Air Quality and Greenhouse Gases Technical Data Report

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Prepared for:

Broadway Subway Project
Ministry of Transportation and Infrastructure

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Abbreviations

AAQO	ambient air quality objectives
CAC	criteria air contaminants
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
d/y	days per year
ESR	Environmental and Socio-Economic Review
GHG	greenhouse gas
g/hp-h	grams per horsepower per hour
g/L	grams per litre
HC	hydrocarbons
h/d	hours per day
hp	horsepower
km	kilometres
km/h	kilometres per hour

LFV	Lower Fraser Valley
L/h	litres per hour
MOTI	Ministry of Transportation and Infrastructure
MV	Metro Vancouver
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
N_2O	nitrogen oxide
O_3	ozone
$PM_{2.5}$	respirable particulate matter (diameter less than 2.5 μm)
PM_{10}	inhalable particulate matter (diameter less than 10 μm)
SO_2	sulphur dioxide
t	tonnes
tpy	tonnes per year
US EPA	United States Environmental Protection Agency
VOCs	volatile organic compounds
μg/m3	micrograms per cubic metre

1.0 INTRODUCTION

This Technical Data Report (TDR) provides the following supplementary information in support of the Environmental and Socio-economic Review (ESR) conducted in support of the Broadway Subway Project (the Project), and includes:

- Baseline air quality and greenhouse gas (GHG) conditions within the Review Area
  - existing baseline criteria air contaminants (CAC) and GHG emissions from all pollution sources (year 2010)
  - forecast baseline conditions without the Project (year 2020 and 2030)
  - existing ambient concentrations of: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), inhalable particulate matter (diameter less than 10 µm [PM_{10}]), respirable particulate matter (diameter less than 2.5 µm [$PM_{2.5}$]) and ozone (O_3).
- Project construction air emissions analysis methods and assumptions

As the Project is a proposed major public infrastructure project that will be supported by federal funding, the Ministry of Transportation and Infrastructure (MOTI) completed a Climate Lens Assessment (MOTI 2019) following Infrastructure Canada requirements, to develop an understanding of potential changes in GHG emissions associated with construction and operation of the Project. Results from the Climate Lens Assessment (i.e., predicted GHG emissions) are noted, where applicable, throughout the TDR.

2.0 EMISSIONS—AIR CONTAMINANTS AND GREENHOUSE GASES

Criteria air contaminants and GHG emission inventories supporting this assessment were obtained from Metro Vancouver and provide an account of total air emissions from all pollution sources for each municipality within its jurisdiction (Metro Vancouver 2017).

Metro Vancouver emission inventories include backcast CAC (i.e., SO_2, oxides of nitrogen (NO_X), CO, PM_{10}, $PM_{2.5}$) and GHG (i.e., carbon dioxide (CO_2), methane (CH_4), nitrogen oxide (N_2O), carbon dioxide equivalents (CO_2e)) emissions by updating past inventories with the current years' methodology and Review Area to allow for a representative comparison of yearly trends. Metro Vancouver also forecasts emissions in five-year increments as a function of population, economy, employment, kilometers travelled, fuel consumed and future growth. Metro Vancouver's emission inventories are grouped into the following categories:

- Mobile sources include on-road (i.e., cars, buses, trucks) and off-road vehicles (i.e., train locomotives, construction equipment, marine vessels, and aircrafts)
- Area sources (e.g., agriculture, vegetation burning, fuel distribution, natural sources, chemical products use, heating, fugitive dust, waste)
- Point sources (e.g., bulk shipping terminals, chemical manufacturing, electrical power generation, heating/cogeneration utilities, metal industries, non-metallic mineral processing, paper and allied products, petroleum products, wood products, concrete batch plants).

Metro Vancouver's most recently released backcast CAC and GHG emissions for the Lower Fraser Valley (LFV) and associated municipalities, is for the year 2010. For the purposes of this appendix and the ESR, the CAC and GHG emission inventories are provided for year 2010, 2020 and 2030.

Emissions for year 2010 are used to establish present or existing conditions. Emissions for year 2020 establish conditions during Project construction. Emissions for year 2030 will apply when the Project is operational.

2.1 2010 CAC AND GHG EMISSIONS

Total 2010 CAC and GHG emissions for Metro Vancouver and the City of Vancouver are summarized in Table 1. Since this data was not available on a municipal scale, the overall contribution of the City of Vancouver emissions to the total Metro Vancouver emissions was used to estimate mobile, area and point sources emissions for Vancouver. For example, it was assumed that if 14% of Metro Vancouver's NO_X emissions came from Vancouver, then 14% of Metro Vancouver's mobile, area and point sources of NO_X emissions also came from Vancouver.

Table 1 shows that Vancouver's 2010 SO_2, NO_X and CO emissions are dominated by mobile sources. Most of Vancouver's PM_{10} and $PM_{2.5}$ emissions come from area and point sources. The CO_2 and N_2O emissions come from mobile sources. Area sources contribute the most CH_4 emissions.

Table 1 2010 CAC and GHG Emissions in Metro Vancouver and City of Vancouver

Source Type		CAC Emissions (tpy[b])						GHG Emissions (tpy[b])			
		SO_2	NO_X	CO	PM_{10}	$PM_{2.5}$	VOCs[c]	CO_2	CH_4	N_2O	CO_2e
Metro Vancouver Total (all sources)[a]		5,792	44,463	253,484	6,850	4,730	N/A	14,704,854	30,540	867	15,726,615
Vancouver Total (all sources)[a]		75	6,186	59,070	1,002	663	N/A	2,596,035	1,012	140	2,662,967
Vancouver %[d]		1%	14%	23%	15%	14%	N/A	18%	3%	16%	17%
Vancouver Mobile Sources	On-road	1	2,354	25,275	83	75	N/A	934,393	15	47	948,778
	Off-road	62	2,492	30,441	178	160	N/A	314,325	22	49	329,504
	Total	63	4,846	55,716	261	235	N/A	1,248,718	37	96	1,278,282
Vancouver Area Sources		3	809	2,675	516	319	N/A	941,351	949	40	976,965
Vancouver Point Sources		9	531	680	224	109	N/A	405,966	26	4	407,720
% Mobile of Total Vancouver		85%	78%	94%	26%	36%	N/A	48%	4%	69%	48%
% On-road of Total Vancouver		1%	38%	43%	8%	11%	N/A	36%	1%	34%	36%

NOTES:

[a] Total Metro Vancouver and Vancouver 2010 CAC and GHG emissions were provided by Metro Vancouver (pers. comm. MV 2017)

[b] Emissions reported in tonnes per year (tpy)

[c] Total Volatile Organic Compounds (VOC) emissions for reporting year were not available

[d] Percentage calculated by taking the ratio of the total Vancouver emissions over all emissions in Metro Vancouver for the given substance

2.2 2020 CAC AND GHG EMISSIONS

Table 2 summarizes the Metro Vancouver and Vancouver forecasted CAC and GHG emissions for 2020. As with the 2010 emission inventory, the distribution between mobile, area and point sources was not available on a municipal scale. In its absence, the overall contribution of the City of Vancouver emissions to the total Metro Vancouver emissions was used to estimate mobile, area and point sources emissions for Vancouver.

Vancouver's 2020 SO_2, NO_X and CO emissions remain dominated by mobile sources. The contribution of on-road emissions, specifically NO_x and CO, are forecast to decrease by 2020, due to on-road vehicle emission management, planning, inspections and maintenance. SO_2 reductions are predicted to occur due to newly-imposed emission standards for marine vessels by the International Marine Organization (IMO 1997).

The GHG emission forecast for 2020 predicts emissions to be consistent with estimates made in 2010 and are in line with population and economic growth (MV 2013). In support of the Climate Lens report (MOTI 2019) Metro Vancouver provided forecasted GHG emissions for 2020.

2.3 2030 CAC AND GHG EMISSIONS

Table 3 shows Metro Vancouver and Vancouver forecast CAC and GHG emissions for 2030. As with the 2010 emission inventory, distribution between mobile, area and point sources was not available on a municipal scale. In its absence, the overall contribution of the City of Vancouver emissions to the total Metro Vancouver emissions was used to estimate mobile, area and point sources emissions for Vancouver.

The NO_x, CO and SO_2 emissions are still dominated by mobile sources and are predicted to level off by 2030.

A slight decline in GHG emissions is predicted for 2030 due to new vehicle engine technology, emissions management and new regulations expected in the future.

Table 2 2020 CAC and GHG Emissions in Metro Vancouver and City of Vancouver

Source Type		CAC Emissions (tpy[b])						GHG Emissions (tpy[b])			
		SO_2	NO_X	CO	PM_{10}	$PM_{2.5}$	VOCs[c]	CO_2	CH_4	N_2O	CO_2e
Metro Vancouver Total (all sources)[a]		1,361	33,181	246,319	6,598	4,127	N/A	15,385,867	16,507	859	16,054,545
Vancouver Total (all sources)[a]		18	4,617	57,401	965	578	N/A	2,716,263	547	138	2,718,495
Vancouver %[d]		1%	14%	23%	15%	14%	N/A	18%	3%	16%	17%
Vancouver Mobile Sources	On-road	0	1,028	19,863	38	34	N/A	919,361	15	24	891,311
	Off-road	5	2,288	33,972	89	80	N/A	382,554	13	67	389,497
	Total	5	3,316	53,835	126	113	N/A	1,301,915	28	91	1,280,808
Vancouver Area Sources		3	814	2,895	597	346	N/A	919,361	491	44	1,030,981
Vancouver Point Sources		9	486	671	241	119	N/A	419,186	28	4	406,707
% Mobile of Total Vancouver		7%	54%	91%	13%	17%	N/A	50%	3%	65%	48%
% On-road of Total Vancouver		1%	17%	34%	4%	5%	N/A	35%	2%	17%	33%

NOTES:

[a] Total Metro Vancouver and Vancouver 2020 CAC and GHG emissions were provided by Metro Vancouver (MV 2017)

[b] Emissions reported in tonnes per year (tpy)

[c] Total VOC emissions for reporting year were not available

[d] Percentage calculated by taking the ratio of the total Vancouver emissions over all emissions in Metro Vancouver for the given substance

Table 3 2030 CAC and GHG Emissions in Metro Vancouver and City of Vancouver

Source Type		CAC Emissions (tpy[b])						GHG Emissions (tpy[b])			
		SO_2	NO_X	CO	PM_{10}	$PM_{2.5}$	VOCs[c]	CO_2	CH_4	N_2O	CO_2e
Metro Vancouver Total (all sources)[a]		1,436	31,230	276,884	7,529	4,384	N/A	16,121,937	15,480	916	16,782,011
Vancouver Total (all sources)[a]		100	5,958	89,503	2,081	1,054	N/A	4,291,221	1,716	314	4,433,351
Vancouver %[d]		1%	14%	23%	15%	14%	N/A	18%	3%	16%	17%
Vancouver Mobile Sources	On-road	1	875	21,607	35	31	N/A	910,737	18	21	882,535
	Off-road	6	2,166	39,312	85	75	N/A	441,655	14	77	449,406
	Total	6	3,041	60,919	120	107	N/A	1,352,391	32	98	1,331,941
Vancouver Area Sources		3	865	2,899	705	370	N/A	1,052,711	450	46	1,081,525
Vancouver Point Sources		9	440	705	277	138	N/A	441,109	31	4	428,210
% Mobile of Total Vancouver		6%	51%	68%	6%	10%	N/A	32%	2%	31%	30%
% On-road of Total Vancouver		1%	15%	24%	2%	3%	N/A	21%	1%	7%	20%

NOTES:

[a] Total Metro Vancouver and Vancouver 2030 CAC and GHG emissions were provided by Metro Vancouver (MV 2017)

[b] Emissions reported in tonnes per year (tpy)

[c] Total VOC emissions for reporting year were not available

[d] Percentage calculated by taking the ratio of the total Vancouver emissions over all emissions in Metro Vancouver for the given substance

3.0 AMBIENT AIR QUALITY

Local and regional ambient concentrations for SO_2, NO_2, CO, PM_{10}, $PM_{2.5}$, O_3 and volatile organic compounds (VOCs) are summarized in Table 4. Local concentrations are based on data from the Vancouver-Kitsilano and Richmond-Airport monitoring stations (locations shown in Section 7.5 of the ESR), considered nearest to the Project and representative of Project conditions. Similarly, regional concentrations reflect a range of concentrations from all LFV monitoring stations operated by Metro Vancouver during the monitoring period.

Table 4 Local and Regional Ambient CAC Concentrations

Species	Averaging Period [e]	Ambient Concentration (µg/m^3)		Metro Vancouver AAQO (µg/m^3)
		Local [a]	Regional (LFV airshed [b])	
SO_2	1-hour	39	13–**346**	196
	24-hour	9	5–59	125
	Annual	1.4	0.3–5	30
NO_2	1-hour	86	59–153	200
	Annual	30	11–34	40
CO	1-hour	1,831	670–2,980	30,000
	8-hour	1,477	432–1,611	10,000
PM_{10}	24-hour	33	28–**55**	50
	Annual	11	9–13	20
$PM_{2.5}$	24-hour	23	19–**37**	25
	Annual	6.6	4.6–6.7	8(6)
O_3	1-hour	104	45–**172**	161
	8-hour	96	74–**146**	128
VOCs [c]	24-hour [d]	122	42–694	-
	Annual	37	22–223	-

NOTES:
Bold values identify an exceedance of the Metro Vancouver Ambient Air Quality Objectives (AAQOs).

[a] The Vancouver-Kitsilano station operated for a partial year in 2014; therefore 2013 ambient SO_2, NO_2, CO, $PM_{2.5}$ and O_3 concentrations are presented for Vancouver-Kitsilano. Based on past ambient trends and no significant changes in emission sources in the local area, 2013 ambient concentrations are assumed to be representative to those that would have been measured in 2014. For consistency, 2013 ambient PM_{10} and VOC concentrations are provided from Richmond-Airport Station

[b] In 2014, Metro Vancouver operated 28 air monitoring stations in the LFV airshed (MV 2015). These values reflect the range of concentrations observed from available data.

[c] VOC ambient data for 2014 is not available from Metro Vancouver; therefore, 2013 has been summarized. Based on past ambient trends and no significant changes in emission sources in the regional area, 2013 ambient concentrations are assumed to be representative to those that would have been measured in 2014.

[d] VOC 24-hour value represents a daily total VOC maximum.

[e] Metro Vancouver has established AAQOs as a function of averaging periods over which the ambient concentration data should be averaged when compared to the objective

3.1 SULPHUR DIOXIDE

Ambient SO_2 concentrations were measured at 16 monitoring stations in the LFV in 2014; one station exceeded the 1-hour ambient air quality objectives (AAQO) for one hour (0.01% of total hours measured in the LFV) in the monitoring period. The 24-hour and annual averages at all stations were below the Metro Vancouver AAQOs. The Vancouver-Kitsilano Station is considered representative of the local air quality near the Project. The maximum 1-hour concentrations measured at the Vancouver-Kitsilano Station in 2013 were well below the Metro Vancouver AAQOs.

3.2 NITROGEN DIOXIDE

In total, 21 monitoring stations in the LFV measured ambient NO_2 concentrations in 2014. Ambient NO_2 concentrations were below the Metro Vancouver AAQOs at all stations. The 2013 maximum 1-hour average NO_2 concentration at Vancouver-Kitsilano was also below the Metro Vancouver AAQO.

3.3 CARBON MONOXIDE

Ambient CO concentrations were measured at 18 monitoring stations in the LFV. Data from all stations were below the Metro Vancouver AAQOs. The 2013 maximum 1-hour average CO concentration at Vancouver-Kitsilano, was below the Metro Vancouver AAQO.

3.4 PARTICULATE MATTER

Ambient $PM_{2.5}$ concentrations were measured at 18 monitoring stations in 2014. Measured concentrations of $PM_{2.5}$ at nine stations exceeded the 24-hour Metro Vancouver AAQO for 0.2% of total hours measured in the LFV. Annual $PM_{2.5}$ concentrations were below the Metro Vancouver annual AAQO at all stations. The 2013 24-hour average $PM_{2.5}$ concentration at the local monitoring station, Vancouver-Kitsilano, was below the Metro Vancouver AAQO.

Ambient PM_{10} concentrations were measured at nine monitoring stations in the LFV; Metro Vancouver's 24-hour AAQO was exceeded at one station. Annual PM_{10} concentrations were below Metro Vancouver's annual AAQO at all stations. Since PM_{10} was not measured at Vancouver-Kitsilano, Richmond-Airport data were used as representative of the local air quality near the Project. The 24-hour average PM_{10} concentration in 2013 was below the Metro Vancouver AAQO.

3.5 OZONE

Ambient O_3 concentrations were measured at 21 monitoring stations in the LFV. Data from two stations exceeded the 1-hour Metro Vancouver AAQO. The 8-hour Metro Vancouver AAQO was also exceeded at five monitoring stations. The 2013 maximum 1-hour average O_3 concentration at Vancouver-Kitsilano was below the Metro Vancouver AAQO.

3.6 VOLATILE ORGANIC COMPOUNDS

Data on VOCs are not available from any of the stations operated by Metro Vancouver in 2014. In the absence of 2014 data, 2013 data were obtained, and reviewed and are considered as representative. Total VOC concentrations were measured by non-continuous sampling systems at seven monitoring stations in the LFV. Regional ambient VOC concentrations were generally higher than those reported from the local station (Richmond-Airport considered representative of the local air quality near the Project).

4.0 CONSTRUCTION EMISSIONS CALCULATION BASIS

Estimated construction phase emissions were calculated to support the assessment of Project-related CAC and GHG emissions. The estimate is supported by the assumptions presented in this section regarding the construction fleet profile and hours of operation of the fleet.

The Project's estimated construction fleet composition is summarized in Table 5, with the fleet broken out into four construction components: station box construction, portal/tunneling, above ground rail construction, and other miscellaneous activities. This information is consistent with the fleet information applied to the Climate Lens Assessment (MOTI 2019).

Table 5 summarizes the assumed generic construction fleet per station along the Alignment; a total of six stations are identified in the Reference Design. As a conservative approach, this assessment assumes that construction activities will occur simultaneously at three stations during the peak construction year. Consequently, CAC and GHG emissions reported below reflect use of construction equipment at three stations simultaneously, and an assumption that working hours are Monday to Saturday (07:00 to 20:00) and Sunday (10:00 to 20:00), 365 days a year, over the course of one year. It is not anticipated that all equipment would be used at any one time along the Alignment. As such, emission estimates are considered conservative.

Table 5 Construction Fleet Composition per Constructed Station

Equipment Type	Number of Units Per Station	Operating details per unit of equipment				
		Engine Power (hp)	Fuel Consumption (L/h)	Load Factor (%)	Operating Time	
					(h/d)	(d/y)
Station Construction						
Articulated Dump Truck (17 m^3)	2	464	40	80	13/10[a]	365
Concrete Pumper (Stationary)	2	27	7.2	21	13	365
Excavator	2	160	19.2	59	13	365
Compressor	2	283	30.3	59	13	365
Rock Drill / Soil Nail Drills	2	200	22.8	59	13	365
Crane	1	230	30.3	59	13	365
Vibratory Piling	1	270	40.0	59	13	365
Portable Light Generator	2	30	2.0	45	13	365
Portal/tunnel						
66 000 lb HDD rig	1	200	22.8	59	13	365
Centrifuge, S/S High Speed	1	27	40.0	59	13	365
Mud Pump	1	1000	40.0	59	13	365
Zoom Boom	1	100	40.0	21	13	365
Backhoe	2	268	17.0	21	13	365
Backup Alarm	2	-		10	13	365
Portable Light Generator	2	30	2.0	45	13	365
Above ground construction						
Vibratory Tamper	1	-		59	13	365
Bulldozer	1	190	40.0	59	13	365
Skid Steer	1	120	9.0	59	13	365
Backhoe	1	83	17.0	59	13	365
Grader	1	120	18.5	59	13	365
Front End Loader - Towing	1	247	17.0	59	13	365
Welding Rig	1	350	22.8	59	13	365
Track Lifting Rig	1	160	22.8	59	13	365
Backup Alarm [b]	4	-		10	13	365
Portable Light Generator	2	30	2.0	45	13	365
Miscellaneous						
Articulated Dump Truck (17 m^3) - Idle for Loading	1	464	40	80	13	365
Portable Light Generator	1	30	2.0	45	13	365

NOTES:
[a] Operating time varies. The equipment will operate 13 hours per day Mon-Sat and 10 hours on Sunday.

The Sulphur in Diesel Fuel Regulations (ECCC 2002) set a maximum limit of 15 mg/kg, which was used to calculate the SO_2 emission factor with the density of diesel (0.85 kg/L) for diesel equipment exhaust emissions.

Exhaust emissions of NO_X, CO, PM and VOC from diesel equipment are based on the Canadian off-road compression-ignition engine emission standards of Tier 3 engines (EC 2005), the corresponding United States Code of Federal Regulation (CFR; [US EPA 2016a]), and United States Environmental Protection Agency NONROAD model documentation (US EPA 2010, Table 8). Although the actual off-road equipment fleet used during construction may be newer (e.g., Tier 4), for the purposes of this assessment the Project construction equipment is conservatively assumed to be Tier 3 compliant.

The off-road diesel engine emission standards (EC 2005) specific to engine power rating and corresponding to Tier 3 equipment are applied as emission factors for NO_X, CO, PM and VOC. Where emission standards are provided for combined NO_X and hydrocarbon (HC) emissions (NO_X+HC), the pollutant-specific emission standards for NO_X and HC are based on the recommended split in the NONROAD model documentation for Tier 2 and Tier 3 engines (US EPA Table 8 in EPA 2010). VOC emission factors are based on the HC emission factor, by subtracting the CH_4 fraction (assumed to be 9.8% of HC emissions) and applying a VOC to non-methane HC ratio of 1.233, based on the MOVES2014a/ NONROAD model speciation profiles (Table 10 in US EPA 2016b). The particulate matter emissions are assumed to be smaller than 10 µm (PM_{10}) and 97% of the PM is assumed to be smaller than 2.5 µm ($PM_{2.5}$) (US EPA 2010).

Exhaust emissions of NO_X, CO, PM_{10}, $PM_{2.5}$ and VOC from on-road diesel equipment are based on emission factors from United States Environmental Protection Agency average in-use emissions from heavy-duty trucks (U.S EPA 2008).

Emissions of GHG from off-road and on-road diesel equipment are based on national inventory emission factors (NIR 2017).

Table 6 and Table 7 summarize the CAC and GHG emission factors used in the assessment for off-road and on-road diesel equipment, respectively.

Table 6 CAC and GHG Emission Factors for Off-Road Diesel Equipment

Species		Units	Emission Factor as a function of power rating [a]					
			25-50 hp	75-100 hp	100-175 hp	175-300 hp	300-600 hp	>750 hp
CAC	SO_2 [b]	g/L of fuel	0.025	0.025	0.025	0.025	0.025	0.025
	NO_X [c]	g/hp-h	5.000	3.300	2.800	2.800	2.800	2.600
	CO	g/hp-h	4.100	3.700	3.700	2.600	2.600	2.600
	PM_{10}	g/hp-h	0.450	0.300	0.220	0.150	0.150	0.075
	$PM_{2.5}$	g/hp-h	0.437	0.291	0.213	0.146	0.146	0.073
	VOC [d]	g/hp-h	0.662	0.221	0.221	0.221	0.221	0.331
GHG [e]	CO_2	g/L of fuel	2681	2681	2681	2681	2681	2681
	CH_4	g/L of fuel	0.07	0.07	0.07	0.07	0.07	0.07
	N_2O	g/L of fuel	0.02	0.02	0.02	0.02	0.02	0.02

NOTES:

[a] Includes only the engine power range applicable to the Project construction,

[b] Calculated based on the maximum limit of Sulphur of 15 mg/kg in diesel (EC 2002).

[c] Pollutant-specific NO_X emission standards derived based on the recommended split of ($HC+NO_X$) emission standard in the NONROAD model documentation (US EPA, 2010a, Table 8).

[d] VOC emission standards derived from the HC emission standard, by subtracting the CH4 fraction (assumed to be 9.8%) of HC emissions and applying a VOC-to-NMHC ratio of 1.233, based on the MOVES2014a/NONROAD model speciation profiles (US EPA, 2016b, Table 10).

[e] Emission factors of GHG for off-road diesel equipment based on national inventory emission factors (NIR 2017)

Table 7 CAC and GHG Emission Factors for On-Road Diesel Equipment

Species		Units	Emissions Factors for Vehicle (Type VIIIb) [a]
CAC	SO_2 [b]	g/L of fuel	0.025
	NO_X [c]	g/mile	10.990
	CO [c]	g/mile	3.109
	PM_{10} [c]	g/mile	0.259
	$PM_{2.5}$ [c]	g/mile	0.238
	VOC [c]	g/mile	0.545
GHG [d]	CO_2	g/L of fuel	2681
	CH_4	g/L of fuel	0.15
	N_2O	g/L of fuel	0.08

NOTES:

a Includes only the vehicle type VIIIb (vehicles > 60,000 lbs) applicable to the Project construction (US EPA 2008)

b Calculated based on the maximum limit of Sulphur of 15 mg/kg in diesel (EC 2002)

c Based on emission factors from US EPA Average In-Use Emissions from Heavy-Duty trucks (US EPA 2008)

d Emission factors of GHG for off-road diesel equipment based on national inventory emission factors (NIR 2017)

Emission calculations were based on the following assumptions:

- Emissions of SO_2 were calculated based on the number of units, fuel consumption, total annual working hours, and SO_2 emission factor of 0.025 g/L for each off-road and on-road equipment, assuming that all diesel sulphur is oxidized.
- Emissions of NO_X, CO, PM_{10}, $PM_{2.5}$ and VOC from each off-road diesel equipment were calculated based on the number of units, engine power, load factor, annual working hours, and the emission factor of each species.
- Emissions of NO_X, CO, PM_{10}, $PM_{2.5}$ and VOC from each on-road diesel equipment were calculated based on the number of unit, average travel speed of 25 km/hour assumed, annual working hours, and the emission factor of each species.
- Emissions of GHG were calculated based on the number of unit, fuel consumption, total annual working hours, and GHG emission factors (CO_2, CH_4, N_2O) for each off-road and on-road equipment. Then the global warming potential were used to convert various gases into equivalent amounts of CO_2e.
- While CAC emissions presented in this report are based on the 2017 NIR emission factors, the 2018 NIR was used to support the assessment of GHG emission undertaken as part of the Climate Lens Assessment (MOTI 2019)

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