a maximum sulphur limit of 0.1 wt% (MARPOL 2008). The emission factors are based on this new fuel requirement and are in units of emissions per units of energy.

The CO_2 emission factor adjustment factor depends on the calculated load factor. The load factor is expressed as a percentage of the vessel's total propulsion power, which is based on the propeller law (a ratio between the actual speed and the maximum speed of the carriers).

Emissions are then estimated based on the energy-based emission factors, together with the activity profile for each vessel (Table 4.5-1 and

).

$$
\begin{aligned}
&Emissions\ (tonnes)\\
&\quad = Power\ Rating\ (kW) \times Load\ Factor \times Emission\ Factor\ \left(\frac{g}{kWh}\right)\\
&\quad \times CO_2\ Emission\ factor\ adjustment\ factor^{*}\ \times Loading\ time\ (h)\\
&\quad \times Number\ of\ Vessel\ Visits \times Unit\ Conversion\ \left(\frac{1\ tonne}{10^6 g}\right)
\end{aligned}
$$

* The CO_2 emission factor adjustment factor was only applied to the calculations of CO_2 emissions.

All vessels during construction are assumed to be Canadian registered and are hence considered domestic shipping and included in the construction total. Estimated GHG emissions from shipping activities during construction to reach full build-out are listed in Table 4.5-3.

Table 4.5-2: Marine Vessel Emission Factors

Emission Factor	Break Bulk/Module Carrier		Tug Boat
	Main Engine	Auxiliary Engine	
Load factor during maneuvering	0.14 (break bulk carrier) 0.15 (module carrier)	0.33 (maneuvering) 0.26 (hotelling)	0.31
Load factor during shipping	0.47 (break bulk carrier) 0.51 (module carrier) (reduced speed zone)	0.28 (reduced speed zone)	
CO_2 (g/kWh)	588.79	690.71	690.00
Adjustment factor for CO_2 during maneuvering	1.11 (break bulk carrier) 1.08 (module carrier)	N/A	N/A
Adjustment factor for CO_2 during shipping	1	N/A	N/A
N_2O (g/kWh)	0.031	0.031	0.02
CH_4 (g/kWh)	0.006	0.004	0.09

Table 4.5-3: Total GHG Emissions from Shipping Activities during Construction

Source	Emissions (tonnes)			
	CO_2	CH_4	N_2O	CO_2e
Vessels	21,046	0.19	1.07	21,369
Tug boats	1,733	0.23	0.05	1,754
Total domestic marine	**22,779**	**0.42**	**1.12**	**23,123**

4.6 On Road Transportation

On road transportation includes LNG Canada related shuttle bus movements transporting workers from the airport to the workforce accommodation centre(s) and from the workforce accommodation centre(s) to the facility and back. It also includes small vehicle usage on site (pickup, SUV, car, van). For the full build out scenario, the following movements are assumed:

- 60 bus movements between Terrace airport and the camp site (~56 km one way)
- 700 bus movements between camp and facility (3 km one way), and
- 1,000 small vehicle movements on site (3 km one way).

Movements are considered per day and represent one way; therefore, distances are doubled to compensate for round-trips. Movements are assumed to occur at 365 days a year during the construction period. Emission factors from Mobile6.2C, which is the Canadian version of the U.S. EPA Mobile6 model (U.S. EPA 2004), for buses and small vehicles are listed in Table 4.6-1.

Table 4.6-1: Emission Factors for On Road Transportation

Transportation Type	Emission Factor (g/km)		
	CO_2	CH_4	N_2O
Shuttle bus service	1,003.017	0.012	0.008
Onsite pickup trucks	487.652	0.004	0.004

SOURCE: U.S. EPA (2004)

Emissions of on road transportation are calculated as outlined below:

$$Emissions\ (tonnes) = Total\ Distance\ (km) \times Emission\ Factor\ \left(\frac{g}{km}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{10^6 g}\right)$$

Estimated GHG emissions from on road transportation during construction for the full build-out scenario are listed in Table 4.6-2.

Table 4.6-2 Total GHG Emissions from On Road Transportation during Construction

Source	Emissions (tonnes)			
	CO_2	CH_4	N_2O	CO_2e
Buses	12,373	0.15	0.10	12,406
Small vehicle	3,437	0.03	0.03	3,447
Total:	**15,810**	**0.18**	**0.13**	**15,854**

NOTE:
Values may not sum to totals shown because of rounding.

4.7 Summary of Construction GHG Emissions

Construction emissions include site preparation, land clearing, installation, construction of the terminal, shipping activities of delivering vessels (from pilotage point to the port) and emissions from on road transportation. Total construction-related emissions amount to 255,742 tonnes CO_2e. Quantities of GHGs released during construction of the LNG facility are summarized in Table 4.7-1. These estimates represent emissions of the construction activities required for the full build-out scenario. Emissions related to land clearing represent most of the GHG construction emissions (65%). Shipping activities and site preparation are the second and third largest emission sources (9% and 8.9%, respectively).

Table 4.7-1: GHG Emissions from the Construction Phase

Source	Emissions (tonnes)				Percent of Total Operation Emissions (%)
	CO_2	CH_4	N_2O	CO_2e	
Land clearing	-	-	-	166,137	65
Site preparation	20,190	1.12	8.20	22,661	8.9
Installation (Phase 1)	7,695	0.43	3.13	8,637	3.4
Installation (subsequent phases)	7,695	0.43	3.13	8,637	3.4
Marine terminal construction (Phase 1)	5,054	0.50	0.94	5,347	2.1
Marine terminal construction (subsequent phases)	5,054	0.50	0.94	5,347	2.1
Shipping activities – domestic marine	22,779	0.42	1.12	23,123	9.0
On road transportation (bus, small vehicle)	15,810	0.18	0.13	15,854	6.2
Total	**84,276**	**3.57**	**17.58**	**255,742**	**100**

NOTE:

Since the equipment numbers and operation hours were given for Phase 1 only, installation and marine construction activities have been doubled in order to conservatively capture the emissions related with the construction to reach full build out.

5 GHG EMISSIONS DURING OPERATION

The operation phase will commence once the Project facilities are constructed and is proposed to continue for at least 25 years. Several Project operation activities will result in GHG emissions (Table 3.0-1).

Fugitive emissions are considered unintentional releases and differ from venting emissions, which are usually voluntary releases of uncombusted gas. Vented CH_4 emissions are associated with facility maintenance activities or are produced when emergency situations require a rapid reduction of system pressure. LNG Canada has a strict no venting policy, except where required for safe operations. Thus, emissions are not expected from this activity, and they are not included in the assessment.

Methods for estimating emissions from operational activities are described in the following Sections.

5.1 Natural Gas-Fuelled Turbines

Each liquefaction processing train contains two gas turbines. Within the four-train scenario, there will be a total of eight natural gas-fuelled turbines.

Quantities of GHGs released to the atmosphere are estimated based on equipment-specific fuel consumption rates and fuel-specific emission factors. A natural gas consumption rate of 5.015 kg/s per turbine was provided by LNG Canada. This rate was based on an engine testing scenario that reached an output rating of 93.4 megawatts. This power rating is assumed to be the maximum load that the unit will be operated at. Emission factors for CH_4 and N_2O are taken from the WCI (2011) *Final Essential Requirements of Mandatory Reporting* (Table 5.1-1). The CH_4 and N_2O emissions are calculated based on the WCI subsection WCI.24 (WCI 2011) as follows:

$$CH_4\ or\ N_2O\ Emissions\ \left(\frac{tonnes}{y}\right) = Fuel\ \left(\frac{m^3}{h}\right) \times Operation\ duration\ \left(\frac{h}{y}\right) \times Emission\ Factor\ \left(\frac{g}{m^3}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{10^6\ g}\right)$$

Table 5.1-1: CH_4 and N_2O Emission Factors for Gas Turbine Emissions

GHG	Emission Factor (g/m^3)	Method
CH_4	0.037	WCI.24, emission factors from WCI.20 Table 20-4: Industrial Methane Emission Factor for Natural Gas
N_2O	0.033	WCI.24, emission factors from WCI.20 Table 20-4: Industrial Methane Emission Factor for Natural Gas

SOURCE: WCI (2011)

CO_2 emissions from the gas turbines are calculated based on a combination of Canadian Association of Petroleum Producers (CAPP 2003) and WCI (2011) methods. This approach is equivalent to WCI.23, Methodology 3 (WCI 2011). The CO_2 emissions are calculated based on the following equation:

$$CO_2\,Emissions\left(\frac{tonnes}{y}\right) = Fuel\left(\frac{m^3}{h}\right) \times Operation\ Duration\left(\frac{h}{y}\right) \times Emission\ Factor\left(\frac{g\ CO_2}{m^3}\right) \times Unit\ Conversion\left(\frac{1\ tonne}{1{,}000\ kg}\right)$$

A site-specific emission factor (Table 5.1-2) is calculated based on the carbon content of a fuel gas analysis provided by LNG Canada (Table 3.0-2). CAPP's (2003) *Calculating Greenhouse Gas Emissions Guide* is used to determine the CO_2 emission factor based on the following equation:

$$CO_2\ Emission\ Factor\left(\frac{kg\ CO_2}{m^3}\right) = [(a + 2b + 3c + 4d + 5e + f) \times 44.01]/23.64$$

NOTE: a to f represent carbon mole fractions of the fuel gas.

Table 5.1-2: CO_2 Emission Factor for Natural Gas Turbines

GHG	Emission Factor (g/m^3)	Methodology
CO_2	1,804.4	Using site-specific GHG reporting emission factor (CAPP 2003)

Based on these calculations, one turbine is estimated to release 384,071 tonnes CO_2e. At full build-out conditions, with four trains (eight gas turbines), the annual CO_2e emissions result in 3,072,570 tonnes CO_2e (Table 5.1-3).

Table 5.1-3: Annual GHG Emissions from the Gas Turbines

Source	Emission Rates (tonnes/y)			
	CO_2	CH_4	N_2O	CO_2e
1 natural gas turbine (GE LMS 100)	381,795	7.8	6.9	384,071
Total for 4 trains (8 turbines)	**3,054,358**	**63**	**56**	**3,072,570**

NOTE:
Values may not sum to totals shown because of rounding.

5.2 Acid Gas Incinerators

Each liquefaction processing train contains one acid gas incinerator. Within the four-train scenario, there will be a total of four incinerators.

The incinerators burn acid gas, predominantly CO_2 and sulphur compounds, that has been removed from the feed gas (natural gas). Fuel volumes of acid gas and fuel gas are based on the flow rates, operation days (344.5 days), and densities provided by LNG Canada. Emissions are calculated separately for acid gas and fuel gas, and follow WCI.363 (WCI 2011).

The emission calculations considered a conservative destruction efficiency of 98% and incorporated the carbon mole fractions of the fuel gas and acid gas (Table 3.0-2). Fuel gas and acid gas CO_2 emission factors are calculated based on CAPP (2003) (see Section 5.1). Emissions of N_2O also follow methods in WCI.363 (WCI 2011), but use a WCI default emission factor and site-specific higher heating value (HHV) of the acid gas and fuel gas (Table 5.2-1).

Table 5.2-1: Variables Used to Calculate Incinerator Emissions

Variable	Value	Unit
Density of CH_4	0.678	kg/m^3
Density of CO_2	1.861	kg/m^3
N_2O flaring emission factor	9.52E-05	kg/GJ
Destruction efficiency	98	%
Flow rate for fuel gas	0.043	kg/s
Flow rate for acid gas	5.34	kg/s
CO_2 emission factor for fuel gas	1,582.42	gCO_2/m^3
CO_2 emission factor for acid gas	299.15	gCO_2/m^3
HHV for N_2O calculations (fuel gas)	32.05	GJ/m^3
HHV for N_2O calculations (acid gas)	5.46	GJ/m^3

The following equations are used to quantify non-combusted CH_4, non-combusted CO_2, hydrocarbons converted to CO_2, and N_2O emissions.

$$Non-Combusted\ CH_4\ Emissions\ \left(\frac{tonnes}{y}\right) = Fuel\ Volume\left(\frac{m^3}{y}\right) \times (1 - Combustion\ Efficiency) \times\ CH_4 Mole\ Fraction \times Density\ of\ \ CH_4\left(\frac{kg}{m^3}\right)\ \times Unit\ Conversion\ \left(\frac{1\ tonne}{1{,}000\ kg}\right)$$

$$Non-Combusted\ CO_2\ Emissions\ \left(\frac{tonnes}{y}\right) = Fuel\ Volume\ \left(\frac{m^3}{y}\right) \times\ CO_2\ Mole\ Fraction \times Density\ of\ CO_2\left(\frac{kg}{m^3}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{1{,}000\ kg}\right)$$

$$Combusted\ CO_2\ Emissions\ \left(\frac{tonnes}{y}\right) = Fuel\ Volume\ \left(\frac{m^3}{y}\right) \times\ Combustion\ Efficiency \times CO_2\ Emission\ Factor \left(\frac{gCO_2}{m^3}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{1{,}000{,}000\ g}\right)$$

$$Combusted\ N_2\,O\ Emissions\ \left(\frac{tonnes}{y}\right) = Fuel\ Volume\ \left(\frac{m^3}{y}\right) \times\ HHV\ \left(\frac{GJ}{m^3}\right)\ \times\ N_2\,O\ Emission\ Factor\ \left(\frac{kg}{GJ}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{1{,}000\ kg}\right)$$

The incineration of acid gas and fuel gas in one incinerator emits 189,280 tonnes CO_2e and 4,629 tonnes CO_2e per year, respectively. Four incinerators emit a total of 775,636 tonnes CO_2e per year (Table 5.2-2).

Table 5.2-2: Annual GHG Emissions from Incinerators

Source	Emission Rates (tonnes/y)			
	CO_2	CH_4	N_2O	CO_2e
Incineration of acid gas (1 incinerator)	173,617	67	47	189,280
Fuel gas to incinerator (1 incinerator)	2,612	19	5	4,629
Total for 1 incinerator	176229	86	52	193,909
Total for 4 trains (4 incinerators)	**704,917**	**345**	**208**	**775,636**

NOTE:
Values may not sum to totals shown because of rounding.

5.3 Flaring

Flares will be used to dispose of hydrocarbon-containing streams via controlled combustion during upset, start-up, or shutdown events, or during maintenance. Five flares are planned for the Project: a warm flare (streams that may contain water vapour), cold flare (streams that do not contain water vapour), spare flare, operational flare, and a storage/loading flare. Total estimated flaring emissions include emissions from the activities mentioned above and from emissions related to the pilot burners.

Pilot burner emissions are calculated using WCI.363(k) (WCI 2011) and the pilot gas consumption rates to the stacks, which were provided by LNG Canada (7.5 kg/h). The pilot gas consumption rate is converted into a yearly fuel volume based on the density of the pilot gas (provided by LNG Canada) and the operating days (344.5 days). Emissions of CO_2 (non-combusted and combusted), CH_4 (non-combusted), and N_2O (combusted) are based on the volume of fuel used for the pilot burners, destruction efficiency (98%), mole fractions of the pilot gas (Table 3.0-2), emission factors, and HHV. Emissions of N_2O are calculated using a default WCI factor (WCI 2011).

The CO_2 emission factor is calculated based on CAPP (2003) (Section 5.1), which incorporates the non-CO_2 carbon content of the pilot gas (Table 3.0-2). The HHV for the N_2O emissions is also Project specific and based on the pilot gas (Table 3.0-2 and Table 5.3-1).

Table 5.3-1: Variables Used to Calculate Flaring Emissions

Variable	Value	Unit
Density of CH_4	0.678	kg/m^3
Density of CO_2	1.861	kg/m^3
N_2O flaring emission factor	9.52E-05	kg/GJ
Destruction efficiency	98	%
Pilot rate	7.5	kg/h
CO_2 emission factor	1,954	gCO_2/m^3
HHV for N_2O calculations	38.89	GJ/m^3

$$Non - Combusted\ CH_4\ Emissions\ \left(\frac{tonnes}{y}\right) = Fuel\ Volume\ \left(\frac{m^3}{y}\right) \times (1 - Combustion\ Efficiency) \times\ CH_4\ Mole\ Fraction \times Density\ of\ \ CH_4 \left(\frac{kg}{m^3}\right)\ \times Unit\ Conversion\ \left(\frac{1\ tonne}{1{,}000\ kg}\right)$$

$$Non - Combusted\ CO_2\ Emissions\ \left(\frac{tonnes}{y}\right) = Fuel\ Volume\ \left(\frac{m^3}{y}\right) \times\ CO_2\ Mole\ Fraction \times Density\ of\ CO_2 \left(\frac{kg}{m^3}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{1{,}000\ kg}\right)$$

$$Combusted\ CO_2\ Emissions\ \left(\frac{tonnes}{y}\right) = Fuel\ Volume\ \left(\frac{m^3}{y}\right) \times\ Combustion\ Efficiency \times CO_2\ Emission\ Factor \left(\frac{gCO_2}{m^3}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{1{,}000{,}000\ g}\right)$$

$$Combusted\ N_2\,O\ Emissions\ \left(\frac{tonnes}{y}\right) = Fuel\ Volume\ \left(\frac{m^3}{y}\right) \times\ HHV\ \left(\frac{GJ}{m^3}\right)\ \times\ N_2\,O\ Emission\ Factor\ \left(\frac{kg}{GJ}\right) \times Unit\ Conversion\ \left(\frac{1\ tonne}{1{,}000\ kg}\right)$$

Pilot burner emissions result in 279.7 tonnes CO_2e per flare stack, which results in a total of 1,398 tonnes CO_2e for all five flare stacks.

During normal operation, there are only small GHG emissions expected from the flare stacks. Larger flaring events are expected during maintenance events every couple of years. To estimate these flaring emissions, a default factor approach, based on past experience from Shell, has been applied. A default factor of 0.3 weight percent of each train's LNG output is assumed to best represent CO_2 flaring volumes occurring during normal operation and during maintenance events. LNG Canada's past experience with operating sites all over the world showed that 0.3% of the output mass of LNG produced can be assumed to be equivalent to the mass of CO_2 discharged by the flares. Because the actual flared gas composition and volumes are unknown, this approach is considered appropriate. With a total LNG output of 6.5 mtpa per train, 0.3 wt% amounts to 57 tonnes CO_2 a day or 19,500 tonnes CO_2 per year per train. These flaring emissions are not expected to occur on a daily basis but rather represent an average over the year. Assuming full build-out, maintenance flaring will amount to 78,000 tonnes CO_2 per year. If these emissions are added to the estimates from the pilot burners, the annual average of flaring emissions amounts to 79,398 tonnes CO_2e per year (Table 5.3-2).

Table 5.3-2: Annual GHG Emissions from Flaring

Input	Emission Rates (tonnes/y)			
	CO_2	CH_4	N_2O	CO_2e
Operational flaring (four trains) (based on 0.3% default factor)	78,000	*	*	78,000
Pilot flaring (five stacks)	810	5.2	1.5	1,398
Total	**78,810**	**5.2**	**1.5**	**79,398**

NOTE:

* Flared fuel volumes and compositions are unknown. 0.3 weight percent of the Project's intake only represents flared CO_2 emissions. CH_4 and N_2O emissions were assumed to be negligible.

5.4 Fugitive Sources

The GHG emissions associated with fugitive leaks from system components are estimated using WCI.363(o) (WCI 2011) and CAPP (2003). This method is recognized by the *BC GHG Reporting Regulation Methodology Manual* (BCMOE 2011). The emissions are calculated based on equipment counts in differing service stream (fuel gas, gas/vapour, light liquid) and gas compositions (inlet and fuel gas (Table 3.0-2), as well as default emission factors. To be conservative, fugitive emissions are assumed to be emitting GHGs during the entire year, with no fixes or leak-prevention activities. Fugitive GHG emissions for the Project are estimated using the following equation:

$$CO_2\ or\ CH_4\ Emissions\ \left(\frac{tonnes}{y}\right) = \sum Equipment\ Count \times Number\ of\ Components\ per\ Equipment\ (Based\ on\ Component\ Schedules) \times Average\ Emission\ Factor for\ Each\ Type\ of\ Component\ \left(\frac{t\ THC}{h}\right) \times Mol\ \%\ in\ Gas\ Stream(CO_2\ or\ CH_4) \times Operating\ hours\ (h)$$

Fugitive GHG emissions associated with the LNG facility are presented in Table 5.4-1. Gas/vapour-related components contributed most to total fugitive emissions. Total CO_2e emissions are estimated to be 25,056 tonnes CO_2e per year. This is less than 1% of total operation emissions.

Table 5.4-1: Annual GHG Emissions from Fugitive Estimates

Source	Emission Rates (tonnes/y)			
	CO_2	CH_4	N_2O	CO_2e
Fuel gas components	0.04	4.4	-	109
Gas/vapours components	0.79	920	-	22,989
Light liquids components	0.07	78	-	1,959
Total	**0.89**	**1,002**	**-**	**25,056**

NOTES:
- denotes negligible amounts are released.
Values may not sum to totals shown because of rounding.

5.5 Shipping Activities

The Project's marine terminal is designed to accommodate LNG carriers between 130,000 m^3 to 266,000 m^3 in holding capacity. The Project expects up to 350 carrier visits per year, depending on the carrier size. To be conservative, emissions are estimated based on 350 visits of the largest carrier possible (i.e., 266,000 m^3). Each carrier is assumed to travel between the Kitimat Harbour Terminal and the pilot boarding location, at or near Triple Island, at an average speed of 12 knots (22.2 km/h) under the escort of one tug boat. Using 12 knots per hour for the largest carriers yields conservative emission rates after engine load, combustion efficiency, and travel time are incorporated. The travel route between the Kitimat Harbour Terminal and the pilot boarding location is assumed to be 289.7 km. It is further assumed that it will take approximately 13 hours on average to travel this distance. During maneuvering, it is assumed that three tugs are available to support the operation; during loading, only one tug assists the carrier. Maneuvering time is set to 3 hours per visit, and loading is expected to take 15 hours on average. It is further assumed that carriers run on marine oil gas and that all tug boats are operating on their own power (diesel) and are not running on shore power. Characteristics of the LNG carriers (266,000 m^3) and the assisting tug boats, as well as further assumptions, are listed in Table 5.5-1.

Table 5.5-1: Marine Vessel Characteristics

Feature	Vessel Type	
	LNG Carrier	Tug Boat
Vessel length (m)	345	36
Cargo capacity (m^3)	266,000	N/A
Main engine power rating (kW)	37,980	1,342
Auxiliary engine power rating (kW)	8,020	N/A
Boiler power rating (kW) – Maneuvering – Loading	371 3,000	N/A
Number of vessel visits per year	350	1–3 tugs per LNG carrier
Total time maneuvering per visit (h)	3	3
Total time loading per visit (h)	15	15
Fuel type	Marine gas oil	Diesel
Distance travelled along Douglas Channel (km) (one way)	289.7	289.7, 1 tug per LNG carrier
Shipping speed (km/h)	22.2 (12 knots)	22.2 (12 knots)
Shipping time along the Channel (h) (one way)	13	13

Emissions from the vessels are estimated from energy-based emission factors and activity profiles for each vessel. Emission factors for the LNG carriers and tug boats are listed in Table 5.5-2. These emission factors and approach used to calculation emissions are based on *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (ICF Consulting 2009).

Table 5.5-2: Marine Vessel Emission Factors

Emission Factor	LNG Carrier			Tug Boat
	Main Engine	Auxiliary Engine	Boiler	
Load factor during berthing	0.06	0.33 (maneuvering) 0.26 (hotelling)	N/A	0.31
Load factor during shipping	0.19	0.28	N/A	0.31
CO_2 (g/kWh)	588.79	690.71	922.97	690
Adjustment factor for CO_2 during berthing	1.59	N/A	N/A	N/A
Adjustment factor for CO_2 during shipping	1.01	N/A	N/A	N/A
N_2O (g/kWh)	0.031	0.03	0.08	0.02
CH_4 (g/kWh)	0.006	0.004	0.002	0.09

The load factors and the adjustment factors for the CO_2 emission factor for the main engine emissions follow the ICF Consulting method (2009) and are calculated the same way as for shipping activities during construction (Section 4.5). Emissions were determined using the following equation:

$$\begin{aligned} Emissions\left(\frac{tonnes}{y}\right) &\\ &= Power\ Rating\ (kW) \times Emission\ Factor\ \left(\frac{g}{kW}\right) \\ &\times CO_2\ Emission\ Factor\ Adjustment\ Factor^{*} \times Berthing\ Unberting\ (h) \\ &\times Load\ Factor \times Number\ of\ Vessel\ Visits\ per\ Year \times Unit\ Conversion\ \left(\frac{1\ tonne}{10^6 g}\right) \end{aligned}$$

* The CO_2 emission factor adjustment factor was only applied for the calculations of the CO_2 emissions.

LNG carriers during operation are assumed internationally registered vessels, tug boats are assumed to be Canadian registered and are considered domestic marine. Domestic Marine emissions are included in the operation total, international marine is excluded. The total annual GHG emissions released by shipping activities from LNG carriers and tug boats while in port and along the shipping route, based on 350 visits a year, are estimated to be 89,894 tonnes CO_2e per year (Table 5.5-3).

Table 5.5-3: Annual GHG Emissions from Shipping Activities

Source	Emission Rates (tonnes/y)*			
	CO_2	CH_4	N_2O	CO_2e
Shipping activities –International marine (LNG carrier (350 visits))	83,396	0.59	4.8	84,827
Shipping activities –Domestic marine (Tug boat (total for 350 carrier visits))	5,008	0.65	0.15	5,067
Total	**88,403**	**1.2**	**4.9**	**89,894**

NOTE:
Values may not sum to totals shown because of rounding.

5.6 Summary of Operation GHG Emissions

Total GHGs released annually during the operation phase of the Project are summarized in Table 5.6-1. Annual operation emissions include emissions of natural gas turbines, acid gas incinerators, and emissions from flaring, fugitive and shipping activities (tug boats only) during the full build-out scenario. Emissions from internationally registered LNG carriers are excluded from the operational total. The annual average emission attributable to operation activities is 4.0 Mt CO_2e. Most GHG emissions are related to the operation of the liquefaction trains (95.2%). Within the full build-out scenario, there will be a total of eight natural gas-fuelled turbines and four incinerators.

Table 5.6-1: GHG Emissions from the Operation Phase

Source	Emission Rates (tonnes/y)				Percent of Total Operation Emissions (%)
	CO_2	CH_4	N_2O	CO_2e	
8 gas turbines	3,054,358	63	56	3,072,570	77.6
4 incinerators	704,917	345	208	775,636	19.6
5 flares	78,810	5.2	1.5	79,398	2.0
Fugitive	0.89	1,002	-	25,056	0.6
Shipping activities - International marine	83,396	0.59	4.8	84,827	-
Shipping activities - Domestic marine	5,008	0.65	0.15	5,067	0.13
Total GHG emissions from Project operation, excluding international marine emissions	**3,843,094**	**1,415**	**266**	**3,957,728**	**100**

NOTE:

Values may not sum to totals shown because of rounding.

6 CONCLUSION

GHG emissions are estimated for the construction and operation phases. Quantification of the GHG releases during decommissioning are not feasible at this time but are expected to be in the range of construction emissions.

Total GHG emissions from construction and operation phases are listed in Table 6.0-1. Project construction is estimated to emit a total of 255,742 tonnes CO_2e over the entire construction period for the full build-out scenario, and Project operation is estimated to emit 4.0 Mt CO_2e annually.

Based on an annual production of 26 mtpa of LNG and 4.0 Mt CO_2e, the Project will reach an emission intensity of 0.15 tonne CO_2e per tonne LNG produced.

Table 6.0-1: Total Project GHG Emission Estimates

Source	Emissions (tonnes)			
	CO_2	CH_4	N_2O	CO_2e
Construction (total)	84,276	3.6	18	255,742
Operation (annual)	3,843,094	1,415	266	3,957,728
Decommissioning	N/A	N/A	N/A	N/A

NOTE:
N/A – not applicable

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