# APPENDIX 5.2-4
## Air Emission Details

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# Emission Estimation Methods

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REPORT

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# 1.0 INTRODUCTION

Woodfibre LNG Limited (WLNG) has proposed to construct and operate a liquefied natural gas (LNG) production, storage and marine carrier transfer facility (the Project) for the export of LNG. The Project will be located approximately 7 kilometres (km) west-southwest of Squamish, British Columbia (BC).

This Appendix supplements Section 5.2 Atmospheric Environment (Air Quality) of the Application for an Environmental Assessment Certificate. The general approach used to evaluate the potential air quality effects of the Project included the following steps:

- Establish the existing air quality and meteorological conditions in the project study areas;
- Develop a representative site specific meteorological dataset for use in the dispersion modelling assessment;
- **Quantify the air emissions from the project for the phase of activity (i.e., construction, operations, and decommissioning) likely to result in the highest overall changes to air quality;**
- Predict the concentrations and deposition rates of indicator compounds released from the project phase that will likely result in the highest overall changes to air quality using dispersion modelling;
- Use dispersion modelling to predict the concentrations and deposition rates of the other compounds required as inputs to other disciplines affected by changes in air quality (e.g., human health); and
- Compare the predicted indicator compound concentrations to available criteria and standards, and assess the relevant significance of these effects.

This appendix outlines the third (**bolded**) step, namely the estimation of air emissions estimations from the Project.

# 2.0 PROJECT DESCRIPTION

During operation phase, the Project will export approximately 2.1 million metric tonnes (MMT) per annum of LNG. Facility infrastructure includes:

- **Power supply system**- BC Hydro substation will supply electricity to the Project. Onsite generators will only be used for the Project's emergency power supply;
- **Natural gas reception system-** Natural gas will be supplied to the facility from western Canadian market hubs through an expansion of the existing gas transmission system by FortisBC;
- **Natural gas processing and liquification facility**- Gas pre-treatment modules will remove unliquifiable components from the feed gas prior to LNG processing. Control and monitoring of the LNG facility will be undertaken from a central control room onsite situated remotely from gas processing but still in the Project area. External and internal communications systems will be located in the central control room. The LNG facility will be water cooled. The system will include an intake structure designed following best management practices (BMPs) for approach velocity and screen size. The structure will be fixed to the ocean floor at a depth of greater than 25 m. The system will also include a discharge diffuser located at a depth of greater than 25 m;

- **Floating storage and off-loading unit**- The floating storage and offloading unit (FSO) will have a capacity of 250,000 $m^3$;
- **Marine terminal**- The FSO will act as the LNG carrier berthing and loading terminal during LNG transfer operations, and will be permanently moored to a dedicated jetty with LNG and vapour transfer facilities. The FSO will be equipped with mooring and LNG transfer equipment for offloading to an LNG tanker. The FSO will be the terminal; and
- **Supporting infrastructure**- The following facilities are to be permanently installed for the life cycle of the Project and will support the safe operation of the processing facilities and marine terminal:
  - New small-craft floats;
  - Upgraded barge ramp for transfer of equipment and materials on and off the site;
  - Electrical substations and step-down transformers connected to the BC Hydro substation and associated power-lines;
  - Site administration and safety facilities;
  - Land-based chemical storage and handling, including diesel fuel storage;
  - New potable water treatment facility;
  - New treatment plant for the treatment of process water, storm water, and wastewater from the FSO, LNG facility, and land-based facilities; and
  - Existing landfill for organic waste and construction materials, including sludge from treatment plant. Hazardous waste will be transported offsite to permitted facilities.

Further details on the operations are provided in Section 5.2 Atmospheric Environment (Air Quality) of the Application for an Environmental Assessment Certificate.

## 3.0 INDICATOR COMPOUNDS

The assessment of air quality focused on predicting changes in the concentrations of selected indicator compounds. These indicator compounds represent compounds that are expected to be emitted from the Project, are generally accepted as indicative in changing air quality, and are compounds for which relevant air quality criteria exist. These indicator compounds include:

- Nitrogen dioxide ($NO_2$);
- Sulphur dioxide ($SO_2$);
- Carbon monoxide (CO);
- Total suspended particulate (TSP);
- Particles nominally smaller than 10 micrometres (µm) in diameter ($PM_{10}$); and
- Particles nominally smaller than 2.5 µm in diameter ($PM_{2.5}$).

Additional compounds that may be emitted from the Project have not been selected as indicator compounds. To address these other compounds, five (5) chemically similar groups of compounds namely volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), hydrogen sulphide and hazardous air pollutants ($H_2S$, HAPS) and metals were included in the dispersion modelling effort. Model predictions for other compounds were provided to the human health discipline, the effects of the other compounds will be addressed in the human health assessment, refer to Appendix 9.2.2-5 - Air Quality Screening of Section 9.2.2 Human Health and Risk Assessment of the Application for an Environmental Assessment Certificate.

## 4.0 EMISSION SOURCE ACTIVITIES

The air quality assessment will be limited to the operation phase of the Project as it is expected that this phase will likely result in the highest overall changes to air quality. However, indicator and other compound emission rates for the construction phase of the Project have been quantified and presented for comparison purposes to further support the assumption that the changes to Air Quality will be greater in the operation phase than the other phases.

Activities resulting in emissions during the construction phase include:

- **Landfill**- Two closed landfills are located on-site. The landfills are historic facilities and were operational earlier on in the site's history when it was a site for a pulp mill. Due to the nature of material decomposition within the landfills, the landfills will emit other compounds during the operation, construction and decommissioning phases of the Project;
- **Non-road engines (vehicle exhaust)**- On-site construction equipment will include excavators, pumps, power generators, dump trucks, cranes, forklifts, graders, and loaders. A majority of the construction equipment will use diesel engines and the operation of these equipment will results in emissions of indicator and other compounds as a result of diesel combustion;
- **Material handling (drops)**- Material such as soil, gravel and overburden will be moved and handled during the construction phase, this material movement would result in the release of fugitive particulate emissions (TSP, $PM_{10}$ and $PM_{2.5}$);
- **Excavating (Bulldozing)**- Bulldozing operations will result in the release of fugitive particulate emissions (TSP, $PM_{10}$ and $PM_{2.5}$);
- **Grading**- Surface grading will result in in the release of fugitive particulate emissions (TSP, $PM_{10}$ and $PM_{2.5}$); and
- **Marine Traffic**- Marine vessels will be used to transport crew and fuel from Squamish to the Project. The operation of these vessels would result in emissions of indicator and other compounds as a result of fuel combustion.

During the operation phase of the Project, emission activities will operate under two schemes: normal operation and upset conditions. Normal operation conditions are considered the conditions under which the facility will operate for the vast majority of the time. Upset conditions are abnormal conditions where flaring of natural gas may take place.

Based on the Project description, as described in Section 2.0, emission activities and sources are listed below:

- **Amine incinerator**- An amine treatment process will be used in for the removal of acid gas (e.g., carbon dioxide [CO2] and other sulphur compounds) contained in the feed gas prior to compression and refrigeration. A thermal oxidizer or incinerator will oxidize the sulphur compounds into a more stable and less toxic form (e.g., sulphur dioxide [SO2]) before releasing them into the atmosphere. The thermal oxidation process will result in the emission of indicator and other compounds;
- **Process combustion**- Process heat requirement at the Project facility will be provided by a hot oil heater. The heater will burn natural gas, thus resulting in the emission of indicator and other compounds;
- **Flare pilots**- All emergency flare stacks at the Project will have a pilot flame that will burn all the time to ensure that relieved gases will be ignited during emergency. The pilot flame is sustained by burning of natural gas, and this will result in the emission of indicator and other compounds;
- **Fugitive emissions**- There is potential for other compound emission releases during the LNG process that cannot be attributable to a specific location, known as fugitive emissions. Fugitive emissions occur over a general area and emissions may be the result of losses from pipe fittings, filling and empting of storage vessels, and release of remnant gases in a flare or a stack. Well managed and newly built facilities can limit the fugitive emission releases but cannot entirely eliminate them with current best management practices and technology;
- **Combustion from HVAC equipment**- Natural gas combustion equipment is used to provide comfort heating to the facility for approximately 6 months of the year. Combustion of natural gas will result in the release on indicator and other compounds;
- **Marine vessel exhaust**- Passenger ferries and water taxies will travel between Squamish and the Project daily to transport employees. An LNG Tanker will be stationed at the facility, with an auxiliary engine running, as part of the LNG storage and shipping operations. Emission from these marine vessels will be indicator compounds due to the combustion of fuel;
- **Landfill-** Two closed landfills are located on-site. The landfills are historic facilities and were operational earlier on in the site's history. Due to the nature of material decomposition within the landfills, the landfills will emit other compounds during the operation, construction and decommissioning phases of the project;
- **Emergency Generators**- When power is unavailable at the facility emergency generators will be used to meet power demands. Emissions from emergency generators will result in the combustion of diesel and the release of indicator and other compounds; and
- **Flaring**- During upset conditions process gas will be flared. Emissions from flaring will be as a result of the combustion of process gas and the release of indicator and other compounds.

A breakdown of which sources are operational in each of the scenarios is provided in Table 1, below:

**Table 1: Summary of Modelling Scenarios**

| Emission Sources | Normal Operation | Upset Conditions |
|---|---|---|
| Amine Incinerator | X | |
| Process Combustion | X | |
| Flare Pilots | X | |
| Fugitive Emissions | X | X |
| HVAC | X | X |
| Marine vessels | X | X |
| Landfills | X | X |
| Emergency generators | | X |
| Flares | | X |

## 5.0 EMISSIONS ESTIMATION

Activities that generate indicator and other compound emissions were identified in Section 4.0. Emission rates for the various emission activities will be calculated using a combination of the following methods:

1) Engineering Calculations from WLNG with a 20% contingency factor applied to the mass emission rate;

*2)* Methodology from *2005 - 2006 BC Ocean-Going Vessel Emissions Inventory (The Chamber of Shipping 2007);*

3) Methodology from IPCC Good Practice Guidance and Uncertainty Management in Natural Greenhouse Gas Inventories Document “Fugitive Emissions from Oil and Natural gas Activities”;

4) Emissions calculated using the US EPA LANDGEM Model for MSW Landfills (US EPA);

5) Methodology and emission factors taken from relevant chapters of the US EPA AP42 documents, in particular:

   a) US EPA (1998) AP-42 Chapter 11.9 Western Surface Coal Mining; and

   b) US EPA (2006) AP-42 Chapter 13.2.4 Aggregate Handling and Storage Piles.

6) Methodology and emission factors from Exhaust and Crankcase Emission Factors for Non-road Engine Modelling – Compression Ignition, (US EPA 2010).

The detailed emission sources, substances emitted and the reference methodology for emission rate calculations (as listed above) are provided in Table 2.

**Table 2: Emission Activities, Substances Emitted and Basis of Calculation**

| Scenario | Source | Description | Variable | Basis of Emissions |
|---|---|---|---|---|
| Construction | Landfill | Fugitive Emissions | VOCs, PAHs, H2S HAPS | (4) |
| | Non-Road Engines | Exhaust Emissions | NOx, CO, $SO_2$, TSP, $PM_{10}$, $PM_{2.5}$, VOCs, PAHs, Metals | (6) |
| | Material Handling | Fugitive Emissions | TSP, $PM_{10}$, $PM_{2.5}$ | (5) |
| | Excavation | Fugitive Emissions | TSP, $PM_{10}$, $PM_{2.5}$ | (5) |
| | Grading | Fugitive Emissions | TSP, $PM_{10}$, $PM_{2.5}$ | (5) |
| | Marine Vessel Exhausts | Exhaust Emissions | NOx, CO, $SO_2$, TSP, $PM_{10}$, $PM_{2.5}$, VOCs, PAHs, Metals | (2) |
| Normal Operation | Landfill | Fugitive Emissions | VOCs, PAHs, H2S HAPS | (4) |
| | Amine Unit Incinerator | Exhaust Emissions | NOx, CO, $SO_2$, TSP, $PM_{10}$, $PM_{2.5}$, VOCs, H2S HAPS | (1) |
| | Process Combustion | Exhaust Emissions | NOx, CO, $SO_2$, TSP, $PM_{10}$, $PM_{2.5}$, VOCs, H2S HAPS | (1) |
| | Flare Pilots | Exhaust Emissions | NOx, CO | (1) |
| | Fugitive Emissions from LNG Facility | Fugitive Emissions | VOCs, PAHs, $H_2S$ HAPS | (3) |
| | Combustion from HVAC equipment | Exhaust Emissions | NOx, CO, | (1) |
| | Marine Vessel Exhausts | Exhaust Emissions | NOx, CO, $SO_2$, TSP, $PM_{10}$, $PM_{2.5}$, VOCs, PAHs, Metals | (2) |
| Upset Conditions | Landfill | Fugitive Emissions | VOCs, PAHs, H2S HAPS | (4) |
| | Fugitive Emissions from LNG Facility | Fugitive Emissions | VOCs, PAHs, $H_2S$ HAPS | (3) |
| | Combustion from HVAC equipment | Exhaust Emissions | NOx, CO, | (1) |
| | Marine Vessel Exhausts | Exhaust Emissions | NOx, CO, $SO_2$, TSP, $PM_{10}$, $PM_{2.5}$, VOCs, PAHs, Metals | (2) |
| | Emergency Generators | Exhaust Emissions | NOx, CO, $SO_2$, TSP, $PM_{10}$, $PM_{2.5}$, VOCs, PAHs, Metals | (1) |
| | Flaring | Exhaust Emissions | NOx, CO, TSP, $PM_{10}$, $PM_{2.5}$, VOCs, | (1) |

The following sections describe the emission calculation approaches for the identified emission activities.

## 5.1 Landfill

The facility has two historic and closed landfills. Neither landfill is equipped with a landfill gas collection system but both may still produce fugitive emissions through the capping. Emission rates for the two landfills were calculated using the US EPA LandGEM model (US EPA, 2005). LandGEM is a Landfill Gas Emissions Model which was developed by the US EPA to estimate air pollutants and other gases from municipal solid waste operations. Inputs to the model include annual waste tonnages from the year of opening to closure which were estimated based on the total volume of the landfill, a waste density of 625 kg/m³ and the number of operating years. BC MoE defaults for the methane generation rate constant and methane generation potential were also used. A summary of the input data used for each landfill is included in Table 3.

**Table 3: LandGEM Inputs**

| Landfill | Area [m²] | Depth [m] | Year Opened | Year Closed | Methane Generation Rate Constant [1/yr] | Methane Generation Potential [m³/tonne] | NMOC as Hexane (ppmv) |
|---|---|---|---|---|---|---|---|
| Pre 1992 | 16,000 | 10 | 1975 | 1991 | 0.02 | 230 | 8000 |
| Post 1992 | 29,000 | 10 | 1991 | 2007 | 0.02 | 230 | 8000 |

The landfill gas emissions produced by each landfill were indicated to be on the decline. Therefore, emission rates for 2014, the current year, were used for conservatism. A summary of the daily emission rates from the landfills are provided in Table 4.

**Table 4: Maximum Daily Emission Rates from the Landfill**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_x$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Landfill | — | — | — | — | — | — | 0.0113 | — | <0.0001 | 0.0006 |

## 5.2 Non-Road Diesel Engines

Various diesel powered surface equipment will be used within the Project site during construction. During the Project's construction phase, surface equipment that will be used will include haul trucks, forklifts, graders, an excavator, and a loader. These vehicle emissions are expected to occur as a result of land clearing and site preparation activities. Emission rates for all vehicular exhaust were calculated using the same method as US EPA NONROAD model. NONROAD uses the emission factors provided in documents published by US EPA (2004a, 2004b, 2010). TSP emission was assumed to be the same as that of $PM_{10}$. The general equation used for calculating indicator and other compound emissions rates is as follows:

$$ER = EF \times Horsepower\ Rating \times LF \times time \times UC_3$$

Where:

- $ER$ = emission rate (tonne/day);
- $EF$ = emission factor (g/hp-hr);
- $Horsepower\ Rating$ = the output power of engine used (hp);
- $LF$ = load factor (unitless);
- $time$ = time that the engine is in operation (hours); and
- $UC_3$ = unit conversion factor to equate the unit of time and mass.

The calculation method follows that of US EPA NONROAD model for selecting the appropriate emission factors and load factors. Emission factors vary depending on the substance of interest, the sulphur content of the fuel, the emission type, the equipment type, and the equipment model year. The emission factors are found using the methods in Exhaust and Crankcase Emission Factors for NONROAD Engine Modeling – Compression Ignition – Report No. NR-009c (US EPA 2004a). Load factor was determined by the type of equipment defined in Median Life, Annual Activity, and Load Factor Values for NONROAD Engine Emissions Modeling – Report No. NR-005c (US EPA 2004b). It was conservatively assumed that all construction equipment will operate 24 hours per day during the construction phase. A summary of the diesel construction equipment to be used at the Facility is provided in Table 5, below:

**Table 5: Construction Equipment Fleet Details**

| Equipment Description | Model Year | Fuel Type | Horsepower | Number of Vehicles |
|---|---|---|---|---|
| Excavator | 2010 | Diesel | 200 | 3 |
| Dump Trucks | 2010 | Diesel | 330 | 5 |
| Cranes | 2010 | Diesel | 320 | 3 |
| Cherry Pickers | 2010 | Diesel | 26 | 4 |
| Fork Lift Trucks | 2010 | Diesel | 111 | 4 |
| Concrete Delivery Trucks | 2010 | Diesel | 350 | 5 |
| Concrete Pumps | 2010 | Diesel | 100 | 2 |
| HGVs (delivering and collecting) | 2010 | Diesel | 350 | 3 |
| Pickup Trucks | 2010 | Diesel | 300 | 8 |
| Flat Bed Trucks | 2010 | Diesel | 100 | 3 |
| Compressors | 2010 | Diesel | 100 | 4 |
| Sump Pumps | 2010 | Diesel | 90 | 4 |
| Generators | 2010 | Diesel | 350 | 6 |
| Water Truck | 2010 | Diesel | 100 | 1 |
| Flatbed Truck with Hydraulic Hoist | 2010 | Diesel | 100 | 2 |
| Boom Truck | 2010 | Diesel | 100 | 2 |
| Grader | 2010 | Diesel | 230 | 1 |
| Paving Machine | 2010 | Diesel | 225 | 1 |
| Skid Steer Loader | 2010 | Diesel | 100 | 1 |
| Vibrator Compactor | 2010 | Diesel | 250 | 1 |

A summary of the daily emission rates from non-road diesel engines are provided in Table 6.

**Table 6: Maximum Daily Emission Rates from Non-Road Diesel Engines**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_x$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Non-Road Engines | 0.3620 | <0.0001 | 0.1479 | 0.0279 | 0.0279 | 0.0271 | 0.0271 | <0.0001 | <0.0001 | <0.0001 |

## 5.3 Material Handling

Soil, gravel and overburden material will be handled and transferred by a loader as part of construction emissions; this handling will result in the release of particulate emissions. All material handling emissions are calculated using the method outlined in AP-42 Chapter 13.2.4 Aggregate Handling and Storage Piles (US EPA 2006). The emission factor calculation is listed below:

$$EF = k \times (0.0016) \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

- $EF$ = the emission factor (kg/tonne);
- $k$ = the particle size multiplier (dimensionless);
- $U$ = the mean wind speed (m/s); and
- $M$ = the material moisture content (%).

And the emission rate equation is:

$$ER = EF \times M_h \times \left(1 - \frac{CE}{100}\right) \times UC$$

Where:

- $ER$ = the emission rate (tonne/day);
- $M_h$ = the material handled (tonne/day);
- $CE$ = the control efficiency of the dust control technique (unitless); and
- $UC$ = the unit conversion factor to equate the mass unit (tonne/kg).

The amount of material handled per day by each dump truck and the loader was estimated assuming that each dump truck carries material at a capacity of 6 tonnes per hour and all material is moved by loader.

To obtain representative local wind speed data, Port Mellon meteorological station's hourly wind record over five years period (2008-2012) was used to calculate the maximum daily average wind speed. The Port Mellon meteorological station is operated by Environment Canada.

The particle size multipliers are provided in AP-42 Chapter 13.2.4 – Aggregate Handling and Storage Piles (US EPA 2006), the particle size multipliers are presented in Table 7.

**Table 7: Particle size multipliers for Material Handling**

| Description | Value |
|---|---|
| TSP ≤ 30 µm, unitless | 0.74 |
| $PM_{10}$, unitless | 0.35 |
| $PM_{2.5}$, unitless | 0.053 |

The moisture content of the material handled was assumed to be that of "exposed ground" listed in the AP-42 chapter.

A summary of the daily emission rates from material handling are provided in Table 8, below

**Table 8: Maximum Daily Emission Rates from Material Handling**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_x$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Material Handling | — | — | — | 0.0016 | 0.0008 | 0.0001 | — | — | — | — |

## 5.4 Excavating

Excavating activities will be undertaken during the construction phase by three excavators, this activity is expected to result in fugitive particulate emissions. Fugitive particulate emissions from bulldozing were quantified using the method detailed in AP-42 Chapter 11.9 Western Surface Coal Mining (US EPA 1998). The emission factors for $TSP_{30}$ and particulate nominally smaller than 15 µm in diameter ($TSP_{15}$) were calculated as follows:

$$EF = \frac{a \times s^b}{M^c}$$

Where:

- $EF$ = the emission factor for particulates (kg/hour/equipment);
- $s$ = the silt content of the material handled (% weight);
- $M$ = the material handled moisture content (% weight);
- $a$ = empirical constant (unitless);
- $b$ = empirical constant (unitless); and
- $c$ = empirical constant (unitless).

The empirical constants (a,b,c) used for $TSP_{30}$ and $TSP_{15}$ are presented in Table 9.

**Table 9: $TSP_{30}$ and $TSP_{15}$ Empirical Constants**

| Constant | $TSP_{30}$ | $TSP_{15}$ |
|---|---|---|
| A | 2.6 | 0.45 |
| B | 1.2 | 1.5 |
| C | 1.3 | 1.4 |

Scaling factors taken from AP-42 Chapter 11.9 Western Surface Coal Mining (US EPA 1998) are used to convert $TSP_{30}$ emission to $PM_{10}$, and $TSP_{15}$ emission to $PM_{2.5}$.and are summarized in Table 10, below.

**Table 10: Scaling Factors for $PM_{10}$ and $PM_{2.5}$**

| | $PM_{10}$ from $TSP_{15}$ | $PM_{2.5}$ from $TSP_{30}$ |
|---|---|---|
| Scaling Factor | 0.75 | 0.105 |

The equation used to calculate the particulate emission rates is as follows:

$$ER = EF \times p \times h \times UC$$

Where:

- $ER$ = the emission rate (tonne/day);
- $p$ = the number of pieces of equipment (equipment);
- $h$ = the daily operating hours (hours/day); and
- $UC$ = the unit conversion factor to equate the mass unit (tonne/kg).

The mean silt and moisture content of overburden, provided in AP-42 Chapter 13.2.4, Table 13.2.4-1 (US EPA 2006), was assumed to be the silt and moisture content of the overburden handled at the Project.

During the land clearing the excavators' engines are assumed over the entire operating day. However, the equipment is not expected to be bulldozing the entire time. Therefore, a utilization factor of 80% was assumed, and applied bulldozing fugitive particulate to emissions.

A summary of the daily emission rates from excavation are provided in Table 11.

**Table 11: Maximum Daily Emission Rates from Excavation**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_x$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Excavation | — | — | — | 0.3424 | 0.0720 | 0.0360 | — | — | — | — |

## 5.5 Grading

Grading activities will be undertaken during the construction phase by the grader and the compactor, this activity is expected to result in fugitive particulate emissions. Fugitive particulate emissions from grading were quantified using the method detailed in AP-42 Chapter 11.9 Western Surface Coal Mining (US EPA 1998b). The emission factors for $TSP_{30}$ and particulate nominally smaller than 15 µm in diameter ($TSP_{15}$) were calculated as follows:

$$EF = dS^{2.5}$$

Where:

- $EF$ = the emission factor for particulates (kg/VKT);
- S= the mean vehicle speed (km/h), assumed to be 5km/h; and
- $d$ = the particle size multiplier (dimensionless).

The empirical constant, d used for $TSP_{30}$ and $TSP_{15}$ are presented in Table 12.

**Table 12: $TSP_{30}$ and $TSP_{15}$ Empirical Constants**

| Constant | $TSP_{30}$ | $TSP_{15}$ |
|---|---|---|
| d | 0.0034 | 0.0056 |

Scaling factors in Table 13 are used to convert $TSP_{30}$ emission to $PM_{10}$, and $TSP_{15}$ emission to $PM_{2.5}$.

**Table 13: Scaling Factors for $PM_{10}$ and $PM_{2.5}$**

| | $PM_{10}$ from $TSP_{15}$ | $PM_{2.5}$ from $TSP_{30}$ |
|---|---|---|
| Scaling Factor | 0.6 | 0.031 |

The equation used to calculate the particulate emission rates is as follows:

$$ER = EF \times VKT \times p \times UC$$

Where:

- $ER$ = the emission rate (tonne/day);
- $VKT$ = the daily distance travelled by the grader (km);
- $p$ = the number of pieces of equipment; and
- $UC$ = the unit conversion factor to equate the mass unit (tonne/kg).

The grader and compactor were assumed to be operating continuously during construction at a speed of 5 km/h.

A summary of the daily emission rates from Grading are provided in Table 14.

**Table 14: Maximum Daily Emission Rates from Grading**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_x$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Grading | — | — | — | 0.0456 | 0.0336 | 0.0202 | — | — | — | — |

## 5.6 Marine Vessels

The facility is situated in Howe Sound. As such, various marine vessels are used to transport equipment, employees and material off-site. A summary of the vessels used at the site and their approximate frequency is given in Table 15.

**Table 15: Marine Vessels**

| Vessels | Frequency | Maximum Power (kW) | Average Speed [km/h] | Maximum Speed [km/h] |
|---|---|---|---|---|
| LNG tanker | 1 LNG tanker makes 3.5 trips per month during construction. LNG tanker loading takes 24 hours | 2,000 Auxiliary Engine (while Loading)<br>34,000 (underway mode)<br>9,000 (manoeuvering) | 0 (while loading)<br>22.2(in transit) | 0 (while loading)<br>38.9 (in transit) |
| LNG Tanker Tug Boats | 3 tugs which accompany the LNG tanker on its 3.5 trips per month | 7456 each | 15.6 | 28.7 |
| Passenger Ferry | 3 times per day | 4,400 | 24.4 | 34.1 |
| Water Taxi | 10 trip per week | 400 | 37.0 | 55.6 |
| Fuel Barge | 1 trip per week during construction | N/A – Pulled by Tug | N/A | N/A |
| Fuel Barge Tug | 1 trip per week during construction | 2,088 | 12.8 | 16.5 |
| Crew boat | 3 trips per day during construction | 1,194 | 42.6 | 50 |

The marine vessel emissions includes indicator and other compounds  The exhaust emission from the Project related vessels from the Project site to Squamish were calculated using the method outlined in *2005 – 2006 BC Ocean-Going Vessel Emissions Inventory* (The Chamber of Shipping 2007).  Within The Chamber of Shipping (2007) marine vessels are categorized as travelling in two modes: underway mode; and maneuvering mode. Emission factors are based on the operation mode of the vessel.

Maximum daily emissions from the LNG tanker occur when it is being loaded at the port over a 24 hour period. As a result, the modelled scenario does not include LNG carrier transit or LNG tanker tug boats as these activities do not occur simultaneously with LNG tanker loading. Emission estimates are provided below however, for comparison.

The equipment necessary to provide shore power to LNG carriers will be installed. However, in the current LNG tank fleet, the ability to use this equipment is very low. WLNG will influence the ships chartered to install the equipment to be able to use shore power. For the purpose of this assessment, it was assumed that no shore power to LNG tankers will be available and that diesel auxiliary engine on board of the LNG carriers will be running. This assumption is very conservative if onshore power will be available or the LNG tankers will use LNG rather than diesel as the primary fuel for the auxiliary engines. Tanker loading will take 24 hours, therefore travel of the tanker which would be accompanied by three tugs from Squamish to the facility were not included in the modelling assessment as it is more conservative to model 24-hour operation of the auxiliary engine.

It was assumed that the vessels would be in maneuvering mode approximately 10% of the total travel time, and in underway mode for the remaining 90% of the time. The emission rates of particulates, $SO_X$, CO and $NO_X$ are calculated using the equation below:

$$ER = P \times EF \times LF \times T \times UC$$

Where:

- $ER$ = the emission rate (g/duration of travel);
- $P$ = the engine power at maximum continuous rating (kW);
- $EF$ = the emission factor (g/kWh);
- $LF$ = the load factor (%);
- $T$ = the duration of travel per day (hour/day); and
- $UC$ = the unit conversion factor to equate the volume and mass (tonne/kg).

The emissions factors for $NO_X$, in both underway mode and maneuvering mode are provided in The Chamber of Shipping (2007). Similarly, the emission factor for $PM_{10}$ and $PM_{2.5}$ in maneuvering mode was provided The Chamber of Shipping (2007). The emissions factors for particulate matter (TSP, $PM_{10}$ and $PM_{2.5}$) for underway mode are a function of brake specific fuel consumption (BSFC) and the sulphur content within the fuel. The emission factor for $SO_X$, in both underway mode and maneuvering mode are a function of the sulphur content within the fuel. Table 16 and Table 17 summarize the emission factors used to calculate the emission rates. It was assumed that the calculated $SO_X$ emissions represented $SO_2$, and the calculated $NO_X$ emissions represented $NO_2$.

**Table 16: Emission Factors for Marine Vessel Emissions- Underway Mode**

| | $NO_X$ | $SO_X$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | HC |
|---|---|---|---|---|---|---|---|
| Slow Vessel – Underway Mode | 17.00 | 4.2S | 1.1 | 0.23 (large vessels)<br>0.20 (smaller vessels) | 0.23 (large vessels)<br>0.20 (smaller vessels) | 0.20 (large vessels)<br>0.18 (smaller vessels) | 0.6 |
| Medium Vessel – Underway Mode | 13.2 | 4.2S | 1.1 | 0.23 | 0.23 | 0.20 | 0.5 |

| | $NO_X$ | $SO_X$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | HC |
|---|---|---|---|---|---|---|---|
| Fast Vessel – Underway Mode | 12 | 4.2S | 1.1 | 0.20 | 0.20 | 0.18 | 0.2 |
| Comment | 2005-2006 BC Ocean-Going Vessel Emissions Inventory | S represents the sulphur content of the fuel in %. | 2005-2006 BC Ocean-Going Vessel Emissions Inventory | Assumed to be same as $PM_{10}$ | Calculated from sulphur content and BSFC | 90% of $PM_{10}$ | 2005-2006 BC Ocean-Going Vessel Emissions Inventory |

**Table 17: Emission Factors for Marine Vessel Emissions - Maneuvering Mode**

| | $NO_X$ | $SO_X$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | HC |
|---|---|---|---|---|---|---|---|
| Slow Vessel – Maneuvering Mode | 49.64 | 12.26S | 7.34 | 0.29 (large vessels) 0.20 (smaller vessels) | 0.29 (large vessels) 0.20 (smaller vessels) | 0.26 (large vessels) 0.18 (smaller vessels) | 10.33 |
| Medium Vessel – Maneuvering Mode | 38.54 | 12.26S | 7.34 | 0.30 | 0.30 | 0.27 | 8.61 |
| Fast Vessel – Maneuvering Mode | 35.04 | 12.26S | 7.34 | 0.20 | 0.20 | 0.18 | 3.44 |
| Comment | 2005-2006 BC Ocean-Going Vessel Emissions Inventory | S represents the sulphur content of the fuel in %. | 2005-2006 BC Ocean-Going Vessel Emissions Inventory | Assumed to be same as $PM_{10}$ | Calculated from sulphur content and BSFC | 90% of $PM_{10}$ | 2005-2006 BC Ocean-Going Vessel Emissions Inventory |

**Table 18: Emission Factors for Auxiliary Engines**

| | $NO_X$ | $SO_X$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | HC |
|---|---|---|---|---|---|---|---|
| Auxiliary Engines | 13.9 | 4.2 | 1.1 | 0.24 | 0.24 | 0.22 | 0.4 |
| Comment | 2005-2006 BC Ocean-Going Vessel Emissions Inventory | S represents the sulphur content of the fuel in %. | 2005-2006 BC Ocean-Going Vessel Emissions Inventory | Assumed to be same as $PM_{10}$ | Calculated from sulphur content and BSFC | 90% of $PM_{10}$ | 2005-2006 BC Ocean-Going Vessel Emissions Inventory |

A fuel sulphur content of 0.1% was assumed for fuel in large vessels and 0.0015% for smaller vessels as per the Sulphur in Diesel fuel Regulations (Department of Justice, 2012). The brake specific fuel consumption is provided in The Chamber of Shipping (2007).

A summary of the daily emission rates from each of the different marine vessels is provided in Table 19.

**Table 19: Maximum Daily Emission Rates from Marine Vessels**

| Vessel | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_x$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| LNG tanker (loading) | 0.6672 | 0.0202 | 0.0528 | 0.0113 | 0.0113 | 0.0102 | 0.0192 | 0.0003 | 0.0001 | — |
| LNG tanker (transit)[1] | 0.2042 | 0.0065 | 0.0171 | 0.0036 | 0.0036 | 0.0032 | 0.0079 | 0.0001 | <0.0001 | — |
| LNG tanker tug boats[1] | 0.2768 | 0.0068 | 0.0182 | 0.0037 | 0.0037 | 0.0033 | 0.0103 | 0.0002 | <0.0001 | — |
| Passenger Ferry | 0.0242 | 0.0008 | 0.0021 | 0.0004 | 0.0004 | 0.0004 | 0.0010 | <0.0001 | <0.0001 | — |
| Water Taxi | 0.0026 | <0.0001 | 0.0002 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | — |
| Fuel Barge (Construction only) | — | — | — | — | — | — | — | — | — | — |
| Fuel Barge Tug (Construction only) | 0.0283 | <0.0001 | 0.0019 | 0.0003 | 0.0003 | 0.0003 | 0.0011 | <0.0001 | <0.0001 | — |
| Crew boat (Construction only) | 0.0103 | <0.0001 | 0.0010 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | <0.0001 | <0.0001 | — |

**Notes: 1. Not modelled**

## 5.7 Amine Incinerator

The amine incinerator is the only source of emissions to the atmosphere from the sour gas removal system. Emission rates for the amine incinerator were provided by WLNG from a series of engineering calculations with a 20% contingency added to the mass emission rates for conservatism. Emission rates were provided in g/s on a worst case 1-hour basis and then converted to tonnes/day based on 24 hour operation of the amine incinerator.

A summary of the daily emission rates from the Amine Incinerator is provided in Table 20.

**Table 20: Maximum Daily Emission Rates from Amine Incinerator**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | NOx | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Amine Incinerator | 0.0912 | 0.0581 | 0.0135 | 0.0012 | 0.0012 | 0.0012 | 0.0039 | — | — | <0.0001 |

## 5.8 Process Combustion

Process combustion equipment includes a hot oil heater. Emission rates for the hot oil heater were provided by WLNG from a series of engineering calculations with a 20% contingency added to the mass emission rates for conservatism. Emission rates were provided in g/s on a worst case 1-hour basis and then converted to tonnes/day based on 24 hour operation of the equipment.

A summary of the daily emission rates from process combustion emissions is provided in Table 21, below

**Table 21: Maximum Daily Emission Rates from Process Combustion Emissions**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | NOx | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Hot Oil Heater | 0.0280 | 0.0405 | 0.0399 | 0.0020 | 0.0020 | 0.0020 | 0.0014 | — | — | <0.0001 |

## 5.9 Flares (Pilot and Flaring)

The facility has a single flare system with four flare stacks which are used during upset conditions or maintenance activities to flare natural gas. The flares are only used in this manner for short periods of less than 24 hours at a time. During normal operation of the facility (i.e. no maintenance), the flares operate on a pilot system. Emissions from the flares both in full operation (Table 22) and from the pilot operation were provided based on engineering calculations by Linde, the flare manufacturer with a 20% contingency added to the mass emission rate. For the pilot operation, emission rates were provided in grams per second (g/s) on a continuous gas consumption rate of 12.5 kg/hour.

The flare specifications for each of the flares modelled at the Facility are included in Table 22. Note that Flaring of LPWF was not modelled for the upset case, because the four flares is one system, and when flaring, at any given time, only one stack will be flaring. Table 22 provides a description of when these stacks would be flaring.

**Table 22: Flaring Parameters**

| Flare | Flaring Condition | Exhaust Rate [kg/hr] | HHV [BTU/lb] | Molecular Weight [kg/mol] | Estimated Max Daily operating time [hour] | Estimated annual operating time [hour] |
|---|---|---|---|---|---|---|
| WWGF | Depressuring feed gas | 256,000 | 21,039 | 16.9 | 0.5 | 1 |
| LPCF | Shut down Tank RG | 80,000 | 17,382 | 17.7 | 14 | 28 |
| CDGF | Major Maintenance of MR Compressor Unit | 760,000 | 19,099 | 30.1 | 0.5 | 1 |
| LPWF | Not Modelled | | | | | |

Upset flaring was modelled as a worst case scenario with maximum gas throughput and all three flares flaring natural gas simultaneously.

A summary of the daily emission rates from Flaring emissions is provided in Table 23.

**Table 23: Maximum Daily Emission Rates from Flaring**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_x$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Flare WWGF (Pilot) | <0.0001 | — | <0.0001 | — | — | — | — | — | — | — |
| Flare LPCF (Pilot) | <0.0001 | — | <0.0001 | — | — | — | — | — | — | — |
| Flare CDGF (Pilot) | <0.0001 | — | <0.0001 | — | — | — | — | — | — | — |
| Flare LPWF (Pilot) | <0.0001 | — | <0.0001 | — | — | — | — | — | — | — |
| Flare WWGF (Depressuring Feed Gas) | 0.0918 | — | 0.4977 | 0.0022 | 0.0022 | 0.0022 | 0.0838 | — | — | — |
| Flare LPCF (Shut down Tank RG) | 1.3205 | — | 7.1971 | 2.8073 | 2.8073 | 2.8073 | 0.2660 | — | — | — |
| Flare CDGF (Major Maintenance of MR Compressor Unit) | 0.2468 | — | 1.3427 | 0.4734 | 0.4734 | 0.4734 | 2.8005 | — | — | — |

## 5.10 Fugitive Emissions

Fugitive emissions of natural gas are expected to be emitted from both the process equipment and the FSO. It is in the interest of Woodfibre to actively mitigate fugitive losses of product; therefore, the facility will be constructed to use new equipment and regular equipment maintenance will be performed. In order to quantify the estimated percentage, the IPCC Good Practice Guidance and Uncertainty Management in Natural Greenhouse Gas Inventories (IPCC, 2001), was used. Section 2.6 of this report relates to fugitive emissions from natural gas activities and gives low, medium and high anticipated gas loses for different types of natural gas facilities. The facility will be new and well managed but for conservatism, the “medium” gas loss percentage for LNG plants was used. This equates to an assumption of 0.05% of the total throughput assumed to be released fugitively from the facility. This percentage was therefore applied to the daily gas throughput of 290 million standard cubic feet per day (MMSCFD) or 338,333 m³/hour to estimate the total releases to atmosphere using the equation below:

$$ER = T \times P$$

Where:

- $ER$ = the emission rate (g/m³/day);
- $T$ = facility throughput (m³/day); and
- $P$ = percentage lost fugitively (assumed to be 0.05%).

Weekly feed gas sampling data for June 2013-December 2013 from a Squamish Gate Station Gas analysis was then averaged and used to speciate the different indicator and other compounds.

A summary of the daily emission rates from Fugitive emissions is provided in Table 24.

**Table 24: Maximum Daily Emission Rates from Fugitive Emissions**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | NOx | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Fugitive Emissions | — | — | — | — | — | — | 0.0005 | <0.0001 | — | <0.0001 |

## 5.11 Combustion from HVAC Equipment

Natural gas combustion equipment is used to provide comfort heating to the Facility for approximately 6 months of the year. Emission rates were provided by WLNG with a 20% contingency added to the mass emission rate and then converted to tonnes per day assuming 24hour operation.

A summary of the daily emission rates from HVAC equipment is provided in Table 25.

**Table 25: Maximum Daily Emission Rates from HVAC Emissions**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_x$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| HVAC | <0.0001 | — | 0.0002 | — | — | — | — | — | — | — |

## 5.12 Emergency Power Generators

The facility has three backup generators which are used to provide power during upset operations. All generators will be compliant with Canadian Tier 4 emission standards, which are the most stringent emission regulations for off-road compression ignition engines. Emission rates for the generators were provided by WLNG from a series of engineering calculations with a 20% contingency added to the mass emission rates for conservatism. Emission rates were provided in g/s on a worst case 1 hour basis and then converted to tonnes/day based on 12 hour operation.

A summary of the daily emission rates from Emergency Power is provided in Table 26.

**Table 26: Maximum Daily Emission Rates from Emergency Power Generators**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_x$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| EPG1 | 0.0303 | — | 0.0063 | 0.0004 | 0.0004 | 0.0004 | 0.0008 | <0.0001 | <0.0001 | — |
| EPG2 | 0.0237 | — | 0.0012 | 0.0012 | 0.0012 | 0.0012 | 0.0002 | <0.0001 | <0.0001 | — |
| EPG3 | 0.2894 | 0.0052 | 0.1201 | 0.0060 | 0.0060 | 0.0060 | 0.0950 | 0.0015 | 0.0001 | — |

# 6.0 EMISSION ESTIMATE CONSERVATISM

In developing emissions for the air quality assessment, conservatism was incorporated into calculation assumptions in the following ways:

- All sources, during both the construction and operation phases, were assumed to be operating at their maximum capacity;
- 20% mass contingency added for emission rates based on engineering calculations;
- The emission calculations represent maximum daily activity levels. The maximum daily emission rate was then applied to every hour of the day irrespective of whether the source was operational for only a portion of the day. Additionally, some sources, for example the marine vessels do not operate every day but for the purpose of this assessment, the maximum daily emissions were applied to every day of the year. For example, the LNG tanker makes only 3.5 trips to the Project facility per month but for the purpose of this assessment, it was assumed to be loading every day;
- During upset conditions all upset condition sources (flares and emergency generators) were modelled operating simultaneously. During actual upset conditions all of these sources will not operate simultaneously; and
- For the construction phase, no dust control procedures were assumed for the excavating, material handling and grading operations emission activities. In reality, a typical best management practice will be followed to minimum fugitive particulate emissions from construction activities.

Based on the conservatism described above it is likely that emission rates will not exceed the rates presented in the Section 7.0. Furthermore, because of the conservatism there is a high level of confidence in emissions rates estimates.

# 7.0 SUMMARY OF EMISSION RATES

Table 27 summarizes the emission rates for the construction phase,

Table 28 summarizes the emission rates for the operation phase of the Project and Table 29 summarizes the emission rates for the upset conditions.

**Table 27: Project Construction Phase Emissions**

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_X$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Landfill | — | — | — | — | — | — | 0.0113 | — | <0.0001 | 0.0006 |
| Non-Road Engines | 0.362 | <0.0001 | 0.1479 | 0.0279 | 0.0279 | 0.0271 | 0.0271 | 0.0004 | 0.0003 | — |
| Material Handling | — | — | — | 0.0016 | 0.0008 | 0.0001 | — | — | — | — |
| Excavation | — | — | — | 0.3424 | 0.072 | 0.036 | — | — | — | — |
| Grading | — | — | — | 0.0456 | 0.0336 | 0.0202 | — | — | — | — |
| Marine Vehicle | 0.0413 | <0.0001 | 0.0031 | 0.0005 | 0.0005 | 0.0005 | 0.0013 | <0.0001 | <0.0001 | — |

| Activity | Maximum Daily Emission rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_X$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| **Total** | **0.4033** | <0.0001 | **0.151** | **0.4181** | **0.1348** | **0.0838** | **0.0397** | **0.0004** | **0.0003** | **0.0006** |

**Table 28: Project Normal Operation Phase Emissions**

| Emission Activity | Maximum Daily Emission Rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_X$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| **Landfill** | — | — | — | — | — | — | 0.0113 | <0.0001 | — | <0.0001 |
| **Amine incinerator** | 0.0912 | 0.0581 | 0.0135 | 0.0012 | 0.0012 | 0.0012 | 0.0039 | — | — | <0.0001 |
| **Process combustion** | 0.028 | 0.0405 | 0.0401 | 0.002 | 0.002 | 0.002 | 0.0014 | — | — | <0.0001 |
| **Flare pilots** | <0.0001 | — | <0.0001 | — | — | — | — | — | — | — |
| **Fugitive emission** | — | — | — | — | — | — | 0.0005 | <0.0001 | — | <0.0001 |
| **Combustion from HVAC equipment** | <0.0001 | — | 0.0002 | — | — | — | — | — | — | — |
| **Marine vessel exhaust** | 0.6941 | 0.0209 | 0.0551 | 0.0118 | 0.0118 | 0.0106 | 0.0202 | 0.0003 | 0.0001 | — |
| **Total Normal Operations** | **0.8134** | **0.1195** | **0.1089** | **0.015** | **0.015** | **0.0138** | **0.0373** | **0.0003** | **0.0001** | **0.0006** |

**Table 29: Project Upset Operation Emissions**

| Emission Activity | Maximum Daily Emission Rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator Compounds | | | | | | Other Compounds | | | |
| | $NO_X$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | H2S HAPS |
| **Landfill** | — | — | — | — | — | — | 0.0113 | <0.0001 | — | <0.0001 |
| **Fugitive emission** | — | — | — | — | — | — | 0.0005 | <0.0001 | — | <0.0001 |
| **Combustion from HVAC equipment** | <0.0001 | — | 0.0002 | — | — | — | — | — | — | — |
| **Marine vessel exhaust** | 0.6941 | 0.0209 | 0.0551 | 0.0118 | 0.0118 | 0.0106 | 0.0202 | 0.0003 | 0.0001 | — |
| **Emergency Generators** | 0.3434 | 0.0052 | 0.1276 | 0.0076 | 0.0076 | 0.0076 | 0.0961 | 0.0015 | 0.0001 | — |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Flaring** | 1.6591 | — | 9.0375 | 3.2828 | 3.2828 | 3.2828 | 3.1502 | — | — | — |
| **Total Upset Conditions** | **2.6966** | **0.0261** | **9.2204** | **3.3023** | **3.3023** | **3.3011** | **3.2783** | **0.0018** | **0.0002** | **0.0006** |

A summary of the total emissions in each phase of the Project is provided in Table 30. Construction emissions are illustrated to be typically much smaller than both normal and upset operation of the Facility, therefore construction emissions were not considered further as part of this assessment. The assessment is limited to the operation phase of the Facility only.

**Table 30: Summary of Total Emissions by phase (tonnes/day)**

| Phase | Maximum Daily Emission Rate (tonne/day) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Indicator compounds | | | | | | Other Compounds | | | |
| | $NO_X$ | $SO_2$ | CO | TSP | $PM_{10}$ | $PM_{2.5}$ | VOC | PAH | Metals | $H_2S$ HAPS |
| Construction | 0.4033 | <0.001 | 0.151 | 0.4181 | 0.1348 | 0.0838 | 0.397 | 0.0004 | 0.0003 | 0.0006 |
| Normal Operations | 0.8134 | 0.1195 | 0.1089 | 0.015 | 0.015 | 0.0138 | 0.0373 | 0.0003 | 0.0001 | 0.0006 |
| Upset Conditions | **2.6966** | **0.0261** | **9.2204** | **3.3023** | **3.3023** | **3.3011** | **3.2783** | **0.0018** | **0.0002** | **0.0006** |

Please note that emissions from the decommissioning phase have not been estimated as part of this assessment. It is anticipated that the emissions from these activities would be considerably smaller than emissions from either construction or operation of the Facility.

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# 8.0 REFERENCES

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