1.0 PURPOSE

This Appendix documents the methods, data, and assumptions that were used to estimate greenhouse gas (GHG) emissions for the Project. The GHGs emitted from the Project include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These three GHGs can be combined as *equivalent* CO_2 (CO_2e) by considering the individual global warming potentials.

The calculated GHG emissions reported herein are based on conservative estimates and may overestimate the actual emissions. GHG reporting requirements should be assessed based on actual annual emission totals and not those reported in this document.

2.0 ASSESSMENT FRAMEWORK

The emissions estimation methods described within follow generally accepted practices for assessing GHGs for Environmental Assessments and, where applicable, international standards and federal and provincial (British Columbia; BC) regulatory reporting guidance documents. Table 1 presents relevant reference material that forms the basis of GHG emission estimates for the Project.

Table 1: Applicable References for Estimation of Greenhouse Gas Emissions

Reference	Program	Source	Date
Greenhouse Gas Industrial Reporting and Control Act	British Columbia Legislation	Government of BC, 2014	November 2014
Greenhouse Gas Emission Reporting Regulation	Provincial Greenhouse Gas Reporting Program	Government of BC, 2015	December 2015
Final Essential Requirements of Mandatory Reporting Amended for Canadian Harmonization	Western Climate Initiative	Western Climate Initiative, 2010	December 2010 (December 2011 Amendment and December 2013 Addendum)
Technical Guidance on Reporting Greenhouse Gas Emissions	Federal Greenhouse Gas Reporting Program	Environment Canada, 2015a	November 2015
The Greenhouse Gas Protocol/A Corporate Accounting and Reporting Standard	Multiple Programs (e.g., Global Reporting Initiative, ISO14001)	World Business Council for Sustainable Development/World Resource Institute, 2004	April 2004 (February 2013 Amendment)

2.1 Greenhouse Gas Industrial Reporting and Control Act, Government of BC (2014)

The *Greenhouse Gas Industrial Reporting and Control Act* (GGIRCA) (Government of BC 2014) came into force in January 2016, replacing the repealed *Greenhouse Gas Reduction Targets Act*. It governs the documentation and reporting of GHG emissions in BC. It allows for benchmarks to be set for different industrial sectors; currently, it provides a limit for liquefied natural gas (LNG) facilities.

2.2 Greenhouse Gas Emission Reporting Regulation, Government of BC (2015)

The Greenhouse Gas Emission Reporting Regulation (Government of BC 2015) specifies criteria for determining which facilities are required to report to the BC Ministry of Environment (MoE), what to include in the report, and when to report. Emission sources are outlined and appropriate calculation methodologies are specified, referencing the WCI's *Final Essential Requirements of Mandatory Reporting* (WCI 2011).

The reporting threshold in the Reporting Regulation is 10 kt of CO_2e.

The BC MoE has created a document (BC MoE 2014a) outlining the current best practices for quantifying and reporting GHG emissions. The document divides GHG sources into four groups: stationary sources, indirect emissions (supplies – paper), mobile sources, and travel for business (Provincial Government only). The stationary and mobile sources are further divided up into direct emissions (i.e., fuel combustion) and indirect emissions (i.e., electricity consumption). The document specifies where to find emission factors and provides a sample GHG calculation.

2.3 Final Essential Requirements of Mandatory Reporting, Western Climate Initiative (2010)

Western Climate Initiative's *Final Essential Requirements of Mandatory Reporting Amended for Canadian Harmonization* (WCI 2010) provides guidance for quantification, reporting and verification of GHG emissions by certain facilities that directly emit GHGs. Calculation methodologies are specified for emission sources required to be included in the emissions calculations, including stationary and mobile sources. Details regarding reporting requirements and schedule are outlined.

The reporting threshold for the WCI is 10 kilotonnes (kt) of CO_2e.

2.4 Technical Guidance on Reporting Greenhouse Gas Emissions, Environment Canada (2015)

The *Technical Guidance on Reporting Greenhouse Gas Emissions* (the Greenhouse Gas Reporting Program [GHGRP] Guideline) (Environment Canada 2015a) provides direction in determining if facilities are required to submit a GHG report to Environment Canada, an overview of the reporting process, and technical information related to GHG emissions estimations. Technical information includes GHG emission sources subject to reporting and information on emission estimation methodologies.

The GHGRP Guideline references GHG estimation methodologies from the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC). The GHGRP Guideline states that "no specific estimation methods are prescribed" and that facilities should choose estimation methods that are most appropriate for their particular industry but are consistent with the guidelines adopted by the UNFCCC for preparing GHG inventories.

Table 3 of the GHGRP references specific IPCC document sections pertaining to each GHG emission source category.

The reporting threshold for the GHGRP is 50 kt of CO_2e.

2.5 The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, World Business Council for Sustainable Development/World Resource Institute (2004)

The World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) have developed the GHG Protocol Corporate Standard (GHG Protocol) (WBCSD/WRI 2004), which provides guidance for preparing corporate GHG inventories, as well as sector-specific and general calculation tools that can be used for estimating GHG emissions. The GHG Protocol has been adopted by the Global Reporting Initiative (GRI), which provides guidance on sustainability reporting for industry.

Following the GHG Protocol, emissions are classified as either direct or indirect. Direct emissions are those generated from sources that are owned by the company. Indirect emissions are those that result from activities of the operating company, but occur at sources owned by another company, such as electrical power consumption. For the purposes of accounting and reporting, these are typically classified as Scope 1, Scope 2 or Scope 3, and are defined as follows:

Scope 1 – Direct GHG emissions:

> Carbon emissions occurring from sources that are owned or controlled by the company (e.g., emissions from combustion in owned or controlled boilers, furnaces and vehicles, and process and fugitive emissions).

Scope 2 – Indirect GHG emissions:

> Carbon emissions from the generation of purchased electricity, heat or steam consumed by the company.

Scope 3 – Other indirect GHG emissions:

> Carbon emissions which are a consequence of a company's activities, but occur from sources not financially or operationally controlled by the company (e.g., emissions from waste, the extraction and production of purchased materials; and employee travel to and from work) (ISO 2006).

The GHG Protocol requires reporting of Scope 1 (direct emissions from site) and Scope 2 (emissions from on-site energy consumption) emissions only. Scope 1 and Scope 2 emissions are typically the focus of most corporate inventories, although many organizations choose to account for other activities such as employee travel and downstream emissions from waste. These sources are classified as Scope 3 (indirect) emissions, and are reported as an option. Figure 1 illustrates examples of sources of GHGs.

Given the nature of gravel extraction operations, Scope 1 emissions will be the most significant and therefore were the primary focus of the GHG inventory. Emissions associated with marine vessels, both maneuvering in the vicinity of the Project (Scope 3) and vessel travel between the Project and the existing BURNCO facility in Langley (Scope 3) were included. In addition, emissions associated with electricity consumption (Scope 2) and land clearing at the Project site (Scope 3) have been considered.

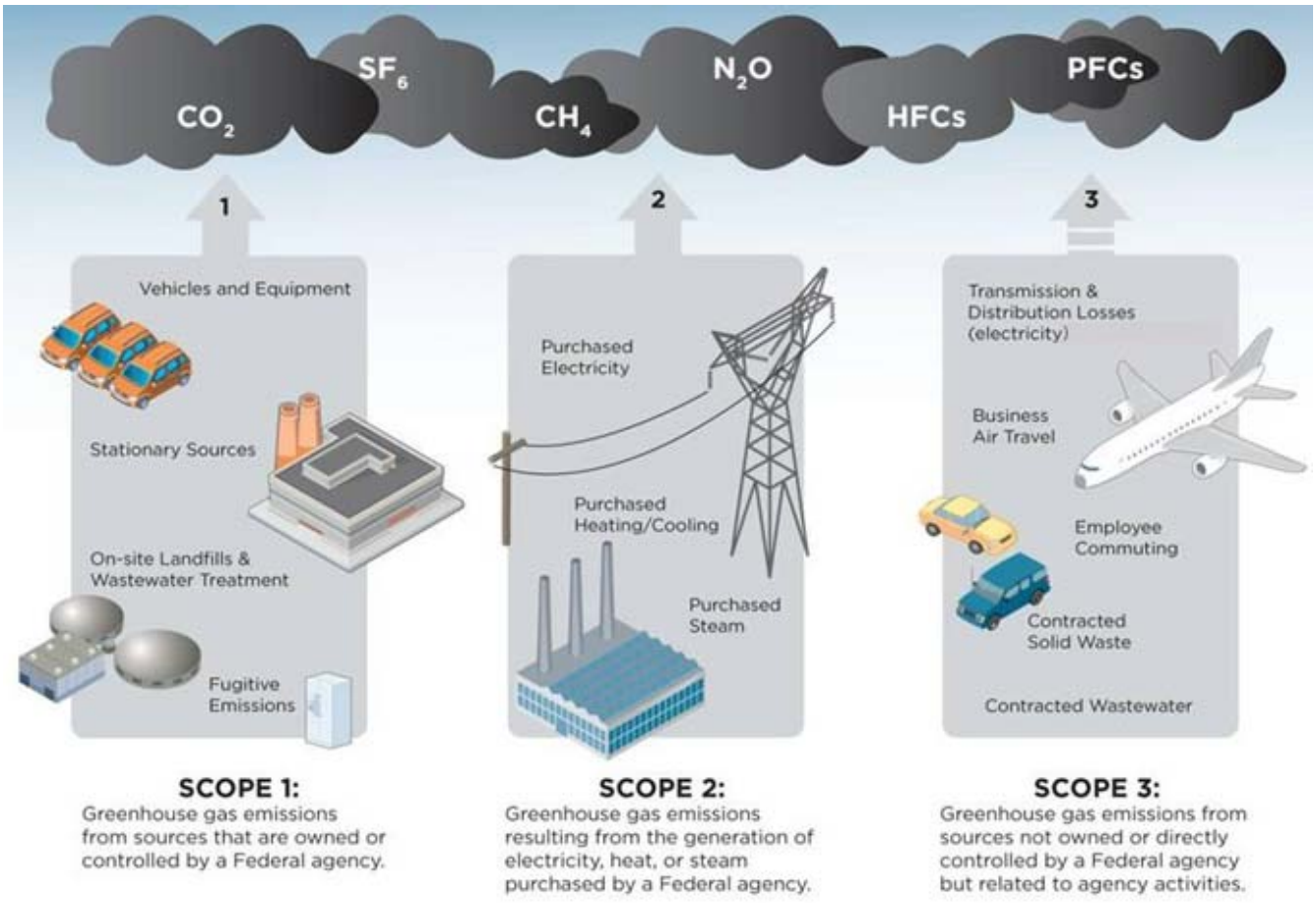

Figure 1: Greenhouse Gas Emissions (Image adapted from U.S. U.S. EPA 2016)

3.0 INVENTORY BOUNDARY

The definition of the inventory boundary, which frames the GHG emission sources that are included in the GHG emissions inventory for the Project, is based on the GRI's GHG Protocol.

Table 2 outlines the GHG inventory boundaries of the GRI's GHG Protocol, the federal GHG reporting program, and the BC GHG Reporting Regulation and presents the source categories included in this report.

Table 2: Source Categories Included in the GHG Protocol, Federal GHG Reporting Program, and BC GHG Reporting Regulation, and Assessed in the Application

Source Category	GHG Protocol	Federal GHG Reporting Program	BC GHG Reporting Regulation	Assessed in EA
On-site stationary fuel combustion sources (Scope 1)	Y	Y	Y	Y
On-site mobile fuel combustion sources (Scope 1)	Y	Y	Y Note 1	Y
Electricity Consumption (Scope 2)	Y	N	N	Y
Marine Vessels (Scope 3)	Y	N	N	Y
Other indirect emissions (Scope 3)	Y	N	N	Y

Note 1: Excludes on-road vehicles

4.0 IDENTIFICATION OF GREENHOUSE GAS SOURCES

Table 3 presents the GHG sources associated with the Project.

Table 3: GHG Emission Sources by Source Category

Source	Source Category	Carbon Containing Materials
Welding	On-site stationary fuel combustion sources (Scope 1)	Propane
On-Site Vehicles	On-site mobile fuel combustion sources (Scope 1)	Diesel/Gasoline
Electricity Consumption	Electricity Purchases (Scope 2)	Fossil Fuel
Barge Tugboat (maneuvering in the vicinity of the Project)	Marine Vessel fuel combustion sources (Scope 3)	Marine Gas Oil
Barge Tugboat (travel between the Project and the Langley BURNCO facility)	Marine Vessel fuel combustion sources (Scope 3)	Marine Gas Oil
Land Clearing	Other indirect emissions (Scope 3)	Vegetation, Soil

5.0 GREENHOUSE GAS EMISSION ESTIMATION METHODOLOGY

The following sections describe the methodologies used for calculating GHG emissions for the project.

5.1 Global Warming Potentials

The emissions of GHGs are expressed as kt of CO_2e, calculated by multiplying the annual emissions of each GHG by its 100-year global warming potential (GWP). The GWP of each gas represents the gas's ability to trap heat in the atmosphere in comparison to CO_2. The GWPs that are used to calculate the Project's GHGs are accepted values of 1, 25 and 298 for CO_2, CH_4, and N_2O, respectively, provided in the IPCC's Fourth Assessment Report (AR4) (Solomon et al, 2007). These values are currently consistent with federal and provincial reporting regulations.

5.2 Calculation Methodology

The basic equation for estimating the GHG emissions from the Project is presented below.

Equation 0: Basic Equation for GHG Estimation

$$ER = (E_{CO2} \times GWP_{CO2} + E_{CH4} \times GWP_{CH4} + E_{N2O} \times GWP_{N2O}) \times OF$$

Where:

- ER = the emission rate (t CO_2e/year)
- E_{CO2} = the annual emission rate (t CO_2/year)
- E_{CH4} = the annual emission rate (t CH_4/year)
- E_{N2O} = the annual emission rate (t N_2O/year)
- GWP_{CO2} = global warming potential of CO_2
- GWP_{CH4} = global warming potential of CH_4
- GWP_{N2O} = global warming potential of N_2O
- OF = annual operational factor

Many of the direct sources of GHG emissions from the Project do not emit continuously over an entire year. Therefore, the emissions have been estimated using the above general approach; the typical annual operational factor was based on data provided by the proponent.

5.3 Stationary Combustion Emissions

Stationary combustion emissions associated with propane use for welding were calculated using WCI.23 methodology, equations 20-1 and 20-10 (WCI 2010). The approach presented by the WCI for calculating CO_2, CH_4 and N_2O emissions from stationary sources is based on fuel consumption and fuel-specific emission factors on a volume basis (e.g., kg CO_2/L). Annual propane consumption at the facility was estimated by the proponent.

Equation 1: Stationary Combustion Emissions (CO_2)

$$E_{CO2} = Fuel \times HHV \times 0.001 \times EF \qquad \textit{(Equation 20-1 of WCI 2010)}$$

Where:

- E_{CO2} = annual CO_2 emission rate from stationary sources (t/year)
- $Fuel$ = annual propane consumption rate by stationary sources (kL/year)
- HHV = higher heating value of propane from Table 20-1a of WCI 2010 (GJ/kL)
- EF = CO_2 emission factor for propane from Table 20-2 of WCI 2010 (kg/GJ)
- 0.001 is the factor to convert from kg to tonnes

Equation 2: Stationary Combustion Emissions (CH_4 or NO_2)

$$E_g = Fuel \times HHV \times EF_g \times 0.000001 \qquad \textit{(Equation 20-10 of WCI 2010)}$$

Where:

- E_g = annual emissions of gas g (CH_4 or NO_2) from stationary sources (t/year)
- $Fuel$ = annual propane consumption rate by stationary sources (kL/year)
- HHV = higher heating value of propane from Table 20-1a of WCI 2010 (GJ/kL)
- EF_g = gas g emission factor for propane from Table 20-2 of WCI 2010 (kg/GJ)
- 0. 000001 is the factor to convert from grams to tonnes

5.4 Mobile Equipment Emissions

Mobile equipment emissions will result from fossil fuel (diesel) consumption within forklifts, bulldozer, excavator, road trucks, and loaders. Emissions were calculated using WCI.280 methodology, equations 280-1 and 280-4 (WCI 2010).

The approach presented by the WCI for calculating CO_2, CH_4 and N_2O emissions from mobile sources is based on fuel consumption and fuel-specific emission factors on a volume basis. Fuel consumption for individual vehicle types was estimated based on methods outlined in the U.S. EPA Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling — Compression-Ignition (US EPA, 2010).

Equation 3: Mobile Equipment Emissions (CO_2)

$$E_{CO2} = Q \times EF \times \frac{1}{10^3} \qquad \textit{(Equation 280-1 of WCI 2010)}$$

Where:

- E_{CO2} = annual CO_2 emissions from mobile equipment (t/year)
- Q = annual quantity of diesel used in mobile equipment (L/year)
- EF = is the emission factor for diesel from Table 20-2 in WCI 2011 (kg/L)
- $\frac{1}{10^3}$ is the factor to convert from kg to tonnes

Equation 4: Mobile Equipment Emissions (CH_4 or NO_2)

$$E_g = Q \times EF_g \times \frac{1}{10^6} \qquad \textit{(Equation 280-4 of WCI 2010)}$$

Where:

- E_g = annual emissions of gas g (CH_4 or NO_2) from mobile sources (t/year)
- Q = annual quantity of diesel used in mobile equipment (L/year)
- EF_g = is the emission factor of gas g for diesel provided in Table 20-2 in WCI 2011 (g/L)
- $\frac{1}{10^6}$ is the factor to convert from grams to tonnes

5.5 Marine Vessels

Emissions associated with the barge tugboat were calculated using the methodology in 2005-2006 BC Ocean-Going Vessel Emissions Inventory (The Chamber of Shipping 2007). Emissions were calculated based on engine power, duration of travel, and fuel-specific emission factors. Vessel maneuvering in the vicinity of the Project and vessel travel (underway) between the Project and the BURNCO facility in Langley were both considered in the assessment. The emissions associated with marine vessels are not required to be reported under the BC Reporting Regulation (Government of BC 2015). However, for completeness, the GHG emissions have been quantified as part of this assessment.

Equation 5: Marine Vessel Emissions

$$ER_g = \left(P \times EF_{g,u} \times LF_u \times T_u\right) + \left(P \times EF_{g,m} \times LF_m \times T_m\right)$$

Where:

- ER_g = annual gas g (CO_2, CH_4 or NO_2) emission rate of the marine vessel (t/year)
- P = engine power at maximum continuous rating of the marine vessel (kW)
- $EF_{g,u}$= emission factor for gas g in underway mode from Table 16 of the Chamber of Shipping, 2007 (g/kWh)
- $EF_{g,m}$= emission factor for gas g in maneuvering mode from Table 17 of the Chamber of Shipping, 2007 (g/kWh)
- $LF_{u/m}$= load factor in underway/maneuvering modes from Table 15 of The Chamber of Shipping, 2007 (%)
- $T_{u/m}$ = duration of travel of marine vessel in underway/maneuvering modes (hours/year)

5.6 Electricity Consumption

GHG emissions due to electricity consumption were calculated based on the anticipated annual electricity consumption of the Project. Emissions were calculated based on the BC Hydro emission factor for purchased electricity from Table 3 within the 2014 BC Best Practices Methodology for Quantifying Greenhouse Gas Emissions (BC MoE 2014b).

Equation 6: Purchased Electricity Emissions

$$E = kWh \times EF_{CO2e} \times \frac{1}{10^6}$$

Where:

- E= annual emission rate for electricity consumption (t/year)
- kWh = annual electricity consumption (kWh/year)
- EF_{CO2e} = carbon dioxide equivalent emission factor (tCO_2e/GWh)
- $\frac{1}{10^6}$ is the factor to convert from kWh to GWh

5.7 Land Clearing

The emissions associated from clearing the land arise from the removal of a carbon sink. The emissions from clearing the forest and grassland are not required to be reported under the BC Reporting Regulation (Government of BC 2015). However, for completeness, the GHG emissions from clearing the grassland and forest have been quantified as part of this assessment.

5.7.1 Deforestation

To quantify the GHG emissions from land clearing of forest land (deforestation), the BC Ministry of Forests, Lands and Natural Resource Operations calculation methodology and quantification tool was used (Dymond 2014). The emission factors used in the quantification tool are a result from a model that has run on data from national and BC GHG inventory reports. 30 years of deforestation activity were used in the compilation of emission factors. Emission factors are segregated by area; this project falls within the South Coast area. The method of deforestation was assumed to be the uproot and decay method. Since the land clearing will occur progressively throughout the Project, the maximum area to be cleared in one year was used in the calculations (6.9 ha). Based on the current mix of forest and grassland at the Project site, a split of forest and grassland of 20% forest and 80% grassland was assumed.

Equation 7: Deforestation Emissions

$$E = EF \times A$$

Where:

- E = the emission rate of CO_2e of deforestation (t/year)
- EF = the emission factor of CO_2e of deforestation provided within Dymond 2014 (t/ha)
- A = the area of forest to be cleared per year (ha/year)

5.7.2 Grassland Clearing

To quantify the GHG emissions from land clearing of grassland, the equations and emission factors presented in Chapter 6 of Volume 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories were used (IPCC 2006).

Equation 8: Land Clearing of Grassland Emissions

$$E = EF \times A \times \frac{44}{12}$$

Where:

- E = the emission rate of CO_2e of land clearing of grassland (t/year)
- EF = the emission factor of Carbon (C) of land clearing of grassland provided in Table 6.3 of IPCC 2006 (t/ha)
- A = the area of grassland to be cleared per year (ha)
- $\frac{44}{12}$ is the conversion factor from Carbon to CO_2e

6.0 DATA REQUIREMENTS

6.1 Parameters Used to Calculate Greenhouse Gas Emission Estimates

Data requirements to calculate GHG emissions of the Project fall into two categories:

- **Project-Specific Input Parameters** – Project-specific consumption data for processes resulting in GHG emissions; and
- **Default Parameters** – Emission factor data or physical data obtained from GHG emission estimation guidelines or reference material.

Table 4 presents the data required for calculating GHG emissions at the facility, broken down into the above categories.

Table 4: Summary of data required for estimating GHG emissions

Data	Variable	Equation	Value	Unit	Source of Data
Project-Specific Input Parameters					
Volume of propane used in stationary combustion in one year	$Fuel$	(1), (2)	7.500	kL/year	BURNCO
Volume of diesel used in mobile combustion in one year	Q	(3), (4)	719,575	L/year	Calculated from the Non-Road Engine Modelling NR-009d (July 2010) (U.S. EPA. 2010)
Duration of tugboat travel – Underway Mode	T_u	(5)	15.5	hours	Based on speed from Seaspan Marine (Beckler 2013) and distance of route provided by BURNCO
Duration of tugboat travel – Maneuvering Mode	T_m	(5)	1.5	hours	Based on mode distribution and distance of route provided by BURNCO
Power of tugboat engine	P	(5)	1268	kW	Manufacturer specifications (Seaspan Website)
Electricity consumption in one year	kWh	(6)	3,724,800	kWh/ year	BURNCO provided electrical power requirement. Assumed 100% of requirement while the mine is active (14 hours/day, 300 days/year) and 10% of requirement while mine inactive
Forest Area	A	(7)	1.38	hectare	Project Description Assumed 20% of project area cleared in the maximum year was forest
Grassland Area	A	(8)	5.51	hectare	Project Description Assumed 80% of project area cleared in the maximum year was grassland

Data	Variable	Equation	Value	Unit	Source of Data
Default Parameters					
Global Warming Potentials	GWP_{CO_2}	(0)	1	N/A	IPCC Fourth Assessment Report 2007 Table 2.14
	GWP_{CH_4}		25		
	GWP_{N_2O}		298		
Emission factor for stationary propane use	EF_{CO_2}	(1)	59.66	kg/GJ	WCI 2011, Table 20-2
	EF_{CH_4}	(2)	0.948	g/GJ	
	$EF_{N_2O,}$		4.267		
Higher heating value of propane	HHV	(1), (2)	25.66	GJ/kL	WCI 2011, Table 20-1a
Emission factor for mobile diesel combustion (Heavy Duty Diesel Vehicle - HDDV)	EF_{CO_2}	(3)	2.663	kg/L	WCI 2011, Table 20-2
	EF_{CH_4}	(4)	0.133	g/L	
	EF_{N_2O}		0.400		
Load factor	LF_u	(5)	80	%	BC Ocean-Going Vessel Emissions inventory (The Chamber of Shipping 2007), Table 15
	LF_m		3		
Marine Gas Oil Emission Factor – Underway Mode	$EF_{CO_2,u}$	(5)	588	g/kWh	BC Ocean-Going Vessel Emissions inventory (The Chamber of Shipping 2007), Table 16
	$EF_{CH_4,u}$		0.074		
	$EF_{N_2O,u}$		0.017		
Marine Gas Oil Emission Factor – Maneuvering Mode	$EF_{CO_2,m}$	(5)	1764	g/kWh	BC Ocean-Going Vessel Emissions inventory (The Chamber of Shipping 2007), Table 17
	$EF_{CH_4,m}$		0.222		
	$EF_{N_2O,m}$		0.050		
Electricity consumption CO_2e emission factor	EF_{CO_2e}	(6)	10	t/GWh	2014 BC Best Practices Methodology for Quantifying Greenhouse Gas Emissions, Table 3
Deforestation emission factor – uproot and decay	EF	(7)	199.83	t CO_2e /ha/yr	Dymond, 2014 Dyk et al, 2012
Emission factor for grassland clearing	EF	(8)	2.5	t C /ha/yr	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 6, Table 6.3 (Temperate Climate)

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