Appendix E1.3
Calculation Methodology for GHG

Contents

Section — Page

Attachment 1 Global Warming Potentials

Attachment 2 Emission Factors

Attachment 3 GHG Descriptions

Appendix E1.3
Calculation Methodology for GHG

E1.3.1 Stationary Source Combustion

E1.3.1.1 Description

Stationary combustion includes the following sources operated at the project location.

Category Assumptions:

- Cargo handling equipment (CHE) and construction equipment within terminal boundaries.[1]
- The fuel used for this equipment will be diesel liquefied propane gas (LPG), or liquefied natural gas (LNG).

Diesel and LPG emission factors for CO_2 were provided directly by the OFFROAD2007 emission factor program in units of grams per horsepower-hour (g/hp-hr). Diesel and LPG CH_4 emission factors were derived from the total organic gas (TOG) OFFROAD2007 emission rates per CARB's staff direction. Emission factors from the California Climate Action Registry's *General Reporting Protocol* (GRP) were used for N_2O and LNG CO_2. Originally in units of kilograms GHG per gallon fuel (kg/gal), the N_2O and CO_2 emission factors were converted to units of g/hp-hr to simplify the emission calculations. This conversion used default values of brake-specific fuel consumption (BSFC) by equipment horsepower category, from OFFROAD2007, and a fuel density value from the GRP. The emission factor conversion from kg/gal to g/hp-hr is shown in Table E1.3-7.

E1.3.1.2 Equations

E1.3.1.2.1 Mass Emissions Estimates

General Equation:

Total Emissions = Emission Factor (g GHG/hp-hr)
× Work Produced (hp-hr)
× 0.000001 (metric tons per gram)

Example:

Given: Equipment power output of 140,000 hp-hr per year

Total Emissions CO_2 *= 568.3 (g* CO_2 */hp-hr) [from Table E1.3-7]*
× 140,000 (hp-hr/year)
× 0.000001 (metric tons per gram)

Total Emissions CO_2 *= 79.6 metric tons*

[1] Although most CHE sources are mobile, they are classified as stationary for the purposes of GHG reporting because they remain onsite.

E1.3.1.2.2 Converting Mass Estimates to Carbon Dioxide Equivalent (CO_2e)

General Equation:

Metric Tons of CO_2e = Metric Tons of GHG × GWP
Global warming potentials (GWPs) are listed in Table E1.3-1.

Example:

Given: GHG Emission Rate = 0.014 metric tons of CH_4;
GWP = 21 (from Table E1.3-1)
Metric Tons of CO_2e = Metric Tons of GHG × GWP
Metric Tons of CO_2e = 0.014 Metric Tons of Methane × 21
Metric Tons of CO_2e = 0.29

E1.3.1.3 Data Requirements – Cargo Handling and Construction Equipment

Fuel Usage:

Propane _________ gallons[2]
Diesel _________ gallons

OR

Propane _________ hp-hr
Diesel _________ hp-hr

E1.3.1.4 Emission Factors

OFFROAD2007 for Diesel and LPG CO_2 emission factors (g/hp-hr)

Table E1.3-2 for original CH_4 and N_2O and LNG CO_2 emission factors (kg/gal)

Table E1.3-7 for converted CH_4 and N_2O and LNG CO_2 emission factors (g/hp-hr)

E1.3.2 Mobile Source Combustion

E1.3.2.1 Description

This source category includes mobile sources that travel both on- and off-site.

Category Assumptions:

- Primarily consists of locomotives, trucks, worker commute vehicles, ships, and tugboats.
- The fuel used will be diesel/distillate/residual fuel, gasoline, or liquefied natural gas (LNG).

For locomotives, emission factors from the GRP (kg/gal) were used for all GHGs. Originally in units of kg/gal, these emission factors were converted to units of g/hp-hr to

[2] Often, offroad equipment usage is provided in hp-hr rather than gallons of fuel consumed. In this case, the gallons of fuel consumed must be derived from the hp-hr by using a brake-specific fuel consumption (BSFC) value (in lb fuel per bhp-hr), which depends on the type of equipment. Offroad 2007 provides typical BSFC values by equipment horsepower category.

simplify the emission calculations. This conversion used a manufacturer-provided BSFC value and a fuel density value from the GRP.

For diesel trucks, CO_2 emission factors in units of grams per mile (g/mi) were obtained directly from the EMFAC2007 emission factor program. Emission factors from the GRP (g/mi) were used for CH_4 and N_2O. For LNG trucks, emission factors from the GRP (kg/gal) were used for CO_2 and (g/mi) for N_2O and CH_4. GRP CO_2 emission factor, originally in units of kg/gal, were converted to units of g/hp-hr to simplify the emission calculations. This conversion used a manufacturer-provided BSFC value and a fuel density value from the GRP.

For worker commute vehicles, CO_2 emissions were obtained from URBEMIS. Details and assumptions regarding the URBEMIS parameters are discussed in Section 3.2.4.4. The CO_2 emission factor, originally in units of kg/gal, was converted to units of g/mi by using average fuel economy data by model year category from the U.S. Department of Transportation, *Summary of Fuel Economy Performance* (October 2006).The total miles traveled were calculated using the CO_2 emission factor in terms of g/mi and the CO_2 yearly emissions from URBEMIS. The CH_4 and N_2O emission factors were obtained from the GRP in units of g/mi. The vehicle years with the most conservative CH_4 and N_2O emission factors were used.

For main and auxiliary engines on ships and tugboats, CO_2 emission factors in units of grams per kilowatt-hour (g/kWh) were obtained directly from Entec (2002) Tables 2.8, 2.9, and 2.10. Emission factors from the GRP (kg/gal) were used for CH_4 and N_2O. These emission factors were converted to units of g/kWh to simplify the emission calculations. This conversion used specific fuel consumption (SFC) values provided by Entec (2002) and fuel density values from the GRP. Emissions from ship boilers were calculated using emission factors from the GRP.

E1.3.2.2 Equations

E1.3.2.2.1 Mass Emissions Estimates

General Equations:

GHGs of Source Category CO_2, CH_4, N_2O

Total Emissions = Emission Factor (g GHG/hp-hr)
× Work Produced (hp-hr)
× 0.000001 (metric tons per gram)

OR

Total Emissions = Emission Factor (g GHG/kWh)
× Power Output (kWh)
× 0.000001 (metric tons per gram)

OR

Total Emissions = Emission Factor (g GHG/mile)
× Vehicle-Miles Traveled (VMT) (miles)
× 0.000001 (metric tons per gram)

Example:

Given: 1,000 truck trips and an average trip length of 20 miles.
Total VMT = 1,000 trips x 20 miles/trip = 20,000 mi

Total Emissions N_2O = 0.05 (g/mile) [from Table E1.3-4]
× 20,000 miles
× 0.000001 (metric tons per gram)

Total Emissions N_2O = 0.001 metric tons

E1.3.2.3 Data Requirements – Locomotives

Fuel Usage:

LNG ________________ gallons
Propane ________________ gallons
Diesel ________________ gallons
Gasoline ________________ gallons

OR

LNG ________________ hp-hr
Propane ________________ hp-hr
Diesel ________________ hp-hr
Gasoline ________________ hp-hr

E1.3.2.4 Data Requirements – Trucks and Worker Commute Vehicles

Miles traveled by fuel type:
LNG ________________miles
Propane ________________miles
Diesel ________________miles
Gasoline ________________miles

Fleet Est. Average miles per gallon by Fuel type
LNG ________________miles/gallon
Propane ________________miles/gallon
Diesel ________________miles/gallon
Gasoline ________________miles/gallon

(Note: EMFAC2007 output tables provide estimates of mpg)

E1.3.2.5 Data Requirements – Ships and Tugboats

Main and Auxiliary Engines:

Residual Fuel ________________ kWh engine output
Distillate Fuel ________________ kWh engine output

Boilers:
Residual Fuel ________________ gal fuel
Distillate Fuel ________________ gal fuel

E1.3.2.6 Emission Factors

Locomotives:

Table E1.3-2 for original emission factors (kg/gal)
Table E1.3-8 for converted emission factors (g/hp-hr)

Trucks:

EMFAC2007 for CO_2 emission factors (g/mile); summarized in Table E1.3-4
Table E1.3-4 for CH_4 and N_2O emission factors (g/mile)

Worker Commute Vehicles:

Table E1.3-2 for original CO_2 emission factors (kg/gal)
Table E1.3-4 for original CH_4 and N_2O emission factors (g/mile)

Marine Vessel Main and Auxiliary Engines:

Table E1.3-2 for original CH_4 and N_2O emission factors (kg/gal)
Table E1.3-5 for CO_2 and converted CH_4 and N_2O emission factors (g/kWh)

Ship Boilers:

Table E1.3-2 for original emission factors (kg/gal)
Table E1.3-6 for converted emission factors (g/Metric Tons of Fuel)

E1.3.3 Electricity Usage

E1.3.3.1 Description

Electrical usage directly related to terminal operations.

Category Summary:

- Includes alternative maritime power (AMP) usage during ship hoteling, and on-terminal electricity consumption for lighting, electric gantry cranes, etc.
- Assumes on-grid consumption

Emission factors for electricity usage were obtained from the GRP.

E1.3.3.2 Equations

E1.3.3.2.1 Mass Emissions Estimates

General Equation:

GHGs of Source Category CO_2, CH_4, N_2O

Total Emissions = Emission Factor (lbs GHG/Megawatt-hour [MWh])

× *Electricity Used* (kWh)
× *0.001 MWh per kWh*
÷ *2,204.62 lbs/metric ton*

Example:

Given: Electricity Usage = 1,000,000 kWh

Total Emissions CO_2 *= 804.54 (lbs* CO_2 */MWh) [from Table E1.3-3]*

$$\times 1{,}000{,}000 \text{ kWh}$$
$$\times 0.001 \text{ MWh per kWh}$$
$$\div 2{,}204.62 \text{ lbs/metric ton}$$

Total Emissions CO_2 *= 364.9 metric tons*

E1.3.3.3 Data Requirements – Electricity Usage

Electricity Usage ______________kilowatt- hours (kWh)

E1.3.3.4 Emission Factors

Table E1.3-3 for emission factors

E1.3.4 Refrigeration

E1.3.4.1 Description

Fugitive emissions of hydrofluorocarbons (HFCs) from refrigerant leakage in refrigerated containers (reefers) while inside California borders.

Category Summary:

- Primarily consist of refrigerated container operation
- Does not include combustion or electrical sources to power refrigeration (calculated elsewhere)

Refrigeration losses were calculated using a mass balance approach. The GRP (Table III.11.1) recommends using an upper bound annual loss rate of 35 percent for commercial air conditioning systems.[3] An average reefer dwell time inside California boundaries was assumed to be 3 days per one-way trip. This estimate assumes an on-terminal reefer dwell time of 2 days, and 1 additional day for transport in and out of the terminal.

E1.3.4.2 Equations

E1.3.4.2.1 Mass Emissions Estimates

General Equation

HFC Emissions from Refrigeration Leakage (kg) =

Total Annual Refrigerant Charge (kg)
× Dwell time (days) / 365
× Assumed Annual Leakage (%)

[3] The 35% annual loss rate is a conservative assumption intended for use in *de minimis* determinations. Actual loss rates are expected to be much lower (roughly 2% per year), as presented in Table 3.9 of the *Guidance to the California Climate Action Registry: General Reporting Protocol* (California Energy Commission, June 2002).

Example:

Given: Annual throughput of 1,000 reefers with an average refrigerant charge of 6.35 kg HFC 134a per reefer (i.e., total annual refrigerant charge of 6,350 kg of HFC 134a).

HFC Emissions from Refrigeration Leakage (kg) =
6,350 kg HFC 134a
× 3 days / 365 days
× 35% annual loss rate

HFC Emissions from Refrigeration Leakage = 18.3 kg HFC 134a

E1.3.4.3 Data Requirements – Refrigeration

Refrigerant Charge _____________kg per reefer

Refrigerant Composition _____________(by HFC listed in Attachment 1)

Attachment 1
Global Warming Potentials

Table E1.3-1. Global Warming Potentials

Greenhouse Gas	GWP (SAR, 1996)
CO_2	1
CH_4	21
N_2O	310
HFC-123	11,700
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-43-10mee	1,300
CF_4	6,500
C_2F_6	9,200
C_3F_8	7,000
C_4F_{10}	7,000
C_5F_{12}	7,500
C_6F_{14}	7,400
SF_6	23,900
Source: U.S. Environmental Protection Agency, U.S. Greenhouse Gas Emissions and Sinks: 1990-2000 (April 2002). Note: This information is found in Table III.6.1 of the CCAR protocol.	

Attachment 2
Emission Factors

Table E1.3-2. GHG Emission Factors for Liquid Fuels

Fuel	Fuel Density	Emission Factor		
		CO_2	CH_4	N_2O
Propane (LPG)	4.24 lb/gal [a]	5.67 kg/gal	0.000091 kg/gal	0.00041 kg/gal
CA Low Sulfur Diesel	7.46 bbl/metric ton	9.96 kg/gal	0.0014 kg/gal	0.0001 kg/gal
Non-CA Diesel/ Diesel No. 2	7.46 bbl/metric ton	10.05 kg/gal	0.0014 kg/gal	0.0001 kg/gal
Liquefied Natural Gas (LNG)	11.6 bbl/metric ton	4.37 kg/gal	0.0059 kg/MMBtu	0.0001 kg/MMBtu
Distillate Fuel Oil [#1, 2, 4, Diesel]	7.46 bbl/metric ton	10.15 kg/gal	0.0014 kg/gal	0.0001 kg/gal
Residual Fuel Oil [#5, 6]	6.66 bbl/metric ton	11.79 kg/gal	0.0015 kg/gal	0.0001 kg/gal
CA Reformulated Gasoline	8.53 bbl/metric ton	8.55 kg/gal	(see Table E1.3-4)	(see Table E1.3-4)

Source: California Climate Action Registry, *General Reporting Protocol* v2.2, March 2007. Tables C.3, C.5, and C.6 (unless otherwise noted).
[a] Source: *AP-42* Appendix A (January 1995).

Table E1.3-3. GHG Indirect Emission Factors for Electricity Consumption

Region	Emission Factor (lb/MWh)		
	CO_2	CH_4	N_2O
Los Angeles	804.54	0.0067	0.0037

Source: California Climate Action Registry, General Reporting Protocol v2.2, March 2007.

Table E1.3-4. CH_4 and N_2O Emission Factors for Mobile Sources

Vehicle Type/Model Years	Emission Factor (g/mile)	
	CH_4	N_2O
Passenger Cars – Gasoline		
Model Year 1966-1972	0.22	0.02
Model Year 1973-1974	0.19	0.02
Model Year 1975-1979	0.11	0.05
Model Year 1980-1983	0.07	0.08
Model Year 1984-1991	0.06	0.08
Model Year 1992	0.06	0.07
Model Year 1993	0.05	0.05
Model Year 1994-1999	0.05	0.04
Model Year 2000-present	0.04	0.04
Light Duty Trucks – Gasoline		
Model Year 1966-1972	0.22	0.02
Model Year 1973-1974	0.23	0.02
Model Year 1975-1979	0.14	0.07
Model Year 1980-1983	0.12	0.13
Model Year 1984-1991	0.11	0.14
Model Year 1992	0.09	0.11
Model Year 1993	0.07	0.08
Model Year 1994-1999	0.06	0.06
Model Year 2000-present	0.05	0.06
Heavy Duty Trucks		
Model Year 1966-1982 (Diesel)	0.10	0.05
Model Year 1983-1995 (Diesel)	0.08	0.05
Model Year 1996-present (Diesel)	0.06	0.05
CNG, LNG (all model years)	3.48	0.05
Source: California Climate Action Registry, General Reporting Protocol v2.2, March 2007. Table C.4.		

Table E1.3-5. Derivation of GHG Emission Factors for Marine Vessels – Main and Auxiliary Engines

Source	Engine Type	Fuel	Fuel Density [b] (barrels/ metric ton)	Specific Fuel Consumption [a] (g/kWh)	Converted Emission Factors (g/kWh)[b]		
					CO_2	CH_4	N_2O
Ships – At Sea	Main	Residual	6.66	195	620	0.0818	0.00545
Ships – Maneuvering	Main	Residual	6.66	215	682	0.0902	0.00601
Ships – At Sea	Main	Distillate	7.46	185	588	0.0811	0.00580
Ships – Maneuvering	Main	Distillate	7.46	204	647	0.0895	0.00639
Ships	Aux	Residual	6.66	227	722	0.0952	0.00635
Ships	Aux	Distillate	7.46	217	690	0.0952	0.00680
Tugs	Main	Distillate / MGO	7.46	203	645	0.0890	0.00636
Tugs	Aux	Distillate / MGO	7.46	217	690	0.0952	0.00680

[a] Source: Entec 2002, Tables 2.8, 2.9, and 2.10
[b] Source: CCAR General Reporting Protocol v. 2.2
MGO = marine gas oil
AUX = Auxiliary Engine

Table E1.3-6. Derivation of GHG Emission Factors for Marine Vessels – Boilers

Source	Engine Type	Fuel	Fuel Density [a] (barrels/metric ton)	Converted Emission Factors (kg/Metric Ton) [e]		
				CO_2	CH_4	N_2O
Ships	Boiler	Distillate	7.46	3,149	0.439	0.0313
Ships	Boiler	Residual	6.66	3,264	0.420	0.0280

[a] Source: CCAR General Reporting Protocol v. 2.2

Table E1.3-7. Derivation of GHG Emission Factors for Off-Road Equipment

Engine Size (hp)	BSFC (lb/hp-hr) [a]	Diesel Fuel Density (barrels/metric ton) [b]	LNG / LPG Fuel Density (barrels/metric ton)	Converted Emission Factors (g/hp-hr)		
				Diesel N_2O	LNG CO_2	LPG N_2O
26-50	0.54	7.46	11.6	7.67E-03	521.49	0.01
51-120	0.49	7.46	11.6	6.96E-03	473.20	0.01
121-175	0.47	7.46	11.6	6.68E-03	453.89	0.01
176-250	0.47	7.46	11.6	6.68E-03	453.89	0.01

[a] Source: Off-road 2007 data file "Equip.csv".
[b] Source: CCAR General Reporting Protocol v. 2.2.

Table E1.3-8. Derivation of GHG Emission Factors for Locomotives (Diesel)

Locomotive Type	BSFC (lb/hp-hr) [a]	Fuel Density (barrels/ metric ton) [b]	Converted Emission Factors		
			CO_2 (g/hp-hr)	CH_4 (g/hp-hr)	N_2O (g/hp-hr)
Line Haul Locomotive	0.355	7.46	507.1	0.071	0.0050
Switch Locomotive	0.355	7.46	502.5	0.071	0.0050

[a] Source: Cat engine 3516B fuel usage factor
[b] Source: CCAR General Reporting Protocol v. 2.2. Appendix B

Attachment 3 GHG Descriptions

Water vapor is the most abundant, important, and variable greenhouse gas in the atmosphere. It is not considered a pollutant; in the atmosphere it maintains a climate necessary for life. The main source of water vapor is evaporation from the oceans (approximately 85%). Other sources include evaporation from other water bodies, sublimation (change from solid to gas) from ice and snow, and transpiration from plant leaves. Water vapor is not one of the six GHGs identified by the World Resources Institute (WRI) as a man-made contributor to global climate change.

Carbon dioxide (CO_2) is an odorless, colorless natural greenhouse gas. Natural sources include the following: decomposition of dead organic matter; respiration of bacteria, plants, animals, and fungus; evaporation from oceans; and volcanic outgassing. Anthropogenic (human caused) sources of carbon dioxide are from burning coal, oil, natural gas, and wood. Concentrations are currently around 370 ppm; some say that concentrations may increase to 540 ppm by 2100 as a direct result of anthropogenic sources (IPCC 2001). Some predict that this will result in an average global temperature rise of at least 2° Celsius (IPPCC 2001).

Methane is a flammable gas and is the main component of natural gas. When one molecule of methane is burned in the presence of oxygen, one molecule of carbon dioxide and two molecules of water are released. There are no health effects from methane. A natural source of methane is from the anaerobic decay of organic matter. Geological deposits known as natural gas fields contain methane, which is extracted for fuel. Other sources are from landfills, fermentation of manure, and cattle.

Nitrous oxide (N_2O), also known as laughing gas, is a colorless greenhouse gas. Higher concentrations can cause dizziness, euphoria, and sometimes slight hallucinations. Nitrous oxide is produced by microbial processes in soil and water, including those reactions which occur in fertilizer containing nitrogen. In addition to agricultural sources, some industrial processes (fossil fuel-fired power plants, nylon production, nitric acid production, and vehicle emissions) also contribute to its atmospheric load. It is used in rocket engines, as an aerosol spray propellant, and in race cars.

Chlorofluorocarbons (CFCs) are gases formed synthetically by replacing all hydrogen atoms in methane or ethane with chlorine and/or fluorine atoms. CFCs are nontoxic, nonflammable, insoluble, and chemically unreactive in the troposphere (the level of air at the earth's surface). CFCs were first synthesized in 1928 for use as refrigerants, aerosol propellants, and cleaning solvents. They destroy stratospheric ozone; therefore their production was stopped as required by the Montreal Protocol. CFCs are not one of the six GHGs identified by the World Resources Institute (WRI) as a man-made contributor to global climate change.

Hydrofluorocarbons (HFCs) are synthetic man-made chemicals that are used as a substitute for CFCs for automobile air conditioners and refrigerants.

Perfluorocarbons (PFCs) have stable molecular structures and do not break down though the chemical processes in the lower atmosphere. High-energy ultraviolet rays about 60 kilometers above Earth's surface are able to destroy the compounds. PFCs have very long lifetimes, between 10,000 and 50,000 years. Two common PFCs are tetrafluoromethane and hexafluoroethane. Concentrations of tetrafluoromethane in the atmosphere are over 70 ppt (EPA 2006d). The two main sources of PFCs are primary aluminum production and semiconductor manufacture.

Sulfur hexafluoride (SF6) is an inorganic, odorless, colorless, nontoxic, nonflammable gas. It also has the highest GWP of any gas evaluated, 23,900. Concentrations in the 1990s were about 4 ppt (EPA 2006d). Sulfur hexafluoride is used for insulation in electric power transmission and distribution equipment, in the magnesium industry, in semiconductor manufacturing, and as a tracer gas for leak detection.

Ozone is a greenhouse gas; however, unlike the other greenhouse gases, ozone in the troposphere is relatively short-lived and therefore is not global in nature. According to CARB, it is difficult to make an accurate determination of the contribution of ozone precursors (NO_X and VOCs) to global warming (CARB 2004b). Therefore, project emissions of ozone precursors would not significantly contribute to global climate change. Ozone is not one of the six GHGs identified by the World Resources Institute (WRI) as a man-made contributor to global climate change.

Aerosols are particles emitted into the air through burning biomass (plant material) and fossil fuels. Aerosols can warm the atmosphere by absorbing and emitting heat and can cool the atmosphere by reflecting light. Cloud formation can also be affected by aerosols. Sulfate aerosols are emitted when fuel with sulfur in it is burned. Black carbon (or soot) is emitted during bio mass burning incomplete combustion of fossil fuels. Particulate matter regulation has been lowering aerosol concentrations in the United States; however, global concentrations are likely increasing. Aerosols are not one of the six GHGs identified by the World Resources Institute (WRI) as a man-made contributor to global climate change.

Source: AEP, 2007.