Appendix 6-A

Air Quality Release Estimates – Sample Calculations

Sample calculations for air contaminant release estimates (from the emissions inventory) during construction and operation are provided in this appendix.

In general, most air contaminant emissions are estimated using the following relation:

$$Emission\ Rate\ (ER) = Emission\ Factor\ (EF)\ \times\ Activity\ Rate\ (A_R)$$

Sample calculations for activities expected to have measurable air contaminant releases associated with the Project are provided.

Construction

Blasting

Releases of air contaminants from blasting are estimated using the annual mass of explosives (emulsion explosive, assumed to be similar to ammonium nitrate-fuel oil, ANFO) expected, provided by the design team, and published emission factors from the United States Environmental Protection Agency (US EPA) AP-42 Chapter 13.3 Explosives Detonation (US EPA 1995a) and the ECCC NPRI Calculator Tool for Pits and Quarries (ECCC 2017). The emission factors are presented in Table 6A-1. The amount of explosives used over the full construction period (site-wide) is expected to be approximately 10,000 tonnes, this was assumed to be evenly distributed over the 30 months of construction, at 4,000 tonnes per year.

An example calculation of the maximum hourly nitrogen oxides (NO_X) emissions rate (ER_{NOX}) from explosives is provided below.

$$ER_{NOX} = \frac{8\ kg\ NO_X}{Mg\ Explosives\ used} \times\ 4{,}000\frac{tonnes}{year} \times \frac{1\ tonne}{1000\ kg}$$

$$ER_{NOX} = 32\frac{tonnes}{years}$$

Emissions from blasting were also calculated for carbon monoxide (CO), sulfur dioxide (SO_2), total particulate matter (TPM), particulate matter with particles having an aerodynamic diameter less than 10 µm (PM_{10}) and particulate matter ($PM_{2.5}$) with particles having an aerodynamic diameter less than 2.5 µm using the same approach with appropriate emission factor for each air contaminant.

Table 6A-1 Emission factors for Blasting

Species	EF	Units
NOx	8	kg/Mg
CO	34	kg/Mg
SO_2	1	kg/Mg
TPM	23.06	kg/Blast
PM_{10}	0.52	scale factor (fraction of total PM)
$PM_{2.5}$	0.3	scale factor (fraction of total PM)

Stockpile Erosion

Fugitive dust emissions are expected from wind erosion of stockpile surfaces during dry, windy periods. Release estimates are calculated using approximate stockpile surface areas provided by the design team and published emission factors from Environment and Climate Change Canada (ECCC) National Pollutant Release Inventory (NPRI) Pits and Quarries Reporting Guide (Section 8.9 Emissions Due to Wind Erosion of Stockpile Surfaces) (ECCC 2017). An example calculation for $PM_{2.5}$ emissions from storage piles is provided below.

The emission factor is estimated as follows, based on the NPRI Pits and Quarries Guide:

$$EF = 1.12 \times 10^{-4} \times J \times 1.7 \times (\frac{s}{1.5}) \times 365 \times (\frac{365 - P}{235}) \times (\frac{I}{15})$$

Where
EF= Emission factor in kg/m^2
J= Particulate aerodynamic factor (1 for TPM, 0.5 for PM_{10}*, and 0.2 for* $PM_{2.5}$ *from ECCC 2017)*
s= Average silt loading of stockpile in percent (%)
P= Average number of days during the year with at least 0.254 mm of precipitation
I= Percentage of time in the year with unobstructed wind speed >19.3 km/h in percent (%)

For $PM_{2.5}$, the aerodynamic factor, *J* is 0.2 (from ECCC 2017). Silt content, *s* is assumed to be 0.5% based on Silt content from Mojave Desert Air Quality Management District, 2000 for "limestone" (ECCC 2017). Days with precipitation and percentage of time with unobstructed wind speeds > 19.3 km/hr is based on the CALMET predicted wind speed and precipitation for the site (33% of the time with winds >19.3 km/hr over the 2020 to 2022 period of the meteorological model and 255 days with precipitation, which is the minimum annual value of the three years of the model).

$$EF_{PM2.5} = 1.12 \times 10^{-4} \times 0.2 \times 1.7 \times (\frac{0.5\%}{1.5}) \times 365 \times (\frac{365 - 255}{235}) \times (\frac{33\%}{15})$$

$$EF_{PM2.5} = 4.72 \times 10^{-3} \frac{kg}{m^2 yr}$$

Emissions are estimated as:

$$ER_{PM2.5} = EF \times Area\ of\ Stockpiles \times Conversion$$

Where
EF= Emission factor in kg/m^2*· year*
Area of Stockpiles = the surface area of the stockpiles in m^2
Conversion = conversion from kg to tonne, where 1 tonne=1000 kg

$$ER_{PM2.5} = 4.72 \times 10^{-3} \frac{kg}{m^2 yr} \times 133{,}280\ m^2 \times \frac{1\ tonne}{1000\ kg}$$

$$ER_{PM2.5} = 0.63 \frac{tonnes}{year}$$

The surface area of the total stockpiles were assumed based on the estimated volume of material stockpiled (200,000 m^3), assuming a maximum pile height of 10 m, and that there would be approximately 20 piles around the construction site.

Emissions from stockpile erosion were also estimated for TPM and PM_{10}.

Material Transfers

Fugitive dust releases generated from material transfers are estimated based on information provided by the design team and estimated emission factors following the calculation method outlined in the US EPA AP-42 Chapter 13.2.4 Aggregate Handling and Storage Piles (US EPA 2006a).

The releases of $PM_{2.5}$ from material transfer at conveyor drop points are estimated as follows:

$$ER_{PM2.5} = EF \times Transfer\ Rate$$

$$EF_{PM2.5} = k \times 0.0016 \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \frac{kg}{Mg}$$

Where:
$EF_{PM2.5}$ = $PM_{2.5}$ emission factor in kg/Mg
k = particle size multiplier = 0.053 for $PM_{2.5}$, 0.35 for PM_{10}, and 0.74 for TPM (US EPA 2006a)
U = mean wind speed in m/s (based on the 2020-2022 average CALMET predicted winds at the site of 4.58 m/s)
M = material moisture content (based on provided ore moisture content of 1% - from Table 13.2.4-1 (US EPA 2006a) for crushed limestone

$$EF_{PM2.5} = 0.053 \times 0.0016 \times \frac{\left(\frac{4.58}{2.2}\right)^{1.3}}{\left(\frac{0.01}{2}\right)^{1.4}} \frac{kg}{Mg} = 5.08 \times 10^{-4} \frac{kg}{Mg}$$

Emissions of $PM_{2.5}$ are then estimated as follows, using the total annual amount of material transferred:

$$ER_{PM2.5} = 5.08 \times 10^{-4} \frac{kg}{Mg} \times 1{,}770{,}000 \frac{t}{a} = 0.90 \frac{t}{year}$$

The amount of material transferred was estimated using the provided amount of required crushed/screened aggregate, 600,000 m^3/year assuming it all has to be loaded and unloaded, and converted to a mass using a density of bulk aggregate (1,475 kg/m^3)

Emissions from material transfers were also calculated for TPM and PM_{10}.

Crushing and Screening

Releases of particulate emissions (TPM, PM_{10}, and $PM_{2.5}$) from crushing and screening activities were estimated based on operating information provided by the design team and published emission factors for TPM and PM_{10} from the US EPA AP-42 Chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing (US EPA 2004) and the Australian National Pollutant Inventory document "Emission estimation technique manual for Gold Ore Processing", Version 2.0 (AUS 2006a). These emission factors are presented in Table 6A-2.

Releases of $PM_{2.5}$ are estimated based on emission factors for low moisture ore (<4%) in Table 2.3 of the Nevada DEP Guidance on Emission Factors for the Mining Industry (NDEP 2017). Moisture content was assumed to be 2.1% based on the moisture content presented in AP-42 Table 13.2.4-1 for Various Limestone Products under stone quarrying and processing (US EPA 2006a). The "controlled" emission factors were used as they apply to materials that have moisture content >1.5% (whether naturally or through wet suppression) and to capture the control from dust collection.

Annual emissions of TPM from crushing at Port au Port are estimated as follows:

$$ER_{TPM} = Annual\ Throughput \times EF_{TPM} \times Conversion$$

Where:
Annual Throughput = Mass of material crushed/screened per year in Mg/year, estimated to be 885,000 MG/year (estimated from a total crushed aggregate quantity of 1,500,000 m^3 distributed evenly over the construction period of 30 months and a density of 1,475 kg/m^3 for crushed aggregate). Assumed the full quantity was both crushed and screened.
EF_{TPM} *= emission factor for total particulate matter in kg/Mg, presented in Table 6A-2.*
Conversion = Conversion from kg to tonnes (1 tonne = 1000 kg)

Emissions of TPM are then estimated as follows:

$$ER_{TPM} = \frac{885{,}000\ tonnes}{year} \times \frac{0.1\ kg}{tonne} \times \frac{1\ tonne}{1000\ kg}$$

$$ER_{TPM} = 8.85\ \frac{tonnes}{year}$$

Emissions from crushing and screening were also calculated for $PM_{2.5}$ and PM_{10}.

Table 6A-2 Emission Factors for Crushing and Screening

Source	Species	EF [kg/Mg]
Primary Crusher	TPM	0.01
	PM_{10}	0.004
	$PM_{2.5}$	0.00061
Grizzly Screen	TPM	0.0125
	PM_{10}	0.0043
	$PM_{2.5}$	0.00065

Laydown Areas

Fugitive dust releases may occur from wind erosion of the laydown areas where the wind turbine components will be stored temporarily prior to being errected. The equation used for estimating these emissions is sourced from the Mojave Desert Air Quality Management District (MDAQMD), Mineral Handling and Processing Industries (MDAQMD 2000), Table 2, as presented in the ECCC NPRI "Pits and Quarries Reporting Guide (ECCC 2017). Silt content is assumed to be 0.5% based on Silt content from Mojave Desert Air Quality Management District, 2000 for "limestone" (ECCC 2017). Percentage of time with unobstructed wind speeds > 19.3 km/hr is based on the CALMET predicted wind speed (33% of the time with winds >19.3 km/hr over the 2020 to 2022 period of the meteorological model) and days with rain >0.252 mm or snow cover were based on the ECCC historical weather normal from the Stephenville Station (255 days with precipitation, which is the minimum annual value of the three years of the model) (ECCC 2023). The equation used for the emission factor is the same equation presented under Stockpile Erosion, above (based on the NPRI Pits and Quarries Guide) (ECCC 2017).

Annual emissions from laydown areas are estimated as:

$$ER_{TPM} = EF \times Surface\ Area\ of\ Laydown\ Areas \times Conversion$$

Where
EF= Emission factor in kg/m²·year, presented in Table 6A-3.
Surface Area of Laydown Areas is the surface area of all laydown areas, in m², estimated to be 1 ha (10,000 m²) per turbine site (Section 2.5.3.1 of Chapter 2: Project Description), up to 328 turbine sites. Assumed that construction would be evenly distributed over the 30 months for approx. 131.2 turbines per year.
Conversion from tonnes to kg (1 tonne = 1,000 kg)

Emissions of TPM are then estimated as follows:

$$ER_{TPM} = 0.024 \frac{kg}{m^2 yr} \times 1{,}312{,}000\ m^2 \times \frac{1\ tonne}{1000\ kg}$$

$$ER_{TPM} = 31.0 \frac{tonnes}{year}$$

Emissions from laydown areas were also calculated for $PM_{2.5}$ and PM_{10}.

Table 6A-3 Emission Factors for Laydown Areas

Species	Emission Factor [kg/m^2]
TPM	2.36E-02
PM_{10}	1.18E-02
$PM_{2.5}$	4.72E-03

Unpaved Roads

Fugitive dust releases from vehicles driving on unpaved roads were estimated using methodology from the US EPA AP-42 Chapter 13.2.2 (US EPA 2006b), road distances, the number of vehicles on the roads, and vehicle weights. The access roads to the wind turbines will be unpaved. It was indicated that dust suppression will be used as required. For the purposes of these calculations, it is assumed dust suppression is used once per month during the summer. Silt content is assumed to be 8.5% based on silt content for "construction sites – scraper routes" (Table13.2.2-1 of US EPA AP-42). The precipitation for the site (255 days with precipitation, which is the minimum annual value of the three year) was obtained from the ECCC historical weather normal (1981-2010) for the Stephenville Airport location (ECCC 2023).

The emission factor for estimating emissions from unpaved roads is estimated as follows:

$$EF = k \times \left(\frac{s}{12}\right)^a \times \left(\frac{W}{2.71}\right)^b$$

Where
EF: Emission factor in kg/vehicle kilometers travelled (VKT)
k = constant in kg/VKT from Table 13.2.2-2 of US EPA AP-42 (units converted), presented below in Table 6A-4
a and b = constants from Table 13.2.2-2 of US EPA AP-42 (unitless), presented below in Table 6A-4
s: Average silt loading of stockpile in percent (%)
W: mean vehicle weight in metric tonnes, presented in Table 6A-5

Table 6A-4 Constants in Emission Factor Equation for Unpaved Roads

Species	k [kg/VKT]	a	b
TPM	1.381	0.7	0.45
PM_{10}	0.423	0.9	0.45
$PM_{2.5}$	0.042	0.9	0.45

The calculation for the emission factor, for TPM, is as follows:

$$EF_{TPM} = \frac{1.381\ kg}{VKT} \times \left(\frac{8.5\%}{12}\right)^{0.7} \times \left(\frac{61.70\ tonnes}{2.71}\right)^{0.45}$$

$$EF_{TPM} = \frac{0.1684\ kg}{VKT}$$

Emissions are estimated as:

$$ER_{TPM} = EF\ \times VKT \times (1 - Control\ Efficiency)\ \times (Natural\ Adjustment) \times Conversion$$

Where
VKT is the vehicle kilometers traveled per year, estimated by the road lengths, number of wind turbine generators (WTG) accessed by each road, and the number of vehicles travelled on the road per year, these values are presented in Table 6A-5
Natural adjustment is calculated as follows:

$$Natural\ Adjustment = \frac{(Operational\ Days - Days\ with\ Snow\ or\ Rain)}{Operational\ Days} \times 100$$

$$Natural\ Adjustment = \frac{(365 - 255)}{365} \times 100$$

$$Natural\ Adjustment = 30\%$$

The control efficiency was obtained from the Western Regional Air Partnership's Fugitive Dust Control Measures Application (WRAP 2004) of 84% for the application of dust suppressants to unpaved roads was applied.

The emission rate for TPM, for the Mainland Access Road, was estimated as follows:

$$ER_{TPM} = \frac{0.1684\ kg}{VKT} \times 537.6\ km\ \times (1 - 0.84)\ \times 30\% \times \frac{1\ tonne}{kg}$$

$$ER_{TPM} = 0.004\ \frac{tonnes}{year}$$

Table 6A-5 Unpaved Road Supporting Data

Road Segment - Origin	Road Segment - Destination	Segment Length [m]	# WTG Accessed via Road Segment[1]	# Vehicles per year[2]	Mean vehicle weight [tonnes/ vehicle][3]	VKT/yr
Mainland Access Road	Port au Port - transportation of WTGs	2,000	37	269	62	537.6
Mainland All network, connector and pad roads	Port au Port - transportation of WTGs	3,000	37	338	62	1015.2
Cape Road All access, network, connector and pad roads accessed from main highway	Port au Port - transportation of WTGs	3,000	38	338	62	1015.2
West Bay Access Road and Network road	Port au Port - transportation of WTGs	2,000	9	338	62	676.8
Red Brook, Limestone, Lower Cove and Ship Cove Access roads and network roads	Port au Port - transportation of WTGs	3,000	28	338	62	1015.2
Boswarlos All access, network and pad roads	Port au Port - transportation of WTGs	2,000	15	293	62	585.6
Site C - northern most sites All network, connector and pad roads	Codroy - transportation of WTGs	4,000	164	802	62	3,206
Construction equipment and materials[6]	All	2,000	-	120	15.00	240

Notes:

[1] Assumptions:

The number of Wind Turbine Generators (WTGs) accessed per road segment was provided by the design team.

There are 4 options for Codroy access roads, but routes have not yet been finalized. Therefore it is assumed each WTG will travel 2 km. The total length of the access road for this site is 4 km.

Assuming the entire length of the road segments are being travelled for all WTGs (conservative estimate since some will be closer than others)

[2] Multiplied number of vehicles by two, to account for round trip

[3] Assumed the gross vehicle weight is 61.7 tonnes, which is the heaviest of wind turbine components as per: https://www.richardstransport.com/services/wind-turbines

Heavy Equipment

Emissions will result from the combustion of diesel fuel in heavy equipment during the construction phase. Air contaminant releases from the combustion of fuel in large mobile equipment are based on models and operational information provided by the design team and published emission factors from the following sources:

For NOx, PM and CO:

- Canadian Off-Road Compression-Ignition Engine Emission Regulations (ECCC 2020), which apply the US EPA standards presented in Nonroad Compression-Ignition Engines - Exhaust Emission Standards (US EPA, 2016). These emission factors are presented in Table 6A-6.

For SO_2:

- Engines >600 hp: US EPA AP-42 Chapter 3.4 Large Stationary Diesel And All Stationary Dual-fuel Engines (emission factor 0.505 lb SO_2/MMBTu)
- Engines <600 hp: Chapter 3.3 Gasoline and Diesel Industrial Engines (emission factor 0.29 lb SO_2/MMBTu)

Emissions were calculated for NO_X, SO_2, CO, TPM, PM_{10} and $PM_{2.5}$.

Emissions are estimated as:

$$ER = EF \times Rated\ Engine\ Power \times hours\ of\ operation \times Conversion$$

Where
EF: Emission factor in g/hp-hr, which are dependent on engine power of the equipment, and provided in Table 6A-7.
Rated Engine Power in hp, which was based on the specifications of the equipment, provided in Table 6A-7.
Annual hours of operation provided by design team, shown in Table 6A-7.

The following calculates the NOx emissions from C390 Excavators:

$$ER_{NO_x} = EF \times Rated\ Engine\ Power \times hours\ of\ operation \times Conversion$$

$$ER_{NO_x} = 0.3\frac{g}{hp - hr} \times 524\ hp \times 3000\frac{hours}{year} \times 1\frac{tonne}{10^6 g}$$

$$ER_{NOx} = 0.47\frac{tonne}{year}$$

Table 6A-6 US EPA/Canada CEPA Tier 1, 2, 3 and 4 NOx, CO and PM Emission Standards for Off-Road Heavy-Duty Diesel Engines

Engine Power	Tier	Model Year	Emission Factors (g/hp-hr)		
			NO_x [a]	CO	TPM
			10102-44-0	630-08-0	N/A-1
≥100 to <175	Tier 1	1997–2000	6.9	-	-
	Tier 2	2003–2006	4.5	3.7	0.22
	Tier 3	2007–2011	2.8	3.7	0.22
	Tier 4 transitional	2012–2013	0.3	-	0.01
	Tier 4 final	2014+	0.3	3.7	0.01
≥175 to <300	Tier 1	1996–2002	6.9	8.5	0.4
	Tier 2	2003–2005	4.5	2.6	0.15
	Tier 3	2006–2010	2.8	2.6	0.15
	Tier 4 transitional	2011–2013	-	-	0.01
	Tier 4 final	2014+	0.3	2.6	0.01
≥300 to <600	Tier 1	1996–2000	6.9	8.5	0.4
	Tier 2	2001–2005	4.5	2.6	0.15
	Tier 3	2006-2010	2.8	2.6	0.15
	Tier 4 transitional	2011–2013	0.3	2.6	0.01
	Tier 4 final	2014+	0.3	2.6	0.01
≥600 to <750	Tier 1	1996–2001	6.9	8.5	0.4
	Tier 2	2002–2005	4.5	2.6	0.15
	Tier 3	2006-2010	2.8	2.6	0.15
	Tier 4 transitional	2011–2013	0.3	2.6	0.01
	Tier 4 final	2014+	0.3	2.6	0.01
≥750	Tier 1	2000–2005	6.9	8.5	0.4
	Tier 2	2006–2010	4.5	2.6	0.15
	Tier 4 transitional	2011–2014	2.6	2.6	0.07
	Tier 4 final	2015+	2.6	2.6	0.03

Table 6A-7 Construction Equipment Fleet and Specifications

Type	Model/Description	No. Units	Rated Engine Power (output)[1]	Operating Hours/yr (per unit)
			hp	
Excavators	C390	1	524	3000
	C349	8	424	3000
	C336	2	300	3000
	C324	3	188	3000
	C305	2	49.2	3000
Haul Trucks	HM400	14	473	3000
	Live Bottom	5	550	3000
	Tandem	5	455	3000
Dozers	D8	2	354	3000
	D6	3	215	3000
	D4	1	130	3000
Roller	CS56	5	157	3000
Loader	988	2	541	3000
	980	2	393	3000
	IT38	2	180	3000
Cranes	LG 1750	4	686	1500
	JLG Lift	8	84	1500
Concrete	Concrete Truck	14	425	1500
	Concrete Pump Truck	2	485	1500
D&B	Copco L8	2	430	1500
	Copco D9	3	33.5	1500
	Explosives Truck	2	485	1500
Grader	G140	2	160	3000
Support	Flat Deck	4	360	1500
	Water Truck	2	700	1500
	Fuel Truck	3	370	1500
	Telehandler	2	111	1500
	support Cranes	10	400	1500
	Boom Truck	4	173	1500
	Pickups	30	250	3000

Note:
[1] Rated engine power values were obtained from specifications for the equipment based on model/description. In cases when the exact model was not provided, conservative assumptions on potential model were made.

Emissions were calculated for NO_X, SO_2, CO, TPM, PM_{10}, and $PM_{2.5}$. It was conservatively assumed that TPM=PM_{10}=$PM_{2.5}$.

Stationary Combustion

Emissions will result from the combustion of diesel fuel in generators, heaters, mobile crushers/batch plant and generators for tower lights. Emissions were estimated using emission factors from the US EPA Chapter 3.4 Stationary Internal Large Stationary Diesel and All Stationary Dual-Fuel Engines (US EPA 1996).

Emissions are estimated as:

$$ER_{TPM} = EF \times Diesel\ Consumption \times Conversion$$

Where
EF: Emission factor in lb/MMBTu, presented in Table 6A-8
Diesel Consumption in MMBTu, which was estimated from the provided quantity of diesel used (~1 ML per site, 2 ML total), the higher heating value of diesel (139,000 btu/ga)l, and conversion of ML to gal (3.7854x10^6 gal/ML).

$$ER_{TPM} = 0.31\frac{lb}{MMBtu} \times 32{,}784.3\frac{MMBTu}{year} \times \frac{1\ tonne}{2204\ lb}$$

$$ER_{TPM} = 4.61\frac{tonne}{year}$$

Emissions were calculated for NO_X, SO_2, CO, TPM, PM_{10}, $PM_{2.5}$, select speciated PAHs and speciated VOCs.

Table 6A-8 Emission Factors for Stationary Internal Combustion – Diesel Engines

Species	CAS Number	Diesel Emission Factor (lb/MMBtu)
Acetaldehyde	75-07-0	7.67E-04
Acrolein	107-08-8	9.25E-05
Anthracene	120-12-7	1.87E-06
Benzene	71-43-2	9.33E-04
1,3-butadiene	106-99-0	3.91E-05
Formaldehyde	50-00-0	1.18E-03
Naphthalene	91-20-3	8.48E-05
Propylene	115-07-1	2.58E-03
Toluene	108-88-3	4.09E-04
Isomers of xylene	1330-20-7	2.85E-04
Acenaphthene	83-32-9	1.42E-06

Table 6A-8 Emission Factors for Stationary Internal Combustion – Diesel Engines

Species	CAS Number	Diesel Emission Factor (lb/MMBtu)
Acenaphthylene	208-96-8	5.06E-06
Benzo (a) anthracene	56-55-3	1.68E-06
Benzo (a) pyrene	50-32-8	1.88E-07
Benzo (b) fluoranthene	205-99-2	9.09E-05
Benzo (k) fluoranthene	207-08-9	1.55E-07
Dibenzo (a,h) anthracene	53-70-3	5.83E-07
Benzo (g,h,i) perylene	191-24-2	4.89E-07
Fluoranthene	206-44-0	7.61E-06
Fluorene	86-73-7	2.92E-05
Indeno(1,2,3-c,d) pyrene	193-39-5	3.75E-07
Phenanthrene	85-01-8	2.94E-05
Pyrene	129-00-0	4.78E-06
Total PAHS		1.68E-04
CO	630-08-0	9.50E-01
NOx, expressed as nitrogen dioxide (NO_2)	10102-44-0	4.41E+00
TPM	N/A-1	3.10E-01
PM_{10}	N/A-2	3.10E-01
$PM_{2.5}$	N/A-3	3.10E-01
SO_2	7446-09-5	2.90E-01
Volatile organic compounds	NA - M16	3.60E-01
Benzene	71-43-2	9.33E-04
1,3-butadiene	106-99-0	3.91E-05
Formaldehyde	50-00-0	1.18E-03
Propylene	115-07-1	2.58E-03
Toluene	108-88-3	4.09E-04
Isomers of xylene	1330-20-7	2.85E-04

Operation

Cooling Towers

An open recirculating cooling tower will be required to cool the electrolysers and these are known to be potential sources of particulate matter. Water used in the cooling tower is sourced from the industrial water system. As the water evaporates, the particulate present in the water can be released into the air, driven by the cooling tower fans (through induced flow). An example calculation of total particulate matter (TPM) release estimates from the cooling towers is provided.

Particulate releases are estimated from the cooling tower following the method described in Environment and Climate Change Canada's (ECCC) NPRI "Wet cooling towers: guide to reporting" (ECCC 2023) which follows the approach in AP-42 Chapter 13.4 (UE EPA 1995b). It was conservatively assumed that TPM = PM_{10} = $PM_{2.5}$. The emissions are total for the full cooling tower unit and were modelled split evenly by cell.

Emissions are estimated as:

$$ER_{TPM} = Total\ Dissolved\ Particulate\ in\ Water\ \times Drift\ Loss\ \times Circulating\ Water\ Rate \times Conversion\ Factors$$

Where
Total Dissolved Particulate in Water is measured in mg/L, from lab analysis to be 649 mg/L as provided by the design team
Drift Loss is a percentage of the water lost due to evaporation and blow down of the system (the amount of water lost to the atmosphere), for induced draft value is 0.02% (US EPA 1995b)
Circulating Water Rate is measured in L/hour, provided from the design team as 50,700 GPM or 11,515,187 L/h.

The hourly emission rate for TPM is estimated as follows:

$$ER_{TPM} = \frac{649\ mg\ TDS}{L\ water} \times\ 0.02\% \times \frac{11{,}515{,}186.8\ L\ water}{hour} \times \frac{1\ hour}{3{,}600\ seconds} \times \frac{1\ g}{1{,}000\ mg}$$

$$ER_{TPM} = 0.42 \frac{g}{s}\ (total)$$

As the cooling tower is expected to operate continuously, the 1-hour, 24-hour and annual average emission rates (prorated on a grams/second basis for modelling) are the same.

Emergency Biodiesel Generator (Combustion Turbine)

The backup power requirements of the site during operation will be met by a 50 MW biodiesel fueled generator. Given the size of the generator, it is modelled as a combustion turbine as it is expected that would be the appropriate technology for that size power requirement. It is designed for emergencies (power outage), and is expected to operate approximately 13 hours at a time. It was assumed power outage might arise for up to four days per year.

The release estimates are based on power demand provided by the design team and emission factors sourced from US EPA AP-42 Chapter 3.1 - Stationary Gas Turbines (US EPA 2000) for regular diesel as factors for biodiesel are not available. Literature has shown that air quality emissions from biodiesel decrease particulates, hydrocarbons and carbon monoxide, while NOx emissions are generally within 2% that of regular diesel (EPA 2002). It was assumed the sulfur content of the fuel will be 15 ppm_w (0.0015%). Shown below are sample calculations for the NO_x emission rates.

$$ER_{NO_x} = EF_{NO_X} \times (Thermal\ Energy\ Flow)_{burning} \times conversion\ factors$$

Where
EF: Emission factor in lb/MMBTu
Thermal Energy Flow is the energy released by the gases combusted in the turbine (in MMBTu/h) (converted from 50 MW to MMBTu assuming that the thermal efficiency is 30% and the alternator efficiency is 90%)

$$ER_{NO_x} = \frac{0.88\ lb\ NO_X}{MMBTu} \times \frac{631.9\ MMBTu}{h} \times \frac{453.592\ g}{lb} \times \frac{1\ h}{3{,}600\ s}$$

$$ER_{NOX} = 70.1\frac{g}{s}$$

The maximum daily emission rate is estimated by prorating the hourly maximum emissions, since the generator runs for at most 13 hours, the daily emissions are calculated as follows:

$$ER_{NO_X} = 70.1\frac{g}{s} \times \frac{13\ h}{24\ h} = 37.95\frac{g}{s}$$

Similarly, since there are only four events assumed per year, the annual emission rate is estimated by prorating the daily maximum emissions:

$$ER_{NO_X} = 37.95\frac{g}{s} \times \frac{4\ days}{365\ days} = 0.42\frac{g}{s}$$

The emission factors used for the remainder of the air contaminants modelled are provided below in Table 6A-9.

Table 6A-9 Emission Factors Used for the Combustion Turbine During Operation

Species	CAS #	Emission Factor [lb/MMBTu]
NO_x	10102-44-0	0.88
CO	630-08-0	0.0033
(SO_2	7446-09-5	0.001515
TPM	N/A-1	0.012
PM_{10}	N/A-2	0.012
$PM_{2.5}$	N/A-3	0.012
Diesel Particulate Matter (DPM)	N/A-4	0.012
Benzene	71-43-2	0.000055
Formaldehyde	50-00-0	0.00028
Naphthalene	91-20-3	0.000035
Total Polycyclic Aromatic Hydrocarbons	N/A-5	0.00004

Flare Stacks

The facility will have three flare stacks that will be used to flare ammonia or hydrogen during non-routine events. The flare pilot will be lit continuously using butane so that it is ready to combust in the event of a non-routine flaring requirement. The flare is used for controlled safety releases of hydrogen and ammonia in non-routine situations. It is estimated that the flare will only be used once per year and conservatively assumed that the full amount of ammonia (11.5 tons or 11,685 kg) could be released over an hour.

The combustion of butane in the flare will result in thermal NO_x emissions. As butane's (C_4H_{10}) composition does not include nitrogen, fuel NOx is not expected to be formed from its combustion. The combustion of ammonia in the flare will also likely result in both thermal NO_x and fuel NO_x emissions. Thermal NO_x emissions are estimated using emission factors from the AP-42 Chapter 13.5 Industrial Flares (US EPA 1995) and from the Texas Commission on Environmental Quality (TCEQ) 2021 Emissions Inventory Guidelines (RG-360/21). Fuel NOx from the combustion of ammonia were estimated using an emission factor from the TCEQ 2021 Emissions Inventory Guidelines. Particulate emissions were estimated using an emission factor from an article "Black Carbon Particulate Matter Emission Factors for Buoyancy Driven Associated Gas Flares (McEwen & Johnson 2012).

Residual emissions of gases sent to flare (ammonia and butane) are calculated assuming a destruction efficiency of 98% (obtained from US EPA AP-42 Chapter 13.5 – Industrial Flares, 1995c).

Thermal NO_x emissions for butane combustion can be found from the following equation:

$$ER_{NO_X,pilot} = EF_{NO_X} \times (Thermal\ Energy\ Flow)_{burning} \times conversion\ factors$$

Where
EF: Emission factor in lb/MMBTu
Thermal Energy Flow is the energy released by the gases combusted in the flare (in MMBTu/h)

$$ER_{NO_X,pilot} = \frac{0.068\ lb\ NO_X}{1{,}000{,}000\ BTu} \times \left(\frac{2.1\ kg\ butane}{h} \times \frac{49.1\ MJ}{kg\ butane} \times \frac{947.8170\ BTu}{MJ}\right) \times \frac{0.45\ kg}{lb} \times \frac{1{,}000\ g}{kg} \times \frac{h}{3{,}600\ s}$$

$$ER_{NO_X,pilot} = 0.00084\frac{g}{s}$$

Similarly, when burning ammonia during the flare event (11,685 kg/h of ammonia):

$$ER_{NO_X,flare,thermal} = \frac{0.068\ lb\ NO_X}{1{,}000{,}000\ BTu} \times \left(\frac{11{,}685\ kg\ NH_3}{h} \times \frac{22.5\ MJ}{kg\ NH_3} \times \frac{947.8170\ BTu}{MJ}\right) \times \frac{0.45\ kg}{lb} \times \frac{1{,}000\ g}{kg} \times \frac{h}{3{,}600\ s} ER_{NO_X,flare,thermal} = 2.135\frac{g}{s}$$

The emission factors used for the remainder of the air contaminants modelled are provided below in Table 6A-10

Table 6A-10 Thermal Emission Factors Used for the Flare During Operation (Pilot and Flaring)

Species	CAS #	Emission Factor [lb/MMbtu]
NO_x	10102-44-0	0.068
CO	630-08-0	0.5496
TPM	N-A-1	0.74798 (kg/10^3 m^3 fuel)

Particulate emissions from the burning of butane (during pilot operation of the flares) were considered from the following equation:

$$ER_{TPM,pilot} = EF_{TPM} \times Volume\ of\ Butane \times conversion\ factors$$

Where
EF: Emission factor in kg/1000 m^3 fuel, as shown in Table 6A-10
Volume of Butane is the total volumetric flowrate of butane in m^3/h

Therefore, the estimated emissions of TPM (also the estimated emissions for PM_{10} and $PM_{2.5}$) are:

$$ER_{TPM,pilot} = 0.8\frac{m^3\ butane}{hour} \times \frac{0.74798\ kg\ TPM}{1000\ m^3\ butane} \times \frac{1\ h}{3{,}600\ s}$$

$$ER_{TPM,pilot} = 1.76 \times 10^{-7}\frac{g}{s}$$

Burning ammonia will also combust to form nitrogen containing compounds, including NO_x. The NOx from fuel emission rate can be calculated from the following:

$$ER_{NO_X,flare,fuel} = Flow\ rate\ of\ ammonia \times EF_{NO_X} \times conversion\ factors$$

Where
Flow rate of ammonia is measured in kg/h
EF: Emission factor in kg NO_x/kg NH_3 (obtained from TCEQ 2021)

$$ER_{NO_X,flare,fuel} = \frac{11{,}684.6\ kg\ ammonia}{h} \times \frac{0.005\ kg\ NO_X}{kg\ ammonia} \times \frac{1{,}000\ g}{kg} \times \frac{1\ h}{3{,}600\ s}$$

$$ER_{NO_X,flare,fuel} = 16.3\frac{g}{s}$$

Therefore the total emission rate of NO_x during a flare event is:

$$ER_{NO_X,flare} = ER_{NO_X,flare,fuel} + ER_{NO_X,flare,thermal} = 18.4\frac{g}{s}$$

To calculate the remaining ammonia, a destruction rate of 98% was assumed as above:

$$ER_{NH_3,flare} = Flow\ rate\ of\ ammonia \times (1 - Destruction\ Rate) \times conversion\ factors$$

Where
Flow rate of ammonia is measured in kg/h
Destruction Rate is the percentage of ammonia consumed in the combustion

$$ER_{NH_3,flare} = \frac{11{,}684.6\ kg\ ammonia}{h} \times (1 - 0.98) \times \frac{1{,}000\ g}{kg} \times \frac{1\ h}{3{,}600\ s}$$

$$ER_{NH_3,flare} = 64.9\frac{g}{s}$$

Marine Vessel and Tugs

Ammonia carriers will be used to ship the product from the Port of Stephenville, with the three most common vessel sizes being 30,000 m^3, 52,000 m^3, and 80,000 m^3. The client provided the number of trips per month depending on the vessel size - if the mid-sized vessel was used, there would be 4 vessel fillings per month at maximum production. The loading system will be a jettyless floating offloading system, floated to the vessel using tugs. Maneuvering will take approximately 2 hours, while loading time was estimated from the loading pipe rate combined with the product volume (ship capacity).

The vessel used was conservatively assumed to be the 50,000 m^3 Capacity Vessel (a LNG Tank Clipper Mars) as this vessel combusts MGO/HFO which would have somewhat higher emissions as opposed to LNG which the larger vessel would use. Due to Canadian water regulations, MGO with maximum sulphur content of 0.10% must be used in Canadian jurisdictions.

The air contaminant emissions are calculated under the assumption that the tug boats are operated during loading as part of the jettyless floating offloading system. Emissions of speciated organic compounds were estimated from an emission factor (AP-42 Chapter 1.3) and the fuel usage rates. Emissions of the criteria air contaminants (NO_2, CO, PM_{10}, $PM_{2.5}$, and SO_2) were estimated using emission factors, the engine power rating (kW), and the load factor.

Hourly criteria air contaminant (CAC) and organic emissions were calculated by:

$$ER_{marine\ vessel} = ER_{hoteling} + ER_{boilers}$$

$$ER_{tugs} = ER_{maneuvering}$$

Where the total emission rate (ER) for the marine vessel is the combination of the emissions from the engines while hoteling, and the emissions from the onboard boilers. The marine vessel used in this assessment was estimated as a 3,600 kW vessel, 26% usage during hoteling. As per the vessel specifications, the onboard boilers consume 0.1326 m^3/h of fuel.

For the tugs, hourly CAC emission rates were calculated by considering the tugs maneuvering around the marine vessel. These emissions were calculated similarly to the marine vessel hoteling calculations. The tugs were each considered to have a 1,540 kW engine, with an engine load of 45% during maneuvering. For the tugs, there were assumed to be no boiler emissions.

The emission rates, during marine vessel hoteling/maneuvering, were calculated by:

$$ER_{hotelling/maneuvering} = Engine\ Power\ Rating \times Load\ Factor \times EF \times conversion\ factors$$

Where
Engine Power Rating is in kW
Load Factor is the fraction of engine power required
EF: the emission factor for a given CAC in g/kWh, or an organic contaminant in lb/MMBTu

The CAC emission rates from the marine vessel boilers were calculated from:

$$ER_{boilers} = Fuel\ Consumption\ \times EF \times conversion\ factors$$

Where
Fuel Consumption is in m^3/h
EF: the emission factor for a given CAC in kg/m^3 of fuel consumed

The organic contaminant emission rates from the marine vessel boilers were calculated from:

$$ER_{boilers} = Engine\ Power\ Rating \times Load\ Factor \times EF \times conversion\ factors$$

Where
Engine Power Rating is in kW
Load Factor is the fraction of engine power required
EF: the emission factor for a given organic contaminant in lb/MMBTu

As an example, for the marine vessel NO_x emissions:

$$ER_{NO_x,hotelling} = 3{,}600\ kW \times 0.26 \times 12.10\frac{g}{kWh} \times \frac{1\ h}{3{,}600\ s} = 3.146\frac{g}{s}$$

$$ER_{NO_x,boilers} = 0.1326\frac{m^3\ fuel\ consumed}{h} \times 2.41\frac{kg}{m^3\ fuel\ consumed} \times 1000\frac{g}{kg} \times \frac{1\ h}{3{,}600\ s} = 0.089\frac{g}{s}$$

$$ER_{NO_x,marine\ vessel} = 3.146\frac{g}{s} + 0.089\frac{g}{s} = 3.235\frac{g}{s}$$

Emissions factors for the CACs considered are shown in Table 6A-11 and Table 6A-12. Emissions factors for the organic contaminants considered are shown in Table 6A-13.

Table 6A-11 Emission Factors Used for Estimating Hoteling/Maneuvering CAC Emission Rates

Species	CAS #	Emission Factor [g/kWh]
NO_x	10102-44-0	12.1
CO	630-08-0	1.1
SO_2	7446-09-5	0.42
TPM	N/A-1	0.18
PM_{10}	N/A-2	0.18
$PM_{2.5}$	N/A-3	0.17

Table 6A-12 Emission Factors Used for Estimating Marine Vessel Boiler CAC Emission Rates

Species	CAS #	Emission Factor [kg/m^3]
NO_x	10102-44-0	2.41
(CO	630-08-0	0.6
SO_2	7446-09-5	1.71
TPM	N/A-1	0.12
PM_{10}	N/A-2	0.12
$PM_{2.5}$	N/A-3	0.03

Table 6A-13 Emission Factors Used for Estimating Organic Contaminant Emission Rates

Species	CAS #	Emission Factor [lb/MMBTu]
Benzene	71-43-2	0.000776
Formaldehyde	50-00-0	7.89E-05
Naphthalene	91-20-3	1.30E-04
Toluene	108-88-3	2.81E-04
Xylenes	1330-20-7	1.93E-04
Acrolein	107-02-8	7.88E-06
Acenaphthylene	208-96-8	9.23E-06
Acenaphthene	83-32-9	4.68E-06
Fluorene	86-73-7	1.28E-05
Phenanthrene	85-01-8	4.08E-05
Anthracene	120-12-7	1.23E-06
Fluoranthene	206-44-0	4.03E-06
Pyrene	129-00-0	3.71E-06
Benz(a)anthracene	56-55-3	6.22E-07
Chrysene	218-01-9	1.53E-06
Benzo(b)fluoranthene	205-99-2	1.11E-06
Benzo(k)fluoranthene	207-08-9	2.18E-07
Benzo(a)pyrene	50-32-8	2.57E-07
Indeno(1,2,3-cd)pyrene	193-39-5	4.14E-07
Dibenz(a,h)anthracene	53-70-3	0.000000346
Benzo(g,h,l)perylene	191-24-2	0.000000556
Total PAHs	N/A-5	0.000212

Daily emission rates were assumed equivalent to the hourly rates since the marine vessel loading will occur over a period greater than 24 hours. The annual emissions were prorated to account for the total loading time (43 hours) and the total number of vessels per year (48 vessels) provided by World Energy GH2. The total, 2,064 hours, was divided by the total number of hours in the year.

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Appendix 6-B

Dispersion Modelling Strategy

Dispersion Modelling Strategy

The California Puff (CALPUFF) dispersion modelling system was used to predict the maximum ground level concentrations of the substances of interest in relation to ambient air quality in the Local Assessment Area (LAA) / Regional Assessment Area (RAA) during normal operation of the Project.

The CALPUFF model is a non-steady-state Gaussian puff dispersion model that incorporates simple chemical transformation mechanisms, complex terrain algorithms and building downwash. It is suitable for estimating ground-level concentrations on local and regional scales, from tens of meters to hundreds of kilometers. The core of this modelling system consists of a meteorological model, CALMET, a transport and dispersion model, CALPUFF, and a post-processor model, CALPOST, which is designed to report the concentrations of the air contaminants of interest.

The CALPUFF model was chosen over AERMOD as it has better algorithms to handle complex terrain and it is the preferred model for studies by the Newfoundland and Labrador Department of Municipal Affairs and Environment (NLDMAE).

CALMET Meteorological Modelling

Meteorology influences the way air contaminant emissions from industrial and natural sources disperse into the atmosphere thus affecting air quality. Atmospheric dispersion of emissions is governed by the amount of turbulence that exists in the mixed layer of air in contact with the ground. Turbulence levels depend on thermal effects (e.g., vertical temperature stratification) and mechanical effects caused by topography, surface roughness, and wind speed. The height of the mixing layer determines the vertical extent to which emissions can diffuse. Meteorology varies with time of day and year and can vary from location to location because of terrain and land cover influences on turbulence and wind field.

The CALMET model was initialized using Weather Research and Forecasting (WRF) modelled data. CALMET uses the 3-D WRF data as an initial guess of the meteorological conditions within the domain before applying the influence of terrain and geophysical surface characteristics (albedo, bowen ratio, surface roughness). CALMET can then combine the WRF model data with any surface observational data or upper air data used to “fine tune” the site-specific meteorology for use in CALPUFF.

The WRF data (ready for input to CALMET) was purchased from Lakes Environmental (Lakes Environmental 2020). The WRF data, covering the three-year 2020-2022 period, consisted of a 4 km resolution 100 km by 100 km grid, centered near the Project site. The use of three years of meteorological data is considered adequate for an environmental assessment as per NL Guideline for Plume Dispersion Modelling (NLDMAE 2012).

Meteorological Data

The meteorological data required by the CALPUFF model to predict plume dispersion and transport includes surface weather data (i.e., wind velocities and direction, temperature, atmospheric stability, and mixing layer depth), and upper air data (i.e., pressure, altitude, temperature, relative humidity, wind speed and direction). CALMET can be executed using both meteorological modelled data (i.e. WRF model data) and observation data (site-specific data) from nearby surface weather stations. Surface wind and temperature data are readily available from meteorological stations, whereas atmospheric stability and mixing layer depth are calculated from additional raw meteorological data including cloud cover, snow cover, and solar radiation. However, for this assessment, WRF data alone were used to initialize CALMET.

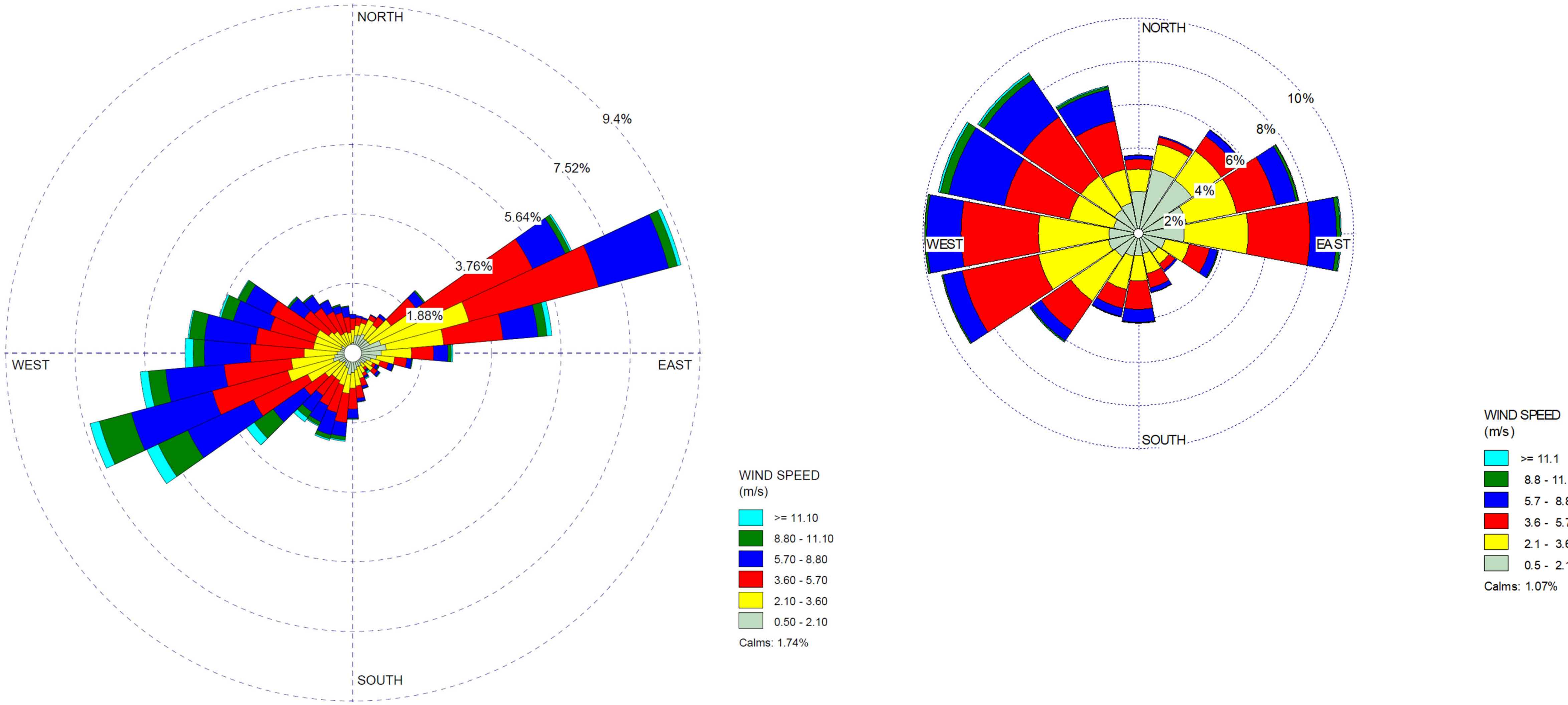
CALMET Meteorological Modelling

The latest version of CALMET (version 6.5.0) was used for this study. The CALMET model was run for the three-year period, 2020 to 2022. A horizontal grid spacing of 500 m was selected for the CALMET modelling and the study area was 90 km by 100 km, consistent with the LAA/RAA. The size of the grid was chosen to cover both construction and operation of the Project.

The CALMET model was initialized using the 4 km grid WRF data at various levels of the atmosphere within the model domain.

The CALMET predicted winds at the Project site (at the facility during operations) covering the 2020 to 2022 model period are shown in Figure 6B.1(a). The winds are predicted to occur most frequently from the northeast. The predominant wind directions are from the southwest and the northeast, with a larger proportion of strong windspeeds from the southwest direction.

For comparison, historical winds at the Stephenville meteorological station have been plotted in Figure 6B.1(b), for the 2018 to 2022 period. In general, the dominant wind directions are from the west (northwest and southwest) and the east. These are partially consistent with the CALMET predictions at the Project site. However, the Project site also has higher elevation terrain almost immediately to the south, which will impact wind directions.



(a) (b)

Figure 6B.1 (a) CALMET Predicted Winds at the Project Site – 2020 - 2022 (b) Winds at Stephenville, NL – 2018 - 2022

CALPUFF Modelling

The latest version of the CALPUFF dispersion model (version 7.2.1) was used to predict ground-level concentrations of the key contaminants of concern expected to be released from the Project during operation. The modelling was conducted in support of the air quality assessment of Project operation. Operation emissions are estimated to be confined to the Hydrogen/Ammonia Production site and Port of Stephenville, both located southeast of the town of Stephenville. The Port of Stephenville is located to the southwest of the facility. The primary modelling area consisted of a 30 km by 30 km area centered on the Hydrogen/Ammonia Production site based on the predicted downwind dispersion extent of expected emission sources. Additional discrete receptors, including public spaces, hospitals and schools, were also included across a larger area of 90 km by 100 km, considered the air quality assessment Local and Regional Assessment Area (LAA/RAA).

Model Inputs

The source data required to run the CALPUFF model includes the following:

- the physical location(s) of the source(s) of air contaminants
- the emission rate(s) of the selected contaminant(s)
- the physical dimensions of the emission source (stack height or release height) and exit diameter (for point sources)
- exhaust gas properties (exit velocity and temperature for point sources)

The model input point source parameters are provided in Tables 6B.1, 6B.2 and 6B.3 below. All of the releases were assumed to occur through vertical stacks.

The air contaminant releases were modelled as maximum hourly, maximum daily and annual average emissions to determine the resulting maximum ground-level concentrations for the same averaging period, for comparison with relevant ambient air quality standards. The maximum hourly rates are estimated as the maximum emission rate that could occur in a given hour (based on operational activity data) and maximum daily emissions are the maximum rate that could occur over a 24-hour period. The maximum daily rates are generally estimated based on the hourly rate, prorated based on the hours of operation per day or hours per day where releases might occur, for sources operating (or with releases occurring) less than 24 hours per day. The annual average rates are estimated based on average activity and operating data for the peak operating year in the lifespan of the Project. Additional details on the variable emission rates are provided in the emissions inventory in Appendix 6A.

Table 6B.1 Model Input Source Characteristics – Point Sources

Source	Process Area	Location (m)		Release Height (m)	Base Elevation (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)
		X	Y					
Flare Stack[1]	Facility	388,143.22	5,376,642.58	95.42	23.00	2.00	1.43	1,273.00
Flare Stack[1]	Facility	388,145.81	5,376,639.09	95.42	23.00	2.00	1.43	1,273.00
Flare Stack[1]	Facility	388,148.04	5,376,636.04	95.42	23.00	2.00	1.43	1,273.00
Cooling Tower Exhaust	Facility	388,163.60	5,375,896.19	8.00	20.00	8.00	5.50	343.15
Cooling Tower Exhaust	Facility	388,168.83	5,375,888.23	8.00	20.00	8.00	5.50	343.15
Cooling Tower Exhaust	Facility	388,173.80	5,375,878.77	8.00	20.00	8.00	5.50	343.15
Cooling Tower Exhaust	Facility	388,178.78	5,375,870.81	8.00	20.00	8.00	5.50	343.15
Cooling Tower Exhaust	Facility	388,183.26	5,375,863.35	8.00	20.00	8.00	5.50	343.15
Emergency Biodiesel Generator	Facility	388,410.41	5,376,042.94	15.00	30.00	4.50	27.50	773.00
Marine Vessel	Harbour	387,392.72	5,375,876.54	35.00	0.00	2.00	22.80	773.00
Tug	Harbour	387,294.91	5,375,957.54	8.40	0.00	0.42	15.00	773.00
Tug	Harbour	387,391.13	5,375,924.17	8.40	0.00	0.42	15.00	773.00

Note:
[1] Stack heights for the flares are preliminary

Table 6B.2 Model Input Emission Rates – Operation – Part 1

Source	Total Emissions (g/s)														
	Total Suspended Particulate (TSP)	Particulate Matter less than 10 microns (PM_{10})	Particulate Matter less than 2.5 microns ($PM_{2.5}$)	Diesel Particulate Matter (DPM)	Nitrogen Oxides (Expressed as NO_x)	Sulphur Dioxide (SO_2)	Carbon Monoxide (CO)	Ammonia (NH_3)	Benzene	Toluene	Xylene	Formaldehyde (HCHO)	Benz[a]anthracene	Benzo[a]pyrene	Benzo[b]fluoranthene
	N/A-1	N/A-2	N/A-3	N/A-6	10102-44-0	7446-09-5	630-08-0	7664-41-7	71-43-2	108-88-3	1330-20-7	50-00-0	56-55-3	50-32-8	205-99-2
Max Hourly															
Flare Stack (per stack, pilot)	-	-	-	-	8.40E-04	-	6.79E-03	-	-	-	-	-	-	-	-
Flare Stack (per stack, flare event)	-	-	-	-	1.84E+01	-	-	6.49E+01	-	-	-	-	-	-	-
Cooling Tower Exhaust (per exhaust)	8.30E-02	8.30E-02	8.30E-02	-	-	-	-	-	-	-	-	-	-	-	-
Emergency Biodiesel Generator	9.55E-01	9.55E-01	9.55E-01	9.55E-01	7.01E+01	1.21E-01	2.63E-01	-	4.38E-03	-	-	2.23E-02	-	-	-
Marine Vessel	5.12E-02	5.12E-02	4.53E-02	5.12E-02	3.23E+00	1.72E-01	3.08E-01	-	6.03E-04	2.18E-04	1.50E-04	6.13E-05	4.83E-07	2.00E-07	8.62E-07
Tug (per vessel)	1.39E-01	1.39E-01	1.11E-01	1.39E-01	2.54E+00	1.25E-03	2.12E-01	-	2.32E-04	8.39E-05	5.76E-05	2.36E-05	1.86E-07	7.67E-08	3.31E-07
Max Daily															
Flare Stack (per stack, pilot)	-	-	-	-	8.40E-04	-	6.79E-03	-	-	-	-	-	-	-	-
Flare Stack (per stack, flare event)	-	-	-	-	7.65E-01	-	-	6.49E+01	-	-	-	-	-	-	-
Cooling Tower Exhaust (per exhaust)	8.30E-02	8.30E-02	8.30E-02	-	-	-	-	-	-	-	-	-	-	-	-
Emergency Biodiesel Generator	5.17E-01	5.17E-01	5.17E-01	5.17E-01	3.79E+01	6.53E-02	1.42E-01	-	2.37E-03	-	-	1.21E-02	-	-	-
Marine Vessel	5.12E-02	5.12E-02	4.53E-02	5.12E-02	3.23E+00	1.72E-01	3.08E-01	-	6.03E-04	2.18E-04	1.50E-04	6.13E-05	4.83E-07	2.00E-07	8.62E-07
Tug (per vessel)	1.39E-01	1.39E-01	1.11E-01	1.39E-01	2.54E+00	1.25E-03	2.12E-01	-	2.32E-04	8.39E-05	5.76E-05	2.36E-05	1.86E-07	7.67E-08	3.31E-07
Average Annual															
Flare Stack (per stack, pilot)	-	-	-	-	8.40E-04	-	6.79E-03	-	-	-	-	-	-	-	-
Flare Stack (per stack, flare event)	-	-	-	-	2.10E-03	-	-	6.49E+01	-	-	-	-	-	-	-
Cooling Tower Exhaust (per exhaust)	8.30E-02	8.30E-02	8.30E-02	-	-	-	-	-	-	-	-	-	-	-	-
Emergency Biodiesel Generator	5.67E-03	5.67E-03	5.67E-03	5.67E-03	4.16E-01	7.16E-04	1.56E-03	-	2.60E-05	-	-	1.32E-04	-	-	-
Marine Vessel	1.16E-02	1.16E-02	1.03E-02	1.16E-02	7.33E-01	3.90E-02	6.98E-02	-	6.57E-05	2.38E-05	1.63E-05	6.68E-06	5.27E-08	2.18E-08	9.40E-08
Tug (per vessel)	3.72E-02	3.72E-02	3.02E-02	3.72E-02	5.76E-01	2.83E-04	4.80E-02	-	3.05E-05	1.10E-05	7.58E-06	3.10E-06	2.44E-08	1.01E-08	4.36E-08

Table 6B.3 Model Input Emission Rates – Operation – Part 2

Source	Total Emissions (g/s)														
	Benzo[k]fluoranthene	**Chrysene**	**Benzo[g,h,i]perylene**	**Anthracene**	**Acenaphthene**	**Acenaphthylene**	**Fluoranthene**	**Fluorene**	**Naphthalene**	**Phenanthrene**	**Pyrene**	**Total Polycyclic Aromatic Hydrocarbons (PAHs)**	**Acrolein**	**Dibenz[a,h] anthracene**	**Indeno[1,2,3-c,d] pyrene**
	207-08-9	**218-01-9**	**191-24-2**	**120-12-7**	**83-32-9**	**208-96-8**	**206-44-0**	**86-73-7**	**91-20-3**	**85-01-8**	**129-00-0**	**N/A-5**	**107-02-8**	**53-70-3**	**193-39-5**
Max Hourly															
Flare Stack (per stack, pilot)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flare Stack (per stack, flare event)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cooling Tower Exhaust (per exhaust)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emergency Biodiesel Generator	-	-	-	-	-	-	-	-	2.79E-03	-	-	3.18E-03	-	-	-
Marine Vessel	1.69E-07	1.19E-06	4.32E-07	9.56E-07	3.64E-06	7.17E-06	3.13E-06	9.95E-06	1.01E-04	3.17E-05	2.88E-06	1.65E-04	6.12E-06	2.69E-07	3.22E-07
Tug (per vessel)	6.51E-08	4.57E-07	1.66E-07	3.67E-07	1.40E-06	2.76E-06	1.20E-06	3.82E-06	3.88E-05	1.22E-05	1.11E-06	6.33E-05	2.35E-06	1.03E-07	1.24E-07
Max Daily															
Flare Stack (per stack, pilot)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flare Stack (per stack, flare event)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cooling Tower Exhaust (per exhaust)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emergency Biodiesel Generator	-	-	-	-	-	-	-	-	1.51E-03	-	-	1.72E-03	-	-	-
Marine Vessel	1.69E-07	1.19E-06	4.32E-07	9.56E-07	3.64E-06	7.17E-06	3.13E-06	9.95E-06	1.01E-04	3.17E-05	2.88E-06	1.65E-04	6.12E-06	2.69E-07	3.22E-07
Tug (per vessel)	6.51E-08	4.57E-07	1.66E-07	3.67E-07	1.40E-06	2.76E-06	1.20E-06	3.82E-06	3.88E-05	1.22E-05	1.11E-06	6.33E-05	2.35E-06	1.03E-07	1.24E-07
Average Annual															
Flare Stack (per stack, pilot)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flare Stack (per stack, flare event)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cooling Tower Exhaust (per exhaust)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emergency Biodiesel Generator	-	-	-	-	-	-	-	-	1.65E-05	-	-	1.89E-05	-	-	-
Marine Vessel	1.85E-08	1.30E-07	4.71E-08	1.04E-07	3.96E-07	7.81E-07	3.41E-07	1.08E-06	1.10E-05	3.45E-06	3.14E-07	1.79E-05	6.67E-07	2.93E-08	3.50E-08
Tug (per vessel)	8.56E-09	6.01E-08	2.18E-08	4.83E-08	1.84E-07	3.62E-07	1.58E-07	5.03E-07	5.10E-06	1.60E-06	1.46E-07	8.32E-06	3.09E-07	1.36E-08	1.63E-08

Building Profile Input Program

The presence of buildings and structures can affect the way air contaminants released from nearby emission sources are dispersed in the atmosphere. Building downwash can occur when wind flows over and around buildings. On the lee side of certain buildings, turbulent wake zones can be created, reducing plume rise and drawing exhaust gases towards the ground.

Building downwash effects (due to potential interactions of structures at the site with exhaust plumes from point sources) were considered in the model using the Building Profile Input Program (BPIP). The Plume Rise Model Enhancement (PRIME) module of CALPUFF was used to model downwash.

The building layout and three-dimensional renderings of the buildings in the model are illustrated in Figure 6B.2 and Figure 6B.3. The red crosshair symbols represent point sources in the model.

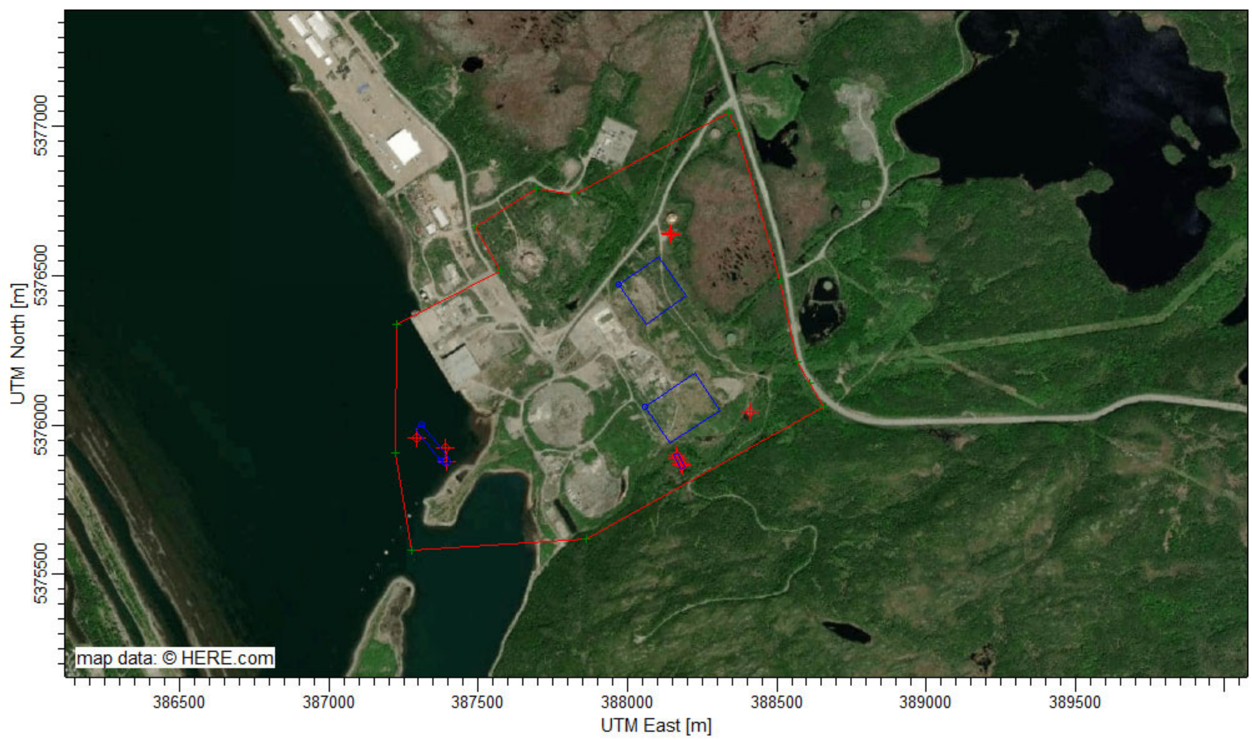


Figure 6B.2 Facility Building Layout

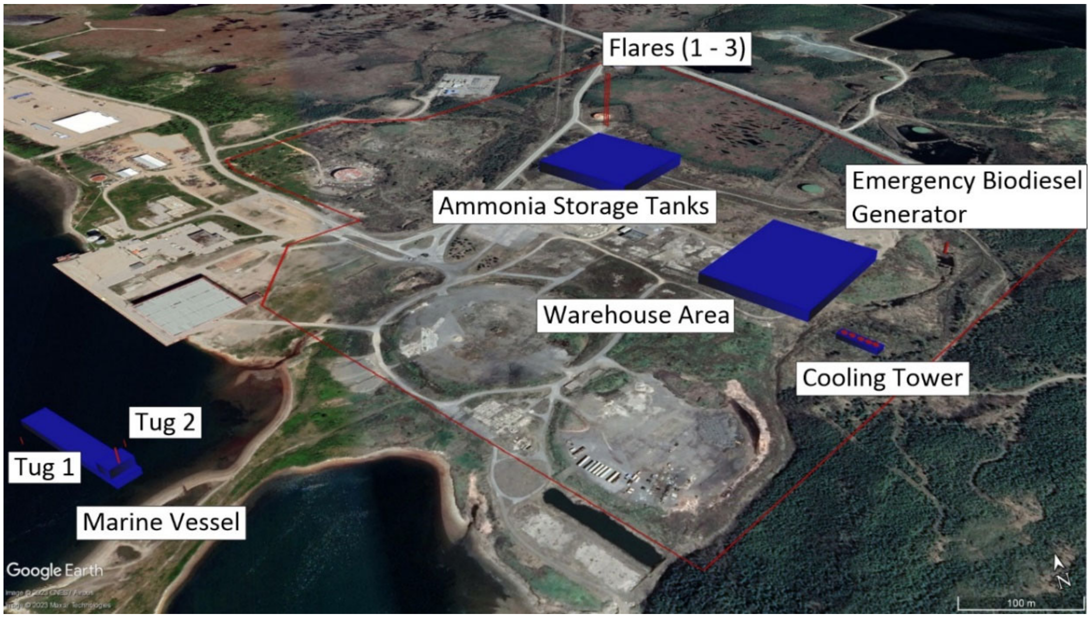


Figure 6B.3 Three-Dimensional Rendering of Processing Plant Buildings (overlayed on Google Earth)

Receptor Grid

The receptor grid used in the model was developed based on the NL Guideline for Plume Dispersion Modelling (NLDMAE 2012). The nested grids were expanded beyond the minimum limits in the model guideline because of the large area of the site.

The receptor grid spacing used in the model is as follows:

- 20 metre spacing along the Project Area boundary
- 50 metre spacing from the center of operation (center of the facility area) out to 750 metres
- 100 metre spacing from 750 metres out to 1,500 metres
- 200 metre spacing from 1,500 metres out to 4,000 metres
- 500 metre spacing from 4,000 metres out to the 15,000 metres (to define the 30 km x 30 km grid)

Gridded receptors that fall within the Project Area boundary (inside the facility and Port of Stephenville property boundaries) were removed from the model. This includes some of the over water receptors, as the port area was extended to cover marine vessels. The maximum predicted concentrations outside the Project Area are used in the assessment for comparison with the ambient air quality standards.

Receptors representing sensitive receptors (hospitals, schools, public areas, etc.) within the LAA were also included in the model, even if they were outside the 30 km x 30 km grid.

The gridded and discrete receptor (sensitive institution) locations are show in Figure 6B.4. A full list of sensitive receptors is summarized in Table 6B.4.

Stantec

- Grid Receptor
- Sensitive Receptor
- Modelled Site Boundary

Proposed Project Features

- Hydrogen / Ammonia Plant Location
- Project Area

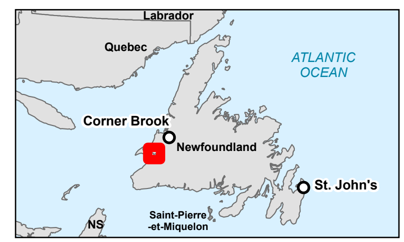
Other Features

- Trans-Canada Highway
- Road
- Transmission Line 230 kV
- Watercourse
- Waterbody
- Wetland
- Forested Area

N

0 4 Kilometres
(At original document size of 8.5x11)
1:200,000

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 21N
2. Data Sources: World Energy GH2, NRCan CanVec, OpenStreetMap
3. Background: NRCan CanVec



Project Location
Stephenville
NL

Prepared by MER on 2023-07-06
QR by AW on 2023-07-19

Client/Project
World Energy GH2 Inc.,
Project Nujio'qonik

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Figure No.
6B.4

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Grid Receptor

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Table 6B.4 Sensitive Receptor Locations

Receptor Number	Easting (m)	Northing (m)	Description
1	372579.42	5379876.46	The Gravels
2	371805.00	5380208.12	Lead Cove
3	359501.36	5382150.64	Piccacdilly Small Craft Harbour
4	359861.32	5383591.60	Piccadilly Park
5	353809.15	5389828.68	RC Cemetery (Lourdes)
6	352653.25	5390206.75	Lourdes Elementary School
7	352789.70	5390254.42	Our Lady of Lourdes Parish Grotto
8	347086.12	5388313.53	Three Rock Cove Roman Catholic Cemetery
9	345614.69	5387375.11	Saint Philomena's Chapel
10	339753.24	5382109.78	Saint Anne Roman Catholic Church
11	339747.72	5382043.58	École Sainte-Anne
12	335008.45	5372717.53	Clinique St. George
13	332375.88	5370473.85	The Boot
14	332779.95	5370395.39	French Bread Oven
15	332779.75	5370423.66	Boutte du Cap Park
16	338668.76	5372552.06	Benoit First Nation Penwaaq L'nu'k
17	335603.52	5371064.52	St. Benedicts Cemetery - Sape' wit Penwa' Wutqutaqne'Katim
18	337373.36	5371599.12	Cape Saint George Marina
19	338065.64	5372340.09	École Notre-Dame-Du-Cap
20	338024.78	5372434.19	Cape St. George Recreation Centre
21	338220.02	5372249.72	Ballfield
22	338320.91	5372246.13	Our Lady of the Cape De Grau Cemetery
23	338194.02	5372310.70	Our Lady of the Cape School
24	338117.79	5372376.61	Park
25	338075.64	5372414.72	Our Lady of the Cape Parish Rectory
26	338737.90	5372383.78	Mawio'mi Cultural Grounds
27	338731.63	5372455.08	Loon Park and Forest
28	338742.01	5372924.57	Benoit First Nation M'gmaw Heritage Park
29	338711.20	5373110.99	Long FIeld
30	338497.82	5373059.38	Joe-Mic's Trail
31	338852.17	5373197.26	Mi'kmaw Heritage Park and Farm
32	339031.65	5373363.65	Big Field
33	339218.88	5373688.43	Cape St. George Community Pasture
34	343134.38	5373866.27	Marches Point RC Cemetery

Table 6B.4 Sensitive Receptor Locations

Receptor Number	Easting (m)	Northing (m)	Description
35	348415.41	5375880.18	Hidden Falls
36	348231.45	5376300.04	Saint Joseph Catholic Church
37	355826.82	5375840.21	Roman Catholic Cemetery (Ship Cove)
38	358581.90	5375812.50	Fishing Shacks
39	358353.33	5376541.78	Our Lady of Fatima Parish Community Centre
40	358197.54	5376614.26	Our Lady of Fatima Catholic Parish
41	372193.16	5379936.41	Danny's Walking Trail
42	369407.90	5377284.24	Our Lady of Mercy Heritage Church
43	373494.27	5379505.51	Dan McIssac Baseball Field and Walking Track
44	373164.65	5379710.13	Saint James Anglican Cemetery
45	373089.24	5379712.97	Saint James Anglican Church
46	373531.48	5379658.19	St Thomas Aquinas Elementary School
47	373608.22	5379751.89	Maria Regina Catholic Church
48	377167.09	5383315.61	Stephenville Radar Station
49	376155.00	5394387.21	Fox Island and Point au Mal Community Centre
50	380128.70	5378869.86	Kippens Recreation Complex
51	380227.31	5379264.26	Kippens Community Garden
52	382112.19	5379015.03	Stephenville High School
53	382864.84	5378066.96	Stephenville Elementary
54	382953.69	5378003.95	St Stephen Roman Catholic Church
55	382983.58	5379601.65	Salvation Army Citadel
56	383178.41	5379114.27	Anglican Church (Stephenville)
57	383795.40	5378953.05	Blanche Brook Park
58	384452.40	5378534.01	Stephenville Harmon Ball Diamond
59	384656.31	5378462.21	Stephenville Aquatic Centre
60	384717.84	5378920.57	College of the North Atlantic
61	385147.50	5379713.39	Stephenville Dome
62	388115.01	5376622.63	Joey's Lookout Trail
63	388041.61	5375280.36	Joey's Lookout
64	385999.01	5381631.09	Whaleback Nordic Ski Club Attraction
65	394706.66	5371532.21	Stephenville Crossin Trestle
66	394178.28	5368946.43	Black Banks Beach
67	390932.30	5366092.87	Turf Point (Indian Cove)
68	391169.41	5365168.34	Siki Bennett Memorial Stadium
69	390632.82	5364547.65	Roman Catholic Cemetery (Saint George's)

Table 6B.4 Sensitive Receptor Locations

Receptor Number	Easting (m)	Northing (m)	Description
70	396581.41	5366735.12	Riverside Rest Area
71	382543.43	5360589.25	Calm Waters Park
72	404870.55	5371040.81	Barachois Pond Provincial Park
73	383395.70	5380139.03	Lewis Hills International Appalachian Trail
74	385083.32	5376523.48	Harmon Seaside Links
75	385731.67	5375320.62	Port Harmon Beach
76	390272.89	5364717.77	Bayview Academy
77	390398.63	5364937.13	K'Taqmkuk Mi'Kmaq Historical Museum
78	388651.25	5364197.11	Cemetery (St. Joseph's 2)
79	388385.70	5364102.26	St. Joseph's Roman Catholic Cemetery
80	371266.47	5344513.38	Trans-Canada Highway Parking
81	367965.85	5337241.92	Crabbes River Park
82	367270.68	5328907.80	Wishingwell Campground
83	320741.87	5305797.39	Beach Point
84	321328.23	5305637.34	Holy Trinity Anglican Church
85	347475.35	5307324.21	Sgt. Craig Gillam Mark Rock Trail
86	355390.26	5318660.72	Trans Canada Highway Parking 2
87	370673.33	5378741.99	Leisure Association Seniors Club
88	382496.66	5361815.71	Flat Bay Community Centre
89	382399.62	5361854.15	St. Anne's Roman Catholic Cemetery
90	379944.48	5361190.40	Powwow Grounds (Flat Bay)
91	370084.41	5349203.57	Heatherton Hall
92	370066.08	5349179.13	St. Joseph's Catholic Church
93	369284.99	5348790.60	Heatheron United Church Cemetery
94	367458.61	5345828.42	Crosswinds Seniors Resort
95	364629.82	5343978.57	E.A. Butler All Grade School
96	361601.68	5342252.38	Wharf (St. David's)
97	381176.06	5378640.67	Silverwood Manor
98	385438.76	5379882.78	Acadian Village
99	385459.92	5379607.61	Sir Thomas Roddick Hospital
100	384840.80	5379554.70	Mayfield Soccer Pitch
101	384112.06	5378777.86	Legion Memorial
102	367992.88	5337172.59	Salmon Run Resort
103	362836.10	5338070.34	Saint Columcille Church
104	356022.49	5336895.27	Cemetery

Table 6B.4 Sensitive Receptor Locations

Receptor Number	Easting (m)	Northing (m)	Description
105	394019.16	5372462.46	Community Ballfield
106	389859.43	5364747.61	Mercy Christian Church
107	386850.92	5381197.31	Gallants/Hillside Interfaith Cemetery
108	390067.07	5364786.22	Mercy Christian Church
109	390275.77	5364790.41	St Joseph Roman Catholic Church
110	393673.26	5373961.16	Saint Michaels Elementary School
111	393930.58	5373588.09	Memorial Garden
112	395122.43	5375785.55	Cemetery
113	392451.30	5380371.29	Scott Pollard Memorial Trail
114	377226.04	5379073.59	Zenzville RV Campground
115	383881.71	5378343.81	Stephenville Middle School
116	383060.25	5377997.19	Cemetery
117	384915.37	5379157.90	Walk-A-Ways Nature Trail
118	385079.36	5379805.68	Hatcher Field
119	372358.57	5379832.06	The Gravels Walking Trail
120	371339.83	5379666.10	Our Lady of Mercy Church Complex and Museum
121	352947.04	5390181.48	Our Lady of Lourdes Parish Grotto
122	344827.75	5386826.61	Three Rock Cove Community Center
123	358722.02	5379137.46	Piccadilly Central High
124	358857.41	5379338.45	Piccadilly Roman Catholic Cemetery
125	332418.62	5370475.38	Boutte du Cap Park
126	374281.26	5379794.12	Pine Tree Trail
127	380066.91	5380051.49	Top of Whaleback Trail
128	386149.38	5381643.08	Whaleback Nordic Ski Club
129	397169.34	5383492.97	Black Duck First Pond Trail
130	394752.81	5359514.48	Steel Mountain Trail
131	382371.26	5378644.41	United Pentecoastal Church
132	383138.76	5378787.60	United Church of Canada
133	344203.65	5306672.08	Newfoundland T'Railway
134	347479.72	5307303.70	Sgt. Craig Gillam Mark Rock Trail

Removal of Meteorological Anomalies

The Newfoundland and Labrador Department of Municipal Affairs and Environment (NLDMAE) has provided guidance in determination of compliance with the ambient air quality standards (2012). In recognition of overpredictions as a result of adverse meteorological conditions, some of the maximum values at each receptor can be removed. Therefore, the modelled impacts will be based on the:

- 9^{th} highest level at any given receptor for a 1-hour averaging period;
- 6^{th} highest level at any given receptor for a 3-hour averaging period;
- 3^{rd} highest level at any given receptor for an 8-hour averaging period;
- 2^{nd} highest level at any given receptor for a 24-hour averaging period.

Conversion of Nitrogen Oxides to Nitrogen Dioxide

Nitrogen oxides (NO_X) are the sum of nitrogen dioxide (NO_2) and nitric oxide (NO). Releases of NO_X from the combustion of fuel consists mainly of NO, with some NO_2. In ambient air, NO converts to NO_2 at rates dependent on atmospheric conditions at the time (primarily related to ambient ozone (O_3) concentrations). Since NO_2 has adverse health effects at much lower concentrations than NO, regulatory criteria only exist for NO_2. For the air quality assessment, the ozone limiting method (OLM) was used to estimate the conversion of NO_X to NO_2, i.e., predict ground-level NO_2 concentrations based on the model results for NO_X. The OLM was applied to the predicted NO_X concentrations based on the relationship identified in the Alberta Air Quality Model Guideline (AESRD 2013), as follows:

If O_3 concentration > 0.9 × NO_X concentration, then NO_2 Concentration = NO_X concentration,

Otherwise, if NO_2 concentration = O_3 concentration + 0.1 × NO_X concentration

The concentrations in the relationship above are in ppb.

The ozone concentration used in the OLM calculations is based on the monthly background concentrations from the NL Guideline for Plume Dispersion Modelling (NLDMAE 2002). These are the NLDMAE recommended ozone values for conversion of NO_X to NO_2 calculations.

References

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Appendix 6-C

GHG Sample Calculations and Supporting Data

This appendix includes details on information used to estimate the greenhouse gas (GHG) emissions from the Project during construction and operation, including activity data used in the calculations and sample calculations for each source.

Carbon Dioxide Equivalency

Emissions from each of the specific GHGs are multiplied by their 100-year global warming potential (GWP) and are reported as carbon dioxide equivalents (CO_{2e}). CO_2e is the standardized way to report GHG emissions.

The GWP (ECCC 2023a) of these GHGs applied in this assessment are as follows:

- Carbon dioxide (CO_2) = 1.0
- Methane (CH_4) = 28
- Nitrous oxide (N_2O) = 265

The GWPs are from the Intergovernmental Panel on Climate Change Fifth Assessment Report (AR5) (IPCC 2014).

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

$$CO_{2e} = (mass\ CO_2 \times 1.0) + (mass\ CH_4 \times 28) + (mass\ N_2O\ \times 265)$$

For example, for stationary combustion during construction, the following sample calculation shows the conversion of the each GHG species emissions to CO_{2e}:

$$CO_{2e} = \left(5{,}362\,\frac{\text{tonnes}}{\text{year}}\ CO_2 \times 1.0\right) + \left(0.156\,\frac{\text{tonnes}}{\text{year}}\ CH_4 \times 28\right) + (0.044\,\frac{\text{tonnes}}{\text{year}} N_2O\ \times 265)$$

$$CO_{2e} = 5{,}378\,\frac{tonnes}{year}$$

Direct and Indirect Emissions

Direct and indirect emissions are defined below.

- Direct GHG Emissions: Refers to GHG emissions or removals from sinks or sources that are owned or controlled by the proponent/Project. Direct emissions are also commonly referred to as Scope 1 emissions.
- Indirect GHG Emissions: Refers to GHG emissions or removals from sinks or sources that are not owned or controlled by the proponent/Project but are a consequence of activities within well-defined boundaries (IPCC 2014). For example, GHG emissions generated by the generation of purchased energy are considered indirect GHG emissions. Indirect emissions from energy (heat and electricity) are commonly referred to as Scope 2 emissions.
- Other Indirect GHG Emissions: Refer to all other indirect emissions, including upstream, downstream, and supply chain GHG emissions. Other indirect emissions (those not associated with indirect energy) are commonly referred to as Scope 3 emissions (WBCSD and WRI 2004).

GHG Sample Calculations – Direct Emissions

Blasting (Construction)

The GHG emissions from blasting were calculated using the following equation:

$$Emissions\ [\frac{tonnes}{year}] = Emission\ Factor\ \left[\frac{tonne\ CO_2}{tonne\ ANFO}\right] \times\ Explosive\ Usage\ \left[\frac{tonne\ ANFO}{year}\right]$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
Emission Factor = Mining Association of Canada (MAC) emission factor (0.189 kg CO_2/kg of ammonium nitrate/fuel oil [ANFO]) (MAC 2014)
Explosive Usage = Total amount of ANFO explosive used per year provided by the design team (4,000 tonnes/year during construction)

The following sample calculation presents the CO_2 emissions from blasting during operation:

$$Emissions\ CO_2 = 0.189\ \frac{tonne\ CO_2}{tonne\ ANFO} \times\ 4{,}000 \frac{tomme\ ANFO}{year}$$

$$Emissions\ CO_2 = 756\ \frac{tomme}{year}$$

It is assumed there are no emissions of CH_4 or N_2O from ANFO blasting as no emission factor is readily available.

Mobile Equipment (Construction and Operation)

The GHG emissions from mobile equipment (on-road and off-road vehicles) were calculated using the following equation:

$$Emissions\ \left[\frac{tonnes}{year}\right] = Emission\ Factor\ \left[\frac{g}{L}\right] \times\ Fuel\ Usage\ [L] \times Unit\ Convesion \left[\frac{1\ tonne}{10^6\ g}\right]$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
Emission Factor = Emission factor, specific to GHG species and vehicle class and presented in Table 6C.1
Fuel Usage = Total annual amount of fuel used provided by design team (38,000,000 L during construction)

Table 6C.1 Mobile and Stationary Equipment Emission Factors

Equipment	CO_2 EF (g/L)	CH_4 EF (g/L)	N_2O EF (g/L)
Mobile Equipment			
Off-road Diesel ≥ 19kW, Tier 1-3	2,680.5	0.073	0.022
Off-road Diesel ≥ 19kW, Tier 4	2,680.5	0.073	0.227
Light Duty Diesel Trucks, Advanced Control	2,680.5	0.068	0.22
Heavy Duty Diesel Vehicles, Advanced Control	2,680.5	0.11	0.151
Stationary Equipment			
Diesel – Refineries and Others	2,681.0	0.078	0.022
Source: ECCC 2023b			

The following sample calculation presents the CO_2 emissions from off-road diesel equipment during construction:

$$Emissions\ CO_2 = 2{,}680.5\ \frac{g}{L} \times\ 38{,}000{,}000\ L \times \frac{1\ tonne}{10^6 g}$$

$$Emissions\ CO_2 = 101{,}859\ tonnes$$

Similar to the above example for CO_2, CH_4 and N_2O would be estimated using their respective emission factors and application of GWPs to calculate the total emissions in CO_2e. It was assumed that half the fuel used for construction was consumed by off-road diesel equipment ≥ 19kW, tier 1-3 and the other half was consumed by off-road diesel equipment ≥ 19kW, tier 4 because the efficiency of the equipment to be used during construction has not yet been finalized.

Emissions for Project operation were estimated following the same method. The design team assumes there will be 10 light duty diesel pick-up trucks operating for 8 hours per day, 365 days per year. The litres of fuel were estimated by multiplying vehicle speed (40 km/hour) by an estimated fuel rating of 16.1 L/100 km (NRCan n.d.).

Stationary Equipment (Construction)

The GHG emissions from stationary combustion during construction were calculated using the following equation:

$$Emissions\ \left[\frac{tonnes}{year}\right] = Emission\ Factor\ \left[\frac{g}{L}\right] \times\ Fuel\ Usage\ [L] \times Unit\ Convesion \left[\frac{1\ tonne}{10^6\ g}\right]$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
Emission Factor = Emission factor for stationary combustion of diesel fuel, specific to GHG species, presented in Table 6C 1
Fuel Usage = Total annual amount of fuel used provided by design team (2,000,000 L during construction)

The following sample calculation presents the CO_2 emissions from diesel stationary combustion during construction:

$$Emissions\ CO_2 = 2{,}681\frac{g}{L} \times\ 2{,}000{,}000\ L \times \frac{1\ kL}{1{,}000\ L} \times \frac{1\ tonne}{10^6 g}$$

$$Emissions\ CO_2 = 5{,}378\ tonnes$$

Similar to the above example for CO_2, CH_4 and N_2O would be estimated using their respective emission factors and application of GWPs to calculate the total emissions in CO_2e.

Diesel will be used in stationary combustion during construction (lighting, generators, crushing plant), the total estimated usage quantity was provided by World Energy.

Flare Pilot (Operation)

The CO_2 emissions from the flare pilot were calculated using the following equation from Canada's Greenhouse Gas Quantification Requirements (ECCC 2022):

$$CO_2\ Emissions\ \left[\frac{tonnes}{year}\right] = CE\ \times 3.664\ \times Flare\ Volume\ \times \left[\frac{MW}{MVC}\right] \times\ CC$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
CE = Combustion efficiency, assumed to be 0.98
3.664 = Ratio of molecular weights, CO_2 to carbon
Flare volume = volume of flare gas (butane) combusted (at 15ºC and 101.325 kPa) in m^3
MW = average molecular weight of the flare gas (butane) combusted during measurement period in kg/kg mole
MVC = molar volume conversion factor at the same reference conditions as the above flare volume, which is 8.3145 × (273.16 + (15ºC/101.325 kPa) = 23.6458 (m^3/kg mole)
CC = average carbon content of the flared gas (butane) which is 0.83 kgC/kg butane

The following sample calculation presents the CO_2e emissions from the flare pilot consuming butane during operation:

$$Emissions\ CO_2e = 0.98\ \times 3.664\ \times\ 22{,}075\ m^3 \times \frac{58.124\ kg/kg\ mole}{23.6458\ m^3/kg\ mole} \times\ 0.83\ kgC/kg$$

$$Emissions\ CO_{2e} = 162\ tonnes$$

Methane (CH_4) emissions are not expected to result from the combustion of butane.

The N_2O emissions from the flare pilot were calculated using the following equation from Canada's Greenhouse Gas Quantification Requirements (ECCC 2022):

$$NO_2\ Emissions\ \left[\frac{tonnes}{year}\right] = CO_2 \times \left[\frac{EF_{N2O}}{EF}\right]$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
CO_2 = Emission rate of CO_2 from flared gas
EF_{N2O} = Default emission factor for petroleum products of 0.5 X 10^{-3} kg N_2O/GJ
N_2O = Default CO_2 emission factor for flare gas of 62.4 kg CO_2/GJ

The following sample calculation presents the N_2O emissions from the flare pilot consuming butane during operation:

$$Emissions\ N_2O = 162\ t\ CO_2\ \times \frac{0.005\ kg\ N_2O/GJ}{62.4\ kg\ CO_2 kg/GJ}$$

$$Emissions\ N_2O = 0.0013\ tonnes$$

Emergency Biodiesel Generator (Operation)

The CO_2e emissions from the 50 MW emergency biodiesel generator were calculated using the following equation:

$$CO_2e\ Emissions\ \left[\frac{tonnes}{year}\right] = Emission\ Factor\ \left[\frac{g\ CO_{2e}}{MJ}\right] \times\ Power\ Usage\ \left[\frac{MWh}{year}\right] \times Conversion\ Factor\ \left[\frac{MJ}{MWh}\right]$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
Emission Factor = the emission factor was provided by the design team for the biodiesel generator (27 g CO_2/MJ)
Power Usage = annual power usage in MWh (2,600 MWh) based on the capacity of the unit (50 MW) and annual hours of operation (approximately 52 hours)
Conversion Factor = Conversion factor of 3,600 MJ per MWh

The following sample calculation presents the CO_2e emissions from the biodiesel generator:

$$CO_2e\ Emissions\ \left[\frac{tonnes}{year}\right] = 27 \left[\frac{g\ CO_{2e}}{MJ}\right] \times\ 2{,}600\ \left[\frac{MWh}{year}\right]\ \times 3{,}600 \left[\frac{MJ}{MWh}\right]$$

$$Emissions\ CO_2e = 252.7\ tonnes$$

Land Clearing – Carbon Stock Change (Construction)

For the carbon stock change emissions from land clearing, the assessment follows the method outlined in the SACC Technical Guide (ECCC 2021) and related IPCC methodologies (IPCC 2019), using the area of land cleared, and information related to the forest/wetlands. The emission calculation methods consider carbon stock changes before and after land conversion. The timber will be salvaged and used, or it will be made available to local communities. It is assumed that of the total timber, 40% will end up being burned (e.g., home heating in local communities), and that 100% of brush would be burned. The following emission factors and parameters were used in the emission calculation (Table 6C.2).

Table 6C.2 Land-Use Change Emission Factors and Parameters

Land Use Conversion	Carbon Stock	Parameters	Values	Units	Reference and Assumption
Forest Land to Settlements	Biomass	Biomass before conversion	60	t dry matter/ha	Boreal coniferous, assumed 20% for belowground biomass (IPCC 2019)
		Carbon fraction of dry matter	0.47	t C/t dry matter	Boreal and Temperate climate region, Conifers (IPCC 2019)
		Dead organic matter fraction	22.5	T C/ha	Boreal coniferous forest, needleleaf evergreen mean (IPCC 2019)
Wetlands to Settlements	Peatlands	Nutrient Rich Peat	0.37	t-CO2-C/ha/year	Nutrient poor, boreal (IPCC (2019))

The change in carbon stock emissions from wetlands was calculated using the following equation:

$$\Delta C_B = \Delta C_G + \Delta C_{conversion} - \Delta C_L$$

Where

ΔC_B *is the change in the living biomass stock (t C/y)*
ΔC_G *is the change due to growth in living biomass (t C/y)*
$\Delta C_{conversion}$ *is the change due to land-use change (t C/y), and* ΔC_L *is the change due to losses of living biomass (t C/y).*

The calculation of $\Delta C_{conversion}$ *uses this equation:*

$$\Delta C_{conversion} = \{(B_{After} - B_{Before}) * Area\} * CF$$

Where B_{After} *is the amount of biomass (dry basis, t/ha) that exists after the project disturbance (assumed to be zero if clear cutting)*
B_{Before} *is the amount of biomass (dry basis, t/ha) that exists before the project disturbance*
Area is the land area that is disturbed (ha)
CF is the carbon fraction of the biomass (t C/t biomass)

The following sample calculation presents the CO_2 emissions from the change in carbon stock from the removal of trees (unburned portion, assumed to be 60% of total 1984 ha of forest cleared) during construction:

$$\Delta C_{conversion} = \{(B_{After} - B_{Before}) * Area\} * CF$$

$$\Delta C_{conversion} = \left\{\left(0 - 60\frac{t}{ha}\right) * 1190\ ha\right\} * 0.47\frac{t\ C}{t\ dm}$$

$$\Delta C_{conversion} = -33{,}564\ \frac{t\ C}{lifetime}$$

Assuming 100% of carbon becomes CO_2:

$$\Delta C_{conversion} = -33{,}564\ \frac{t\ C}{lifetime}\ x\frac{44\frac{g}{mol\ CO_2}}{12\frac{g}{mol\ C}}$$

$$\Delta C_{conversion} = -123{,}068\ \frac{tonnes\ CO_2}{lifetime}$$

Similarly, the change in carbon stock from wetlands was estimated and included in the total.

To estimate these emissions from the burning of trees or other biomass, the amount of carbon in the biomass that is burned must first be estimated using the following:

$$Total\ Carbon\ Burned\ (t\ C) = B_{Before} * Area * CF + C_o * Area$$

Where
B_{Before}, CF were previously defined
C_o is the dead wood/litter present prior to the disturbance (t C/ha)

The following sample calculation presents the carbon burned in the biomass (assumed to be 40% of trees, 100% bush):

$$Total\ Carbon\ Burned\ (t\ C) = B_{Before} \times Area \times CF + C_o \times Area$$

$$Total\ Carbon\ Burned\ (t\ C) = 60\ \frac{t\ dm}{ha} \times (1{,}984\ ha \times 40\%) \times 0.47\frac{t\ C\ dm}{ha} + 22.5\frac{t\ C}{ha} \times 1{,}984\ ha$$

$$Total\ Carbon\ Burned\ (t\ C) = 67{,}010$$

The Total Carbon Burned is then multiplied by 0.9 to get mass of the carbon that will be converted to CO_2 and by 0.01 to get the mass of carbon that will be converted to CH_4. The conversion from carbon to CO_2 uses the ratio of the molecular weights (3.664). The conversion from carbon to CH_4 uses the ratio of the molecular weights (1.336).

The following sample calculation presents the CO_2 emissions from burning of trees and brush:

$$Emissions\ CO_2 = 67{,}010\ t\ C \times 90\% \times 3.664$$

$$Emissions\ CO_2 = 220{,}091 \frac{tonnes}{constructon\ phase}$$

The N_2O emissions from biomass or DOM burning is calculated as:

$$N_2O = 0.00017 \times CO_2$$

Where N_2O is the mass of N_2O and CO_2 is the mass of CO_2.

Land Clearing – Loss of Carbon Sinks (Construction)

For the carbon sink loss estimates, the change in GHG sequestration was estimated following the SACC Technical Guide (ECCC 2021), the area of land cleared, and site-specific data mixed with forestry data published by NRCan.

The draft Technical Guide describes the methodology to be used when quantifying the change to carbon sinks. The following equation from the draft Technical Guide was used to estimate the carbon sink impact (CSI):

$$CSI = \sum_{i,j} \left((NatFlux - PostDFlux)_{i,j} \right) \times T_{i,j} \times A_{i,j}$$

Where:
NatFlux is the natural annual carbon accumulation rate of the land (t C/ha/y), calculated shown below
PostDFlux is the post-disturbance flux rate (t C/ha/y), set to zero as there will be no sequestration from the trees/wetlands once they are cleared for the Project
i is the land use class
j is the disturbance activity
t is the time interval (year), and
A is the land area in hectares (ha), presented in Table 6C 3 for the region.

The equation to calculate natural flux of a forest stand is:

$$NatFlux_{Forest} = \frac{BM_{MCC} - BM_{Current}}{Age_{MCC} - Age_{Current}}$$

BM stands for the biomass in dry t C/ha.
MCC is the maximum carrying capacity, which is the point in which a tree will act as a carbon sink until, and is dependent on the species and ecozone.

At the MCC, there is a net zero or even net positive exchange of carbon with the environment. Because of this, the carbon sink impact is calculated for the time that the tree would have taken to reach the MCC or 100 years, whichever comes first.

The values applied for age at MCC and live biomass at MCC are presented in Table 6C.3. There were no available data for hardwood species in Newfoundland, as such, it was assumed that a value for Labrador in the same ecozone and for the species of interest could be substituted. There were multiple entries for boreal shield east ecozone birches in Labrador, the chosen Labrador value was conservative as it had the highest age at MCC.

Table 6C.3 Maximum Carrying Capacity of Trees in Region

Province	Ecozone	Species	Site Index	Age at MCC (A_{MCC})	Live Biomass at MCC (BM_{MCC}) (t C/ha)
Newfoundland	Boreal Shield East	Balsam fir	NA	58	85
Labrador[1]	Boreal Shield East	Birch	5-9.9	104	62

Notes:

[1] There were no available data for hardwood species in Newfoundland, as such, it was assumed that a value for Labrador in the same ecozone and for the species of interest could be substituted.

Source: ECCC 2021

The current age of forest used was 102.5 years, estimated from the 2001 Canada's Forest Industry Report (NRCan 2001) for the region and adding 22 years to account for the time since the report was published. The region was noted to be composed of forests 61-100 years old and 101-140 years old in 2001, the median age from the younger range was conservatively used. The biomass per hectare used was 87.5 tonnes/ha which was estimated from Canada's Forest Biomass Resources Report (NRCAN 1997), conservatively applying the higher density in the region across the full area.

The natural annual carbon accumulation rate of the land from clearing of hardwood (birch) forests were calculated as follows:

$$NatFlux_{Forest} = \frac{62\,\frac{t\,C}{ha} - 43.75\,\frac{tC}{ha}}{104\,years - 102.5\,years}$$

$$NatFlux_{Forest} = -12.2\,\frac{t\,C}{ha\,\cdot year}$$

The carbon sink impact from the hardwood (birch) forests is then estimated as follows:

$$CSI = \left(12.2\,\frac{t\,C}{ha\,\cdot year} - 0\,\frac{t\,C}{ha\,\cdot year}\right) \times 1.5\,years \times 44.25\,ha$$

$$CSI = -807.5\,t\,C$$

The sum of all carbon sink impacts for the land clearing zones is taken as the total CSI (Table 6C.4).

Table 6C.4 Area of cleared land by zone and corresponding biomass content

Zone	Represented by	Hectares	Biomass Total (t /ha)	Biomass Carbon (t C/ha)[2]
Hardwood	birch	44.2	87.5	43.75
Softwood	balsam fir	1584.3	87.5	43.75
Mixedwood	balsam fir	118.1	87.5	43.75
Mixedwood	birch	118.1	87.5	43.75
Unknown Forest[1]	birch	119.0	87.5	43.75

Notes:
[1] Conservatively assumed to be birch
[2] The average carbon content is generally 50% of the tree's total volume (Birdsey 1992)

For the loss of carbon sinks from wetlands, the SACC draft Technical Guide (ECCC 2021) provides default factors for natural flux. It was conservative assumed that the wetlands were fen, in which the natural flux applied was 0.33 t C/ha/year. According to the draft Technical Guide, the time period to use for wetlands is 100 years.

GHG Sample Calculations – Indirect Emissions

Electricity Consumption

The GHG emissions from electricity consumption (grid power) were calculated using the following equation:

$$Emissions \left[\frac{tonnes}{year}\right] = Emission\ Factor \left[\frac{t\ CO_{2e}}{MWh}\right] \times\ Consumption\ [MWh]$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
Emission Factor = the electricity consumption emission factor for Newfoundland and Labrador (17 g CO_{2e}/kWh, or 0.017 t CO_2e/MWh) from Canada's National Inventory Report (ECCC 2023b)
Annual Consumption = annual estimated electricity consumption from the grid, provided by the design team (52,560 MWh during the entire construction period, and 630,000 MWh per year during operation)

The following sample calculation presents the CO_{2e} emissions from electricity consumption during construction:

$$Emissions\ CO_{2e} = 0.017\ \frac{t\ CO_{2e}}{MWh}\ \times\ 52{,}560\ MWh$$

$$Emissions\ CO_2e = 894\ tonnes$$

Emissions for Project operation were estimated following the same method.

GHG Sample Calculations – Other Indirect Emissions (Scope 3)

Transportation of Wind Turbine Components (Construction)

Emissions for the transportation of Project components during construction were estimated by using the same method used for direct emissions from the use of mobile equipment, described above, and by using emission factors for heavy duty diesel vehicles (Table 6C.1). The following assumptions were made:

- It is assumed the wind turbines will be transported from the Port of Stephenville, West Bay berth, or Aguathuna berth to their final locations for assembly and installation
- The distance travelled depended on the port/berth origin and the area of delivery (on Port au Port or Codroy), these are presented in Table 6C.5
- The number of turbine deliveries required were from the Transportation Study, and are presented in Table 6C.5
- The fuel efficiency of the transport trucks is assumed to be 39.5 L/100 km (NRCan 2019)

Table 6C.5 Turbine Component Delivery Numbers and Distances

Areas[1]	Number of turbines	Number of Components	Daily Delivery Round Trips	Days of Turbine Delivery	Estimated distance (one-way) (km)
Area 1 from West Bay	121	1,694	6	282	35
Area 2 from Aguathuna Mine	24	336	6	56	5
Area 3 from the Port of Stephenville	26	364	6	61	90
Area 4 from the Port of Stephenville	143	2,002	6	334	90

Note:
[1] Areas 1-4 are depicted in Figure 6C.1

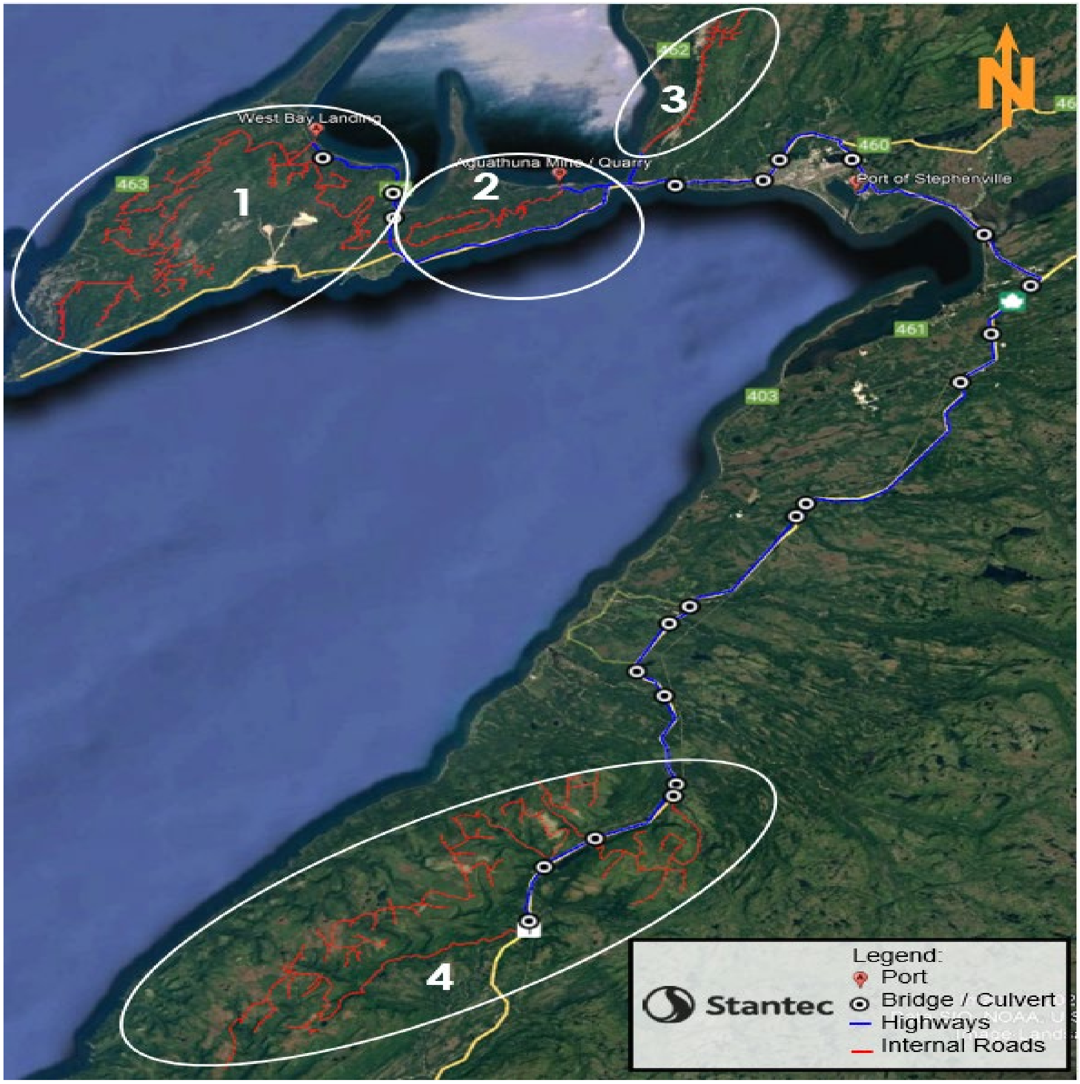

Figure 6C.1 Areas of Delivery for Wind Turbine Components During Construction

Marine Transportation of Supplies and Products

The GHG emissions from the marine transport of supplies and products were estimated using the following equation:

$$Emissions\left[\frac{tonnes}{year}\right] = Shipping\ Distance\ (nautical\ miles) \times\ Vessel\ Tonnage\ (tonnes) \times Emission\ Factor\ \left[\frac{gCO_2e}{tonnage\ deadweight \cdot nautical\ miles}\right] \times Trips\ per\ Year \times Conversion\ Factor\ \left[\frac{1\ tonne}{10^6 grams}\right]$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
Shipping Distance = the distance travelled by the vessels in nautical miles (nm) (2,857 from Hamburg, Germany to Port of Stephenville as the route outlined in the Project Description, this was applied for both construction and operation phases)
Tonnage = the total deadweight of the vessel (loaded while delivering, empty on return route)
Emission Factor = emission factor from the International Marine Organization (IMO) document Fourth Greenhouse Gas Study 2020 (IMO 2020), dependent on vessel type & size (Table 6C 7)
Trips per Year = the number of trips required per year (for the construction and operation periods), detailed in Table 6C 6
Conversion Factor = Conversion factor of 1 tonne in 1,000,000 grams

The numbers of vessel trips are presented in Table 6C.6, and the emission factors for marine shipping are presented in Table 6C.7.

Table 6C.6 Number of Vessel Trips

Phase	Vessel	Component	# trips per year[1]	Tonnage Deadweight [tonnes][2]	Tonnage Empty [tonne]
Construction	Vestvind	Blades + Plant Components	45	10,238	5,119
	Boldwind	Towers	26	10,000	5,000
	Rotra Vente	Nacelles	17	8,929	4,465
Operation	50,000 m3 capacity vessel (assumed Clipper Mars)	Ammonia Product	54	40,174	20,087

Notes:
[1] Number of trips per year were projected by World Energy. The vessel for plant component trips were not specified and were conservatively assumed to be the Vestvind.
[2] Deadweight values were obtained from specifications for the specific vessel types, whereas the empty weight values were assumed to be 50% the deadweight.

Table 6C.7 Emission Factors for Marine Shipping

Phase	Vessel	Emission Factor Category	Emission Factor ($g\ CO_2$/deadweight tonnage nautical miles)
Construction	Vestvind	General Cargo 10,000-19,999 dwt	17.1
	Boldwind		17.1
	Rotra Vente	General Cargo 5,000-9,999 dwt	19.4
Operation	50,000 m^3 capacity vessel (assumed Clipper Mars)	Liquified gas tanker, 50,000-99,999 cmb	9.5
Source: IMO 2020			

The following sample calculation presents the CO_2e emissions from marine shipping on Vestvind vessels, when full (one-way), during the construction period:

$$CO_2e\ Emissions\ \left[\frac{tonnes}{year}\right] = 2857\ nm\ \times\ 10238\ tonnes\ \times\ \left[\frac{17.1\ g\ CO2}{tonne - nm}\right] \times 45\ trips\ \times\ \left[\frac{1\ tonne}{10^6 grams}\right]$$

$$Emissions\ CO_2e = 22{,}408\ tonnes$$

The same estimation was applied for the empty weight (one-way), assuming the vessel would return empty to its origin.

Tug Boats (Construction and Operation)

The GHG emissions from the use of tug boats were calculated using the following equation:

$$Emissions\ \left[\frac{tonnes}{year}\right] = Emission\ Factor\ \left[\frac{t\ CO_2e}{hour}\right] \times Hours\ of\ Operation$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
Emission Factor = Default emission factor for tug boats (0.8 t CO_2e/hour) (IMO 2020)
Annual Hours of Operation = the number of hours the tug boats operate in a given period of time

The following sample calculation presents the CO_2e emissions from the use of tug boats during construction:

$$CO_2e\ Emissions\ \left[\frac{tonnes}{year}\right] = \left[\frac{0.8\ tonnes\ CO_2e}{hour}\right]\ \times\ 5{,}100\ hours$$

$$Emissions\ CO_2e = 4{,}080\ tonnes$$

It was assumed that 2 tug boats are required to assist each marine vessel, of 30-hours per deliver during construction and 43 per loading during operations. The number of vessels required per phase were provided by World Energy.

Marine Vessel Hoteling (Construction and Operation)

The GHG emissions from vessel unloading/loading at port (hoteling) were calculating using the following equation:

$$Emissions \left[\frac{tonnes}{year}\right] = Emission\ Factor \left[\frac{g}{L}\right] \times\ Fuel\ Usage\ [L] \times Unit\ Convesion \left[\frac{1\ tonne}{10^6\ g}\right]$$

Where:

Emissions = Annual Emission Rate [tonnes/year]
Emission Factor = Emission factor, specific to GHG species and marine diesel fuel presented in Table 6C.8
Fuel Usage = Total annual amount of fuel used, estimated based on # trips per year (Table 6C.6), # hours hoteling (30 hours for each trip), and fuel consumed per hour

Table 6C.8 Marine Diesel Emission Factors

Equipment	CO_2 EF (g/L)	CH_4 EF (g/L)	N_2O EF (g/L)
Marine Diesel	2680.5	0.25193	0.07198
Source: ECCC 2023a			

The fuel consumed by the marine vessels during the construction period were estimated as follows:

- Vestvind marine vessels were assumed to have 3 Volvo Penta D13 main diesel generator sets, each of which consume 25 gallons (approximately 95 litres) per hour (SRA 2011), or a total of 284 litres per hour for all 3 engines
- Boltwind marine vessels were assumed to use two MAN 6L16/24 - Tier III main generators (570 kW) during hoteling, which consume 195 g/kWh fuel (100% load) for a total of 258 litres per hour (MAN 2011)
- Rotra Vente marine vessels were assumed to have two 511-596 kW Scania engines, consuming 210 litres per hour each for a total of 420 litres per hour (Scania n.d.)

The fuel consumed by the marine vessels during the operation period were determined as follows:

- The 50,000 m^3 capacity marine vessels are assumed to consume 7 tons of fuel per day (Solvang ASA 1998), or 343 litres per hour.

The following sample calculation presents the CO_2 emissions from marine vessel hoteling (Vestvind vessels) during the construction period:

$$Emissions\ CO_2 = 2{,}680.5\ \frac{g}{L} \times\ 369{,}645\ L \times \frac{1\ tonne}{10^6 g}$$

$$Emissions\ CO_2 = 1{,}000\ tonnes$$

Transportation of Waste

Emissions for the transportation of waste during construction were estimated by using the same method used for direct emissions from the use of mobile equipment, described above, and by using emission factors for heavy duty diesel vehicles (Table 6C.2). The following assumptions were made:

- Waste will be removed by trucks to a nearby landfill
- The distance travelled is assumed to be 90 km from the Project site to the landfill, assumed to be Wild Cove waste disposal site in Corner Brook, NL
- The design team estimates there could be as many as 40 trucks per day during peak construction. As a conservative assumption, it was assumed there will be 40 trucks travelling 90 km to and from the landfill each day for the duration of the construction period (30 months).
- The fuel efficiency of the transport trucks is assumed to be 35 L/100 km (NRCan 2019)

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