APPENDIX 10-I

Greenhouse Gas Emissions Estimates – MOECC-AQ-13

NEXTBRIDGE INFRASTRUCTURE

1.0 INTRODUCTION

This appendix was prepared to support the amended Environmental Assessment (EA) Report for the East-West Tie Transmission Project (the Project). The following sections summarize the emission calculations regulations followed to quantify the air quality and greenhouse gas (GHG) emissions used in the air quality and GHG assessment.

This appendix documents the methods, input parameters, and assumptions that were used to estimate the annual GHG emissions for the Project.

The GHG indicator compounds included the following:

- carbon dioxide (CO_2);
- methane (CH_4); and
- nitrous oxide (N_2O).

There are no Project activities that are expected to emit sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) or hydrofluorocarbons (HFCs); therefore, these compounds are not included in the GHG assessment.

The emission estimation methods described in this Appendix follow generally accepted practices for conducting Environmental Assessments.

2.0 PROJECT ACTIVITIES

GHG emissions were assessed for activities described in the *Amended Environmental Assessment Report for the East-West Tie Transmission Project*, based on process descriptions and equipment/vehicle specifications provided by NextBridge. Scientifically accepted and well documented emission factors from the Ministry of the Environment and Climate Change (MOECC) *Ontario Guideline for Greenhouse Gas Emissions Reporting* (MOECC 2015) were used. Emission factors from the Intergovernmental Panel on Climate Change (IPCC) were also used where local guidance was not available. A discussion of the global warming potentials is provided in Section 5.0.

A summary of the activities for which GHG emissions were calculated is provided in Table 10-I-1.

Table 10-I-1: Project Activities Expected to Release Greenhouse Gases

Activity	Greenhouse Gas		
	Carbon dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)
Emissions in Construction Phase			
Mobile Equipment	X	X	X
Biomass Burning[1]	X	X	X
Land Clearing[2]	X	—	—

X = activity emits the selected greenhouse gas; "—" = no expected release of the selected greenhouse gas

1) Cleared vegetation will be burned except for merchantable timber, and vegetation in provincial parks and conservation areas.

2) The land clearing emission estimates account for the removal of a carbon sink and thus the loss of annual removal of carbon from the atmosphere. This also occurs during the operation phase.

3.0 DATA SOURCES / ASSUMPTIONS

Details on the parameters used to calculate the GHG emissions, data sources used, and/or whether an assumption was made are provided in Table 10-I-2. The summary of mobile equipment parameters used to estimate the annual GHG emissions for the Project is provided in Table 10-I-3.

Table 10-I-2: Data Sources and Assumptions for Greenhouse Gas Emission Parameters

Activity	Parameter	Value	Unit	Source/Assumption
Mobile Equipment	Fuel Type	Diesel	—	Assumed that all mobile equipment is fueled by diesel.
	Equipment Types	Various	—	Based on communication with NextBridge on November 15, 2017.
	Equipment hours of operation	Various	hrs/day	Based on communication with NextBridge on November 15, 2017.
	Emission factors	2,663 (CO_2) 0.133 (CH_4) 0.4 (N_2O)	g/L	Table 20-2 of Appendix ON.20 of the Ontario Guideline for Greenhouse Gas Emissions Reporting (as set out under O. Reg. 452/09 under the EPA) (December 2015, PIBs 9906e).
	Load factors	Various	—	Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling (US EPA, 2010, NR-005d)
	Horsepower	Various	hp	Based on rated horsepower outlined in equipment specifications

Table 10-I-2: Data Sources and Assumptions for Greenhouse Gas Emission Parameters

Activity	Parameter	Value	Unit	Source/Assumption
Land Clearing and Biomass Burning[1]	Vegetated area to be cleared	1,999	ha	The area in the Project footprint (3,490 ha) that contains vegetation, including merchantable timber. This is based on Geographic Information System (GIS) analysis of vegetation types in the Project footprint
	Vegetated area for biomass burning	153	ha	The area within the Project footprint (3,490 ha) that contains vegetation to be burned (not merchantable timber). This is based on GIS analysis of vegetation types in the Project footprint.
	Above-ground net biomass growth (GW)	1	Tonnes d.m. ha^{-1} yr^{-1}	Based on Table 4.12 of IPCC (2006b) Vol 4, Chapter 4. Assumes the area to be cleared is boreal coniferous forest.
	Ratio of below-ground biomass to above-ground biomass (R)	0.39	Tonnes root d.m. $^{-1}$	Based on Table 4.4 of IPCC (2006b) Vol 4, Chapter 4. Assumes the area to be cleared is boreal forest with a density of less than 75 tonnes/ha.
	Carbon fraction of above-ground biomass (CF) for land clearing	0.47	Tonne C^{-1}	Based on Table 4.3 of IPCC (2006b) Vol 4, Chapter 4. Assumes the area to be cleared is boreal forest with broad-leaves and conifers.
	Combustion factor (CF) for biomass burning	0.33	Dimension-less	Based on Table 2.6 of IPCC (2006b) Vol 4, Chapter 4. Assumes post logging slash burn of boreal forest.
	Mass of fuel available for combustion	50	Tonnes d.m. ha^{-1}	Based on Table 4.7 of IPCC (2006b) Vol 4, Chapter 4. Assumes the area to be cleared is boreal coniferous forest.
	Length of project lifespan	50	Years	Based on communication with NextBridge.
	Length of construction phase	2	Years	Based on communication with NextBridge.
	Emission factor for burning (GEF)	1,569 (CO_2) 4.7 (CH_4) 0.26 (N_2O)	g/kg d.m.	Based on Table 2.5 of IPCC (2006a) Vol 4, Chapter 2. Assumes the area to be cleared is extra tropical forest.

1) The land clearing emission estimates account for the removal of a carbon sink and thus the loss of annual removal of CO_2 from the atmosphere.

CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide hrs = hours; g = gram; L = litre; hp = horsepower; ha = hectare; d.m. = tonnes of dry material; yr = year; C = carbon; kg = kilogram; — denotes not applicable

Table 10-I-3: Mobile Equipment Summary

Mobile Equipment	# of Units	Gross Power (hp)	Load Factor	Operating Hours during Entire Construction Period (hours)	Total Annual Fuel (L/y)
Pickup	50	365	0.50	2,039	3,664,455
ATV	53	50	0.50	2,508	654,615
Grader	4	179	0.64	1,184	106,854
Dump	8	717	0.41	891	412,711
Dozer #1	3	363	0.75	2,376	382,218
Dozer #2	4	139	0.75	1,782	146,359
Excavator	10	417	0.53	575	250,469
Feller	5	203	0.70	2,418	338,489
Skidder	5	250	0.70	2,418	416,858
Processer	5	303	0.70	1,008	210,588
Flatbed	10	455	0.50	1,579	707,581
Drill Rig	1	305	0.43	65	1,674
Small Drill Rig	5	300	0.43	2,465	313,212
Large Drill Rig	1	540	0.43	1,369	62,642

Table 10-I-3: Mobile Equipment Summary

Mobile Equipment	# of Units	Gross Power (hp)	Load Factor	Operating Hours during Entire Construction Period (hours)	Total Annual Fuel (L/y)
Crane	4	1340	0.47	526	260,844
Pier Driller	5	1005	0.43	2,288	973,867
Backhoe	2	127	0.48	1,468	35,249
Flyable Rig	10	48	0.43	2,377	96,645
Forklift	20	173	0.30	41	8,429
Mulcher	8	275	0.59	34	8,607

hp = horsepower; L/y = Litres per year.

4.0 CALCULATIONS

The GHG emissions, including carbon dioxide (CO_2), methane (CH_4) and nitrous Oxide (N_2O), were calculated for mobile equipment (vehicle exhaust), land clearing and biomass burning.

The assessment generally followed the calculation methods in the *Guideline for Greenhouse Gas Emissions Reporting* (MOECC 2015), as set out under O. Reg. 452/09 under the *Environmental Protection Act*. Additionally, IPCC guidelines from *Guidelines for National Greenhouse Gas Inventories: Vol.4* (IPCC 2006a) were used to calculate greenhouse gas emissions from land clearing, as guidance is not provided under O. Reg. 452/09.

The sample calculations in the following subsections demonstrate how the GHG emission estimates were developed. The results are all in units of tonnes of equivalent CO_2e per year (tonnes/year), as required under the assessment methods discussed in Section 10.2 of the amended EA Report for the East-West Tie Transmission Project.

4.1 Mobile Equipment

The GHG emissions from mobile equipment were calculated based on fuel consumption and fuel-specific emission factors on an energy basis as presented in Appendix 18 of the O. Reg. 452/09 Guideline for calculating CO_2, CH_4 and N_2O emissions. For the purposes of this assessment, Calculation Methodology 1 (Equation 280-1 and 280-4) from the O. Reg. 452/09 Guideline was used. This method is based on equipment rating, load factor, and the default fuel specific emission factor (kilogram per gigajoule [kg/GJ] or gram per gigajoule [g/GJ]) from Table 20-2, Table 20-3, and Table 20-4 of ON.20 (General Stationary Combustion).

It was assumed that all mobile equipment is fueled by diesel. The annual fuel consumption for each type of vehicle was calculated based on based on the vehicle horsepower.

The following is a sample calculation for the fuel consumption of a pickup truck:

$$\text{Fuel Consumption}$$
$$= \text{BSFC}\ \frac{\text{lb}}{\text{hp} - \text{hr}} \times \text{hp} \times \frac{\text{LF}}{\text{fuel density}} \times \frac{\text{kg}}{\text{lb}} \times \text{hrs during construction period}$$
$$\times\ \text{length of construction}\ \times \#\ \text{of equipment}$$
$$= 0.367 \frac{\text{lb}}{\text{hp} - \text{hr}} \times 365\ \text{hp} \times \frac{0.5}{0.845\text{kg/L}} \times 0.45359 \frac{\text{kg}}{\text{lb}} \times 2{,}039\ \text{hrs}\ \times \frac{12\ \text{months/year}}{25\ \text{months in construction}} \times\ 50\ \text{pickups}$$
$$\text{Fuel Consumption} = 3{,}664{,}455\ \text{L/yr}$$

Where:
BSFC = Brake specific fuel consumption conversion (lb/hp-hr), and
LF = loading factor

Crank case load factors for non-road Engine Modelling (Compression Ignition) – U.S. EPA 009d (July 2010) were used to calculate the greenhouse gas exhaust emissions. The following was completed to calculate the annual emissions of carbon dioxide from the pickup trucks:

$$\text{ER} = \text{EF} \frac{\text{g}}{\text{L}} \times \text{Vehicle Fuel Consumption}\ \frac{\text{L}}{\text{yr}} \times \frac{1\ \text{tonne}}{1{,}000{,}000\ \text{g}}$$

Where:
ER = emission rate (tonnes/yr), and
EF = emission factor (g/L)

$$\text{ER} = 2{,}663 \frac{\text{g}}{\text{L}} \times 3{,}664{,}455 \frac{\text{L}}{\text{yr}} \times \frac{1\ \text{tonne}}{1{,}000{,}000\ \text{g}}$$

$$\text{ER} = 9{,}758 \frac{\text{tonnes}}{\text{year}}$$

4.2 Land Clearing

Changes to GHGs associated with clearing biomass from the land for the project were calculated using methods set out in Chapter 4 of the IPCC (2006b) Report, Volume 4.

The amount of carbon that would be sequestered by the land if it were to remain intact (i.e., the carbon sink) was calculated to determine the impact that the land clearing will have on GHGs. The results of this calculation provides an estimate for the annual loss of GHG sequestering due to clearing of the land (i.e., loss of the carbon sink).

Loss of Carbon Sink

Emissions from the loss of a carbon sink represents the amount of carbon that could have been removed from the atmosphere by the biomass cover in the area had the land not been cleared, it represents lost carbon removal potential in the years after land clearing. The equation below presents the method for calculating the annual increase in biomass carbon stored due to biomass growth ***(C_G)*** (tonne C yr^{-1}). This annual carbon storage is considered a loss for this project since this carbon storage will be removed when the land is cleared.

The total area of land cleared for the Project is the total vegetated area in the Project footprint, which is 1,999 ha (including merchantable timber). In the interest of conservatism, the entire area is assumed to be boreal forest.

$$C_G\,(C) = A \times GW \times (1 + R) \times CF$$

Where:

A = the total area of forested land (ha)

GW = the average annual above-ground biomass growth (tonnes dry matter ha^{-1} yr^{-1})

R = the ratio of below to above-ground biomass

CF = the carbon fraction of dry matter (tonnes C tonnes dry $matter^{-1}$)

$$C_G(C) = 1{,}999\ \text{ha} \times 1\ \frac{\text{tonnes d. m.}}{\text{ha year}} \times (1 + 0.39) \times 0.47\ \frac{\text{tonne C}}{\text{tonnes d. m.}}$$

$$C_G(C) = 1{,}306\ \frac{\text{tonnes C}}{\text{year}}$$

The total carbon emissions is then converted to CO_2 using molecular weights.

$$C_G\,(CO2) = C_G(C) \times \frac{\text{MolecularWeight of CO2}}{\text{MolecularWeight of C}}$$

$$C_G\,(CO2) = 1{,}306\ \text{tonnes C} \times \frac{44}{12}$$

$$C_G\,(CO2) = 4{,}787\ \frac{\text{tonnes CO2}}{\text{year}}$$

The annual amount of carbon dioxide storage that will be lost from clearing the land is 4,787 tonnes CO_2/year. Since this is a loss of a carbon sink, this is included as annual emissions of CO_2. These annual emissions are associated with the construction phase of the Project since the sink is removed during construction.

4.3 Biomass Burning

GHG emissions from the burning of vegetation removed during the land clearing operations were calculated using methods set out in Chapter 2 of the IPCC (2006b) Report, Volume 4. The total area of land cleared for the Project that does not include merchantable timber is 153 ha. A conservative approach was taken and it was assumed that the entire area is boreal forest and will be burned. While provincial parks and conservation areas have not been excluded from the biomass burning calculations, in practice, no burning will be occurring in the provincial parks and conservation areas.

The following is a sample calculation for CO_2 emissions associated with biomass burning. The same calculation was completed for CH_4 and N_2O, using the respective emission factors.

$$\text{Lfire} = \text{A} \times \text{MB} \times \text{CF} \times \text{GEF} \times 10^{-3}$$

Where:

A = the total area of forested land (ha)

MB = the mass of fuel available for combustion (tonnes dry matter ha^{-1})

CF = the combustion factor (dimensionless)

GEF = the emission factor for biomass burning (g/kg dry matter)

$$\text{Lfire} = 153\ \text{ha} \times 50\ \frac{\text{tonnes d. m.}}{\text{ha}} \times 0.33 \times 1{,}569\ \frac{\text{g}}{\text{kg d. m.}} \times 10^{-3}$$

$$\text{Lfire} = 3{,}958\ \text{tonnes CO2}$$

The total CO_2 emissions are then divided by the length of the construction period (2 years) to determine the annual emissions.

$$\text{Lfire} = \frac{3{,}958\ \text{tonnes CO2}}{2\ \text{years}}$$

$$\text{Lfire} = 1{,}979\ \frac{\text{tonnes CO2}}{\text{year}}$$

5.0 GLOBAL WARMING POTENTIALS

Emissions from CO_2, CH_4 and N_2O were converted to equivalent CO_2 (CO_2e). The GHG emissions are expressed as tonnes of CO_2e by multiplying the annual emissions of each GHG by its 100-year global warming potential (GWP). The GWP of each gas represents the gas's ability to trap heat in the atmosphere in comparison to CO_2.

The provincial GWPs were used to calculate emissions as they are consistent with UNFCCC reporting guidelines (UNFCCC 2014). As shown in Section 6, CH_4 and N_2O have a small contribution to the total GHG emissions in CO_2e (Table 10-I-5), which becomes negligible when compared to the provincial and federal totals (Table 10-I-6). Therefore, the difference in the GWPs for CH_4 and N_2O will not be measurable. A comparison the federal and provincial GWPs is provided in Table 10-I-4.

Table 10-I-4: Federal and Provincial Global Warming Potentials

GHG Compound	Federal GWPs (Canada Gazette, 2016)	Provincial GWPs (O. Reg. 452/09)
CO_2	1	1
CH_4	25	21
N_2O	298	310

6.0 GREENHOUSE GAS ASSESSMENT

6.1 Emission Rates

The GHG emissions were estimated for the construction phase of the Project as a bounding condition. For the construction phase, the emissions consist of mobile fuel combustion from road and non-road vehicles and equipment, and the emissions from biomass burning and land clearing. The emissions from the construction phase and the percentage that each source contributes to the overall GHG emissions from the Project is provided in Table 10-I-5. Tonnes of CO_2e were calculated using the provincial GWPs from the UNFCCC reporting guidelines (UNFCCC 2014).

Table 10-I-5: Summary of Greenhous Gas Emissions During Construction of the Project

Source	Annual Greenhouse Gas Emissions (tonnes/year)[1]			Annual Total (tonnes/year)[1]	Percentage Contribution (%)
	CO_2	CH_4	N_2O	CO_2e	
Construction					
Mobile Equipment	24,000	1.2	3.6	25,000	78%
Land Clearing	4,800	—	—	4,800	15%
Biomass Burning	2,000	5.9	0.33	2,200	7%

1) The values have been adjusted to two (2) significant digits to represent the level accuracy.

6.2 Greenhouse Gas Results

The annual overall emissions in tonnes of CO_2e for the Project construction phase is provided in Table 10-I-6. Greenhouse gas emissions by source is presented in Tables 5, above. The construction phase GHG emissions represent 0.02% of the provincial total and 0.004% of the Canada-wide total. It should be noted that these GHG emission estimates are conservative relative to reported federal as it includes CO_2 emissions from biomass burning, which are not reportable under the federal program. A comparison to the global GHG emissions total was not completed as GHG emissions from the Project represent a negligible fraction of national GHG emissions.

Table 10-I-6: Comparison of Project Greenhouse Gas Emissions to Canadian and Ontario Emissions

Source	Construction Emissions [CO2e tonnes/year]
GHG Emissions	32,000
Comparison to Canada-wide Total	0.004%
Comparison to Ontario Total	0.02%
Canada-wide GHG Emissions (2014)[(1)]	**732,000,000**
Ontario-wide GHG Emissions (2014) [(1)]	**170,000,000**

1) Obtained from National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada. (Environment and Climate Change Canada, 2016)

7.0 REFERENCES

Canada Gazette. 2016. *Canada Gazette Part I, Vol. 150, No. 50*. December 10, 2016.

Environment and Climate Change Canada. *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada. (Environment.* ISSN: 2371-1329

IPCC. 2006a. *Guidelines for National Greenhouse Gas Inventories: Vol.4 Ch. 2: Generic Methodologies Applicable to Multiple Land-Use Categories*

IPCC. 2006b. *Guidelines for National Greenhouse Gas Inventories: Vol.4 Ch. 4: Forest Land.*

MOECC. 2015. *Guideline for Greenhouse Gas Emissions Reporting.* PIBs 9906e.

UNFCCC (United Nations Framework Convention on Climate Change). 2014. *Reporting Guidelines*.

U.S. EPA (United States Environmental Protection Agency). 2010. *Exhaust and Crankcase Emission Factors for Non-road Engine Modeling – Compression-Ignition.* NR-009d. U.S. EPA, Office of Transportation and Air Quality.