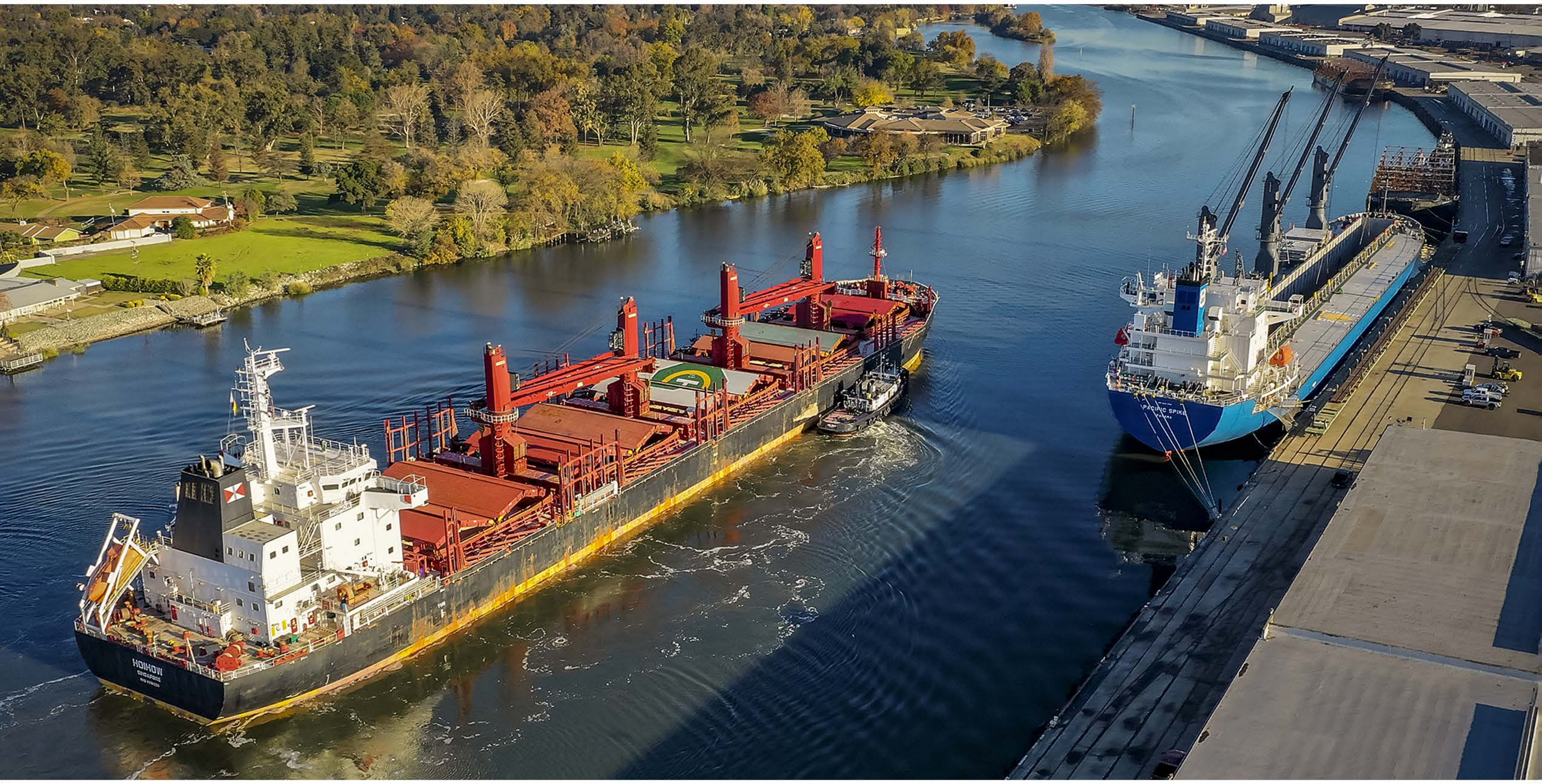
PORT OF STOCKTON
INVENTORY OF AIR EMISSIONS - 2018

Port of Stockton
CALIFORNIA



Prepared by:

STARCREST CONSULTING GROUP, LLC
ENVIRONMENTAL MANAGEMENT • AIR QUALITY • CLIMATE • SUSTAINABILITY

February 2021

INVENTORY OF AIR EMISSIONS FOR CALENDAR YEAR 2018

Prepared for:

Port of Stockton

February 2021

Submitted by:

Starcrest Consulting Group, LLC

Established 1997

Project Principal:
Archana Agrawal
archana@starcrestllc.com
(909) 597-8205

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

The following individuals and their respective companies and organizations assisted with providing the technical and operational information described in this report, or by facilitating the process to obtain this information. This is the 1st Annual Inventory of Air Emissions report and this endeavor would not have been possible without their assistance and support. We genuinely appreciate their time, effort, expertise, and cooperation. The Port of Stockton and Starcrest Consulting Group, LLC (Starcrest) would like to recognize and thank the following individuals:

Michael Vilarino, ADA Scales, Inc.
David Williamson, Community Fuels
Robert Calverley, American Containers, Inc.
Greg Artlip, Best Logistics, Inc.
Matt Duaime, CALAMCO
Allan Castaneda, CalPortland Company
Dustin Hirashima, Green Planet 21
Scott Baker, Central Valley Ag Grinding
Chuck De Jong, H.J. Baker & Bros., LLC
Mike Lambert, Heavy Transport, Inc.
William James, Lowes HIW, Inc.
Nancy Junziker-Klaes, Martin Operating Partnership
Shawn Bundy, Metropolitan Stevedore Co.
Jeffery Unsinger, Pacific Ethanol Stockton, LLC
Ray Smith, Newstar Energy
Carlos DeJesus Jr., SSA Marine, Inc.
Sal Rodriguez, Tesero Logistics Operations, LLC
Ozzie Gomez, Tiger-Sul Products, LLC
Brett Reisinger, Wilmar Oils & Fats, Inc.
Paul Ferreira and Shawn Ross, Yara North America, Inc.
Michael Ogieglo, Ceres Marine Terminals, Inc.
Troy Esch, Marine Express, Inc.
Dan Zandell, Brusco Tug & Barge, Inc.
Richard Grigsbay and Randy Egusquiza, Central California Traction Company

The Port of Stockton and Starcrest would like to thank the following regulatory agency staff who contributed, commented, and coordinated the approach and reporting of the emissions inventory:

Leland Villalvazo, San Joaquin Valley Air Pollution Control District
Esteban Gutierrez, San Joaquin Valley Air Pollution Control District
Cory Parmer, California Air Resources Board
Francisco Dóñez, U.S. Environmental Protection Agency, Region 9

Starcrest would like to thank the following Port of Stockton staff members and consultants for assistance during the development of the emissions inventory:

Jeff Wingfield, Director, Environmental and Public Affairs
Jason Cashman, Environmental and Regulatory Affairs Manager
Victoria Lucero, Public Affairs Coordinator
Shannon Arnold, Director of Marketing and Sustainability, Rebel Marketing Pros
Lena Desantis, Anchor QEA
Katie Chamberlin, Anchor QEA

ACKNOWLEDGEMENTS(CONT'D)

Authors:

Archana Agrawal, Principal, Starcrest
Bruce Anderson, Principal, Starcrest
Rose Muller, Consultant, Starcrest
Randall Pasek, Consultant, Starcrest
Joseph Ray, Principal, Starcrest

Contributors:

Guiselle Aldrete, Consultant, Starcrest
Steve Ettinger, Principal, Starcrest
Jill Morgan, Consultant, Starcrest
Paula Worley, Consultant, Starcrest

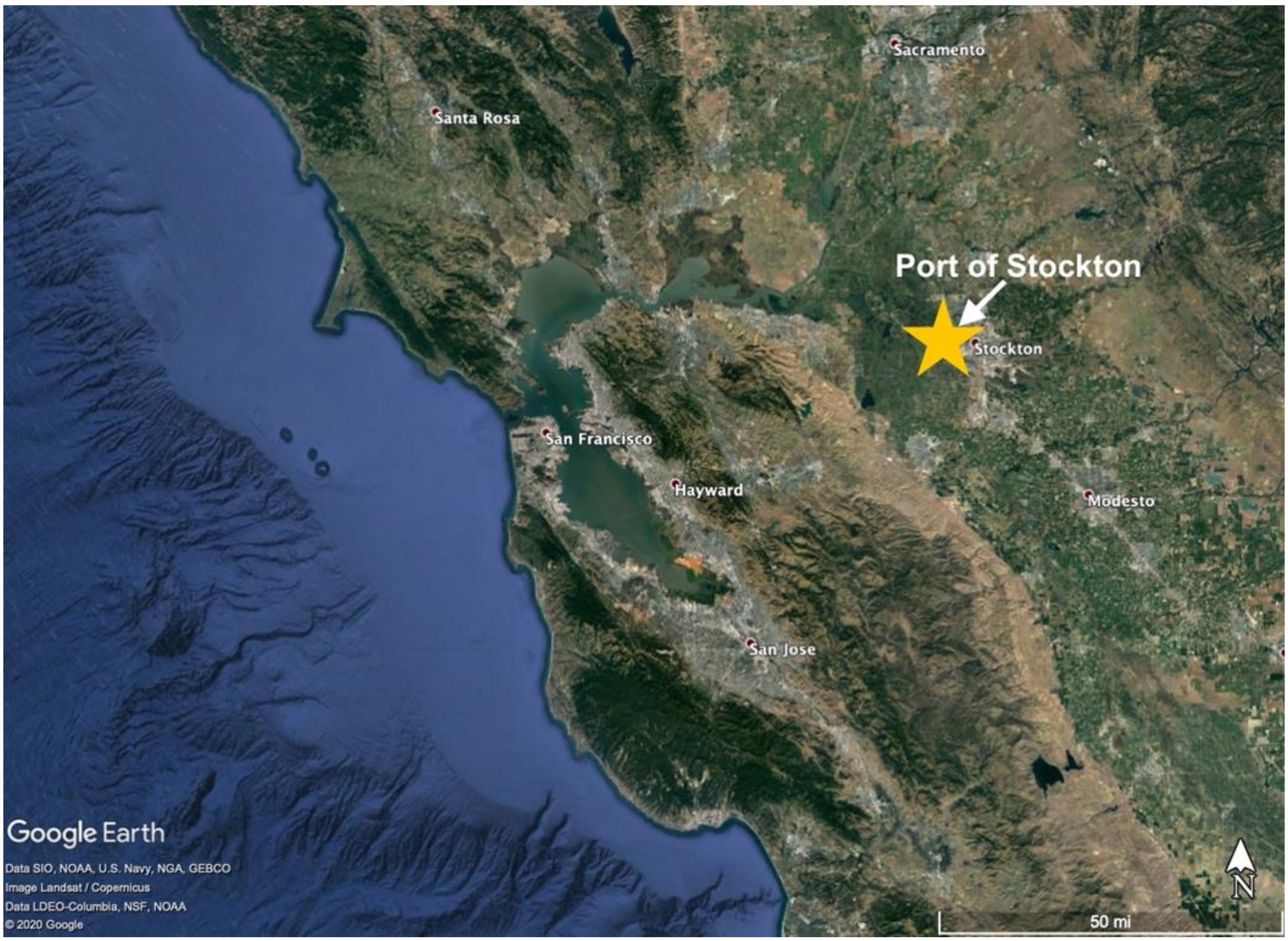
Document Preparation: Denise Anderson, Consultant, Starcrest

Cover: Melissa Silva, Principal, Starcrest

EXECUTIVE SUMMARY

The Port of Stockton is an inland facility situated on a deep-water channel located in the extended San Francisco Bay Area. Operating since 1933, the Port of Stockton is the 4th busiest port in California and handles dry bulk, breakbulk, liquid bulk and project cargoes. The Port is situated in the hub of four major freeways, two transcontinental railroads, an international waterway and a regional airport, and has warehouse storage and handling facilities for both dry and liquid bulk materials, facilities and equipment to handle break-bulk and containerized cargoes by land or sea.

Figure ES.1: Port of Stockton Location



The air emissions from mobile sources that routinely operate at the Port are included in the inventory presented in this report. Emissions from stationary sources (e.g., factories, power plants, refineries, etc.) are not included in the inventory and their emissions are estimated and tabulated by others (California Air Resources Board and San Joaquin Valley Air Pollution Control District). However, greenhouse gas emissions include some emissions from stationary sources as greenhouse gas emissions inventories are developed using internationally accepted protocols that include emissions from stationary sources as well as mobile sources. This activity-based inventory of air emissions is for calendar year 2018 for the following source categories:

- Ocean-going vessels (OGV)
- Harbor craft
- Cargo handling equipment (CHE)
- Locomotives
- On-Road Vehicles (Heavy-duty trucks and Port-owned vehicles)
- Port-owned Stationary Source Greenhouse Gas (GHG)

Development of this activity-based inventory was coordinated with a technical working group (TWG) comprised of representatives from the Port and the air regulatory agencies: U.S. Environmental Protection Agency, Region 9 (EPA), California Air Resources Board (CARB), and the San Joaquin Valley Air Pollution Control District (SJVAPCD). The TWG members are experts in the emissions inventory field and are an important part of the emissions inventory process as the Port seeks their advice and consensus regarding the methodologies and information used to develop the emission estimates in this report.

Table ES.1 presents the summary of the Port's 2018 emission inventory by major source category. The OGV category emissions dominate the Port's total emissions ranging from 31% (CO) to 99% (SO_x) of the total depending on the pollutant. The other four categories contribute somewhat equally to the remaining emissions apart from PM emissions from the on-road vehicles which are substantially less than the other categories. Figures ES.2-ES.5 illustrate the emission of PM_{10}, NO_x, HC, and CO_2e, for 2018 and again shows that the emissions of the OGV category dominate the Port's emissions.

Table ES.1: Port of Stockton 2018 Emissions Summary

	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Ocean-going vessels	2.9	2.8	2.3	127.7	6.9	11.5	4.7	9,646
Harbor craft	0.65	0.60	0.65	15.03	0.01	7.15	1.45	946
Cargo handling equipment	0.42	0.38	0.41	18.57	0.03	11.92	1.87	2,460
Locomotives	0.79	0.72	0.79	26.43	0.02	6.31	1.62	2,424
On-Road Vehicles	0.06	0.06	0.06	13.64	0.04	3.16	0.63	4,090
Total	**4.82**	**4.57**	**4.21**	**201**	**7.00**	**40.04**	**10.26**	**19,565**

Figure ES.2: PM_{10} Emissions

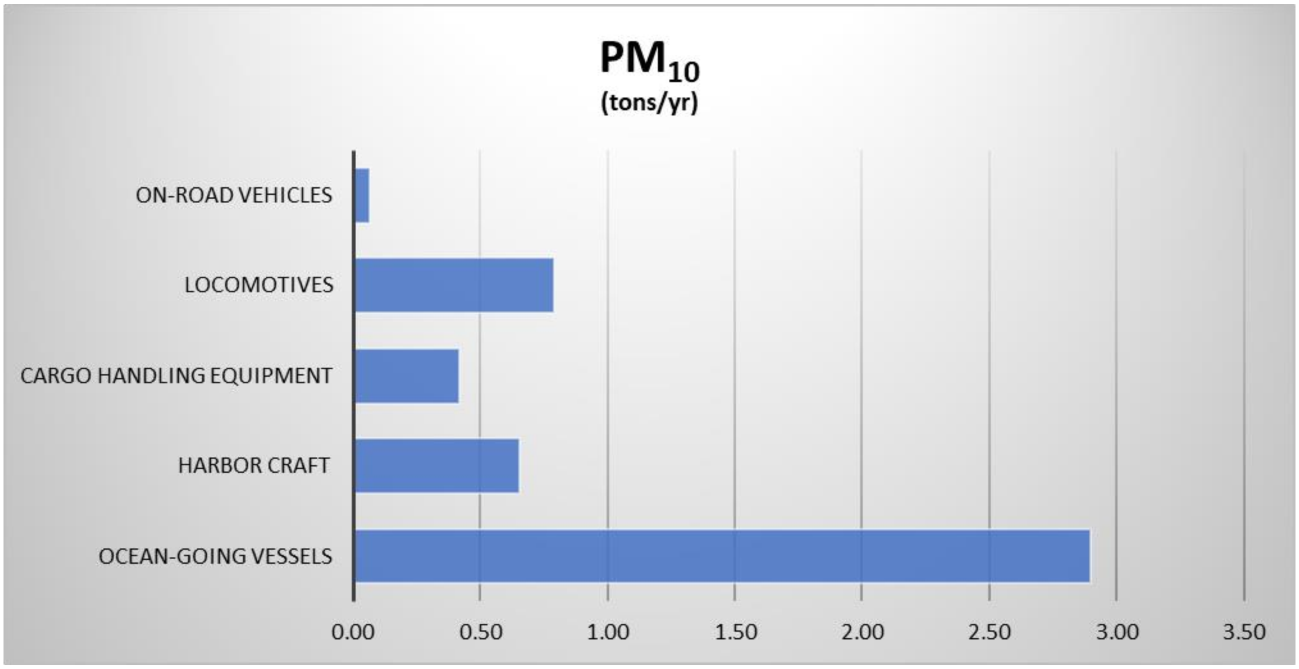


Figure ES.3: NO_x Emissions

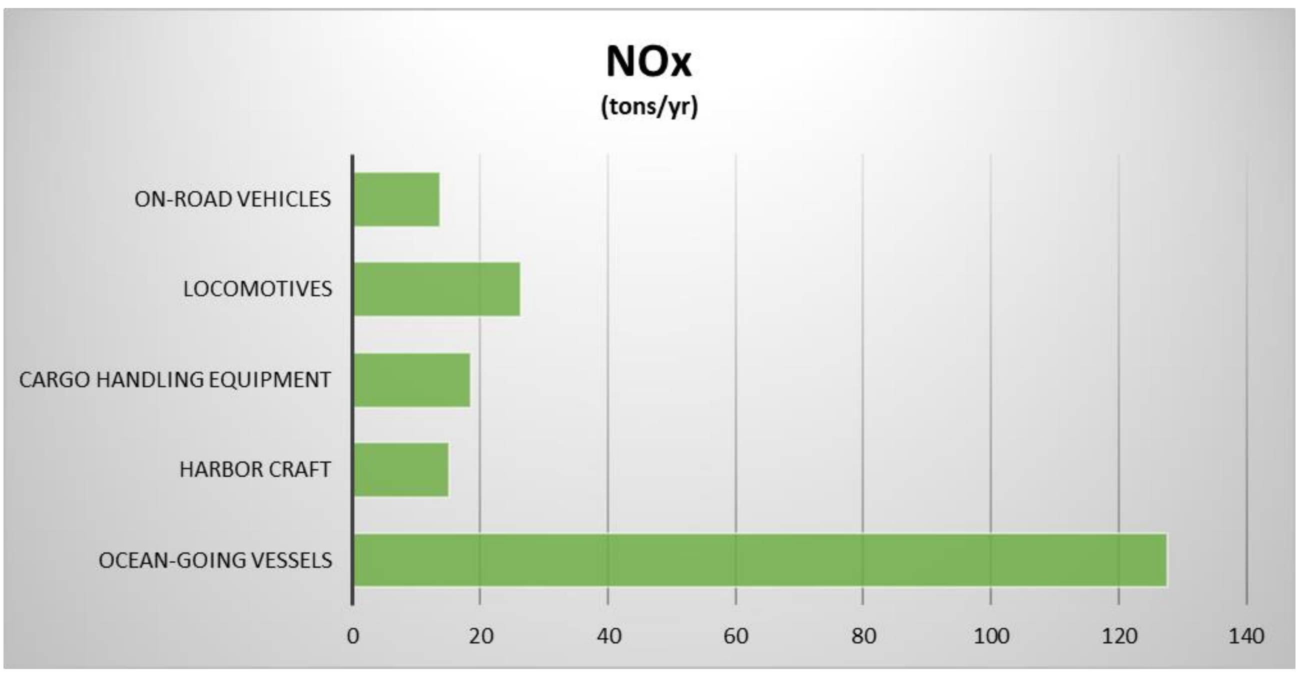


Figure ES.4: HC Emissions

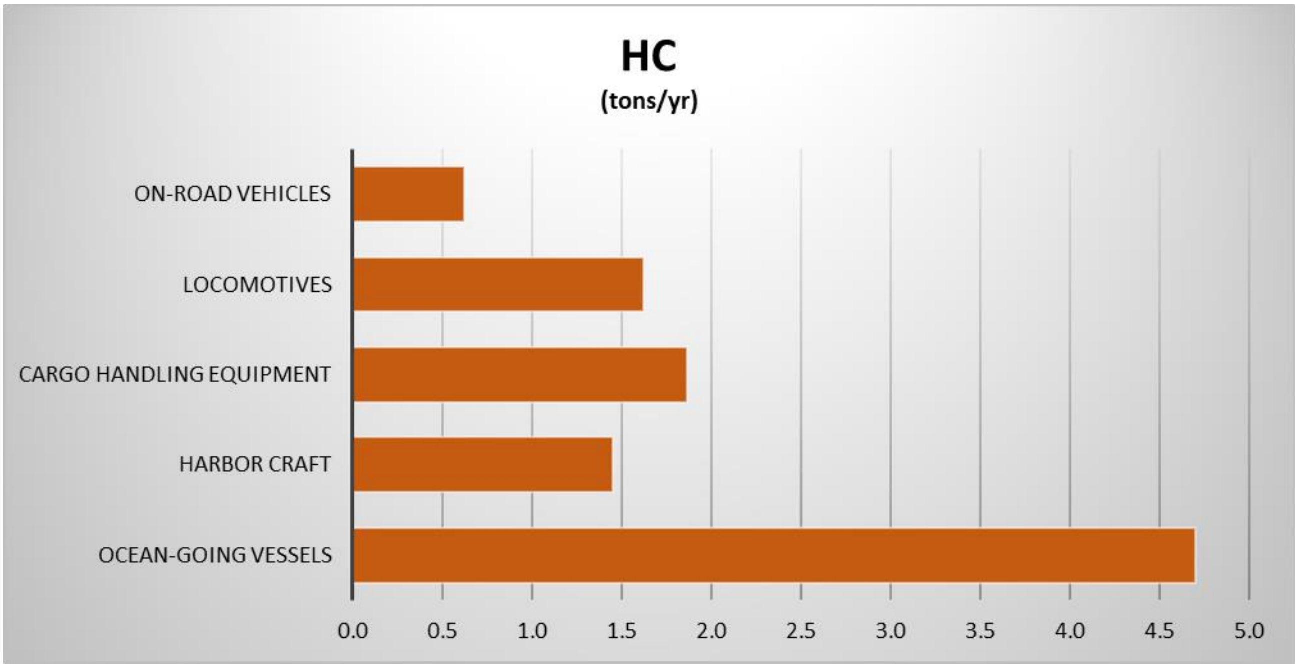


Figure ES.5: CO_2e Emissions

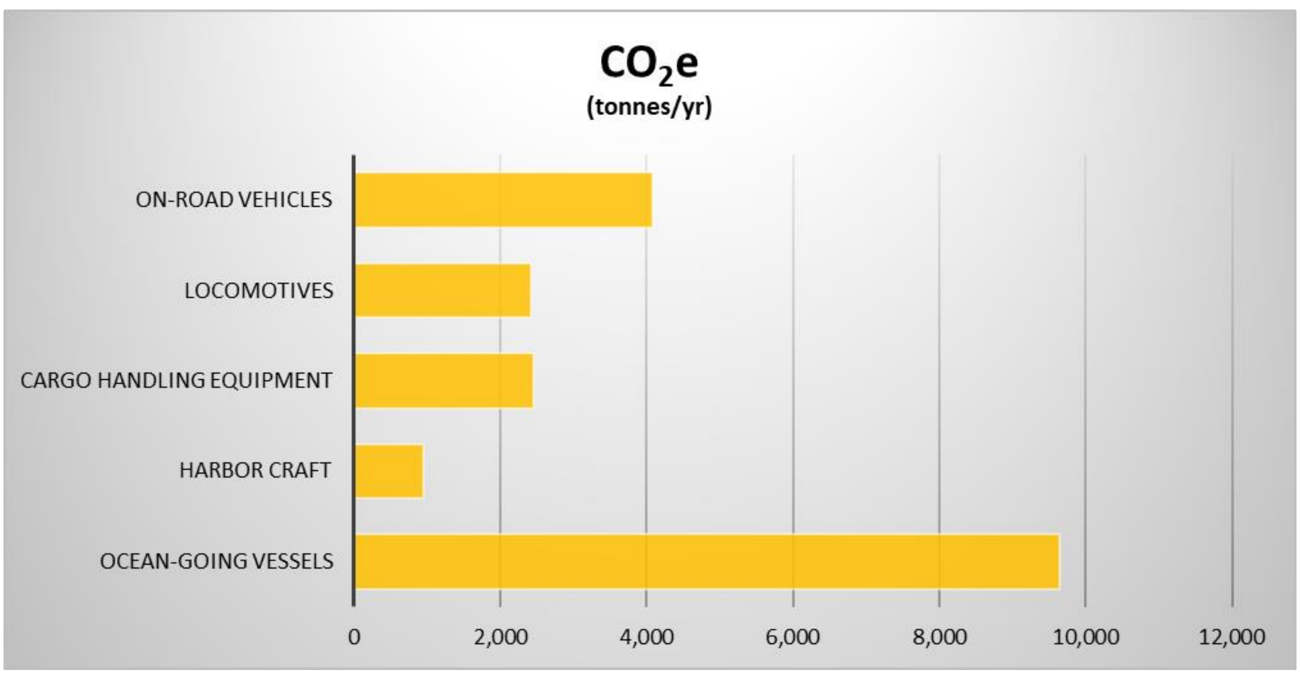


Table ES.2 summarizes the GHG emissions (CO_2e) for scopes 1 and 2. The GHG emissions are dominated natural gas combustion and mobile source tailpipe emissions.

Table ES.2: Summary of Scope 1 and 2 GHG Emissions, CO_2e tonnes

Emissions Scope	Source		CO2e tonnes
Scope 1	Port Stationary Sources	Natural Gas Combustion	1,994
	Port Mobile Sources	Cargo Handling Eqipment and Passenger Vehicles (Light and Medium Duty Trucks and Automobiles) - Exhaust	1,133
Scope 2	Port Stationary Sources	Purchased Electricity	146
Total			3,272

Table ES.3 and Figure ES.6 compare the 2018 emissions for the San Joaquin Valley Air Pollution Control District (APCD) as reported by the California Air Resources Board[1]. San Joaquin Valley APCD emissions presented below include the entire counties of San Joaquin, Stanislaus, Merced, Madera, Fresno, Tulare and Kings and part of Kern County. The portion of Kern County in the SJVAPCD straddles the Sierra Nevada and Tehachapi mountains. The 2018 APCD emissions were generated using the CARB CEPAM emissions forecasting tool and are shown in tons per year. The CARB CEPAM forecasting tool emissions for 2018 are projected from 2012[2] and represent anthropogenic as well as non-anthropogenic emissions sources. As shown, the maritime port-related emissions for Port of Stockton are 0% to 0.26% of the total regional emissions and more than 99.7% of the emissions in the SJVAPCD are from non-port related sources.

Table ES.3: 2018 Emissions Comparison to Regional Emissions

	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons
2018 San Jouaquin Valley APCD	114,900	37,299	1,613	81,975	3,820	372,461	293,540
2018 Port of Stockton	4.8	4.6	4.2	201.4	7.0	40.0	10.3
POS Compared to SJVAPCD	**0.00%**	**0.01%**	**0.26%**	**0.25%**	**0.18%**	**0.01%**	**0.00%**

[1] See: *https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php*
[2] CEPAM 2012 emissions were the base year for the 2016 federal eight-hour ozone standard (75 ppb) State Implementation Plan (Ozone SIP).

SECTION 1 INTRODUCTION

The Port of Stockton inventory includes the following port-related emission source categories:

- Mobile sources
  - Ocean-going vessels (OGV)
  - Harbor crafts
  - Cargo handling equipment (CHE)
  - Locomotives
  - On-Road Vehicles (Heavy-duty trucks and Port-owned vehicles)
- Stationary Sources
  - Port-owned Stationary Source Greenhouse Gas (GHG)

Exhaust emissions of the following pollutants are estimated with reporting units as noted:

- Criteria pollutants and precursors in tons
  - Oxides of nitrogen (NO_x)
  - Oxides of sulfur (SO_x)
  - Particulate matter (PM) (10-micron, 2.5-micron)
  - Hydrocarbons (HC)
  - Carbon monoxide (CO)
- Toxic air contaminant diesel particulate matter (DPM) in tons,[3] which is the particulate matter emitted from diesel internal combustion engines. PM_{10} diesel exhaust are surrogate for DPM, except for PM_{10} emitted from boilers.
- Greenhouse gases, expressed as carbon dioxide equivalent (CO_2e), in tonnes (metric tons), including:
  - Carbon dioxide (CO_2)
  - Nitrous oxide (N_2O)
  - Methane (CH_4)

[3] In 1998, the California Air Resources Board (CARB) identified diesel particulate matter as a toxic air contaminant. California EPA Air Resources Board, Resolution 98-35, 27 August 1998. See: *https://www.arb.ca.gov/regact/diesltac/res98-35.pdf.*

To normalize the three GHG values into a single number representing CO_2 equivalents (CO_2e), the GHG emission estimates are multiplied by the following values and summed.[4]

- CO_2 – 1
- CH_4 – 25
- N_2O - 298

Development of this activity-based inventory was coordinated with a technical working group (TWG) comprised of representatives from the Port and the air regulatory agencies: U.S. Environmental Protection Agency, Region 9 (EPA), California Air Resources Board (CARB), and the San Joaquin Valley Air Pollution Control District (SJVAPCD). The TWG is an important part of the emissions inventory process as the Port seeks the consensus of the air regulatory agencies regarding the methodologies and information used to develop the emission estimates in this report.

[4]EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015*, April 2017.

Table 1.1 provides a description of the pollutants and greenhouse gases.

Table 1.1: Pollutant and Greenhouse Gases Description

Pollutant	Sources	Health & Environmental Effects
Oxides of nitrogen (NO_x) is the generic term for a group of highly reactive gases; all of which contain nitrogen and oxygen in varying amounts. Most NO_x are colorless and odorless.	NO_x form when fuel is burned at high temperatures, as in a combustion process. The primary manmade sources of NO_x are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	NO_x can react with other compounds in the air to form tiny particles adding to PM concentrations. NO_x is an ozone precursor and is also associated with respiratory health effects.
Particulate matter (PM) refers to tiny, discrete solid or aerosol particles in the air. Dust, dirt, soot, and smoke are considered particulate matter. **PM_{10}** consists of particles measuring up to 10 micrometers in diameter; and **$PM_{2.5}$** consists of fine particles measuring 2.5 micrometers in diameter or smaller.	Vehicle exhaust (cars, trucks, buses, among others) are the predominant sources of fine particles in urban areas. In rural areas, land-clearing burning and backyard burning of yard waste contribute to particulate matter levels.	Fine particles are a concern because their very tiny size allows them travel more deeply into lungs, increasing the potential for health risks. Exposure to $PM_{2.5}$ is linked with respiratory disease, decreased lung function, asthma attacks, heart attacks and premature death.
Hydrocarbons (HC) are included in the emissions inventory because they react with NO_x to form ozone.	HC come from the transportation sector: cars and light trucks, marine vessels, and heavy-duty diesel vehicles. Other sources include gasoline-powered yard equipment, gasoline refueling, industrial solvents, and auto-body paint shops, among others.	In addition to contributing to the formation of ozone, some HC are air toxics which can contribute to a wide range of adverse health effects.
Carbon monoxide (CO) is a colorless, odorless, toxic gas commonly formed when carbon-containing fuel is not burned completely.	CO forms during incomplete combustion of fuels. The majority of CO comes from on and off-road vehicle engine exhaust.	CO combines with hemoglobin in red blood cells and decreases the oxygen-carrying capacity of the blood. CO weakens heart contractions, reducing the amount of blood pumped through the body. It can affect brain and lung function.

Table 1.1: Pollutant and Greenhouse Gases Description (cont'd)

Pollutant	Sources	Health & Environmental Effects
Oxides of sulfur (SO_x) is the generic term for the group of colorless, corrosive gases produced by burning fuel containing sulfur, such as coal and oil, and by industrial processes such as smelters, paper mills, power plants and steel manufacturing plants. The US EPA considers all SOx to be harmful to human health, with SO_2 found to be in the greatest concentration in the atmosphere.	SO_x emissions are primarily a result of sulfur contaminants in fuels used by cars, trucks, vessels, locomotives and cargo handling equipment. Over the past decade, levels of sulfur in diesel and gasoline fuels have decreased dramatically due to federal regulations set by the EPA, which resulted in decreasing SO_x emissions.	SO_x is associated with a variety of respiratory diseases. Inhalation of SO_x can cause increased airway resistance by constricting lung passages. Some of the SO_x become sulfate particles in the atmosphere adding to measured PM levels.
Diesel particulate matter (DPM) is the solid component of diesel exhaust and is a significant component of PM. DPM is typically composed of carbon particles, a large portion of which are referred to as black carbon, and organic compounds, many of which contain cancer-causing substances. In 1997, CARB classified DPM as a toxic air contaminant[5].	Sources of diesel emissions include diesel-powered trucks, buses and cars (on-road sources); diesel-powered marine vessels, construction equipment, trains and aircraft support equipment (non-road sources).	DPM and diesel exhaust has been shown to contribute up to 80% of the carcinogenic health risk related to the portion of outdoor air pollutants classified as "toxics" (based on CA risk estimate). DPM is linked with health effects typical of all PM, including heart problems, aggravated asthma, chronic bronchitis and premature death.
Greenhouse gases (GHG) included in this emissions inventory are carbon dioxide, methane, and nitrous oxide. There are other gases that contribute to climate change that are not significantly emitted by maritime-related sources and are not included in this inventory.	GHG come from both natural processes and human activities. Increases of human-made GHG are most responsible for the recent changes in GHG concentrations in the atmosphere. Most GHG generated from human activities come from transportation and electricity generation.	Climate change, also referred to as global warming, occurs when excessive amounts of GHG accumulate in our atmosphere. These gases trap heat, causing the temperature of the earth to rise.

[5]See: *https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health*

1.1 Geographical Domain

The geographical domain for each of the source categories is defined below.

- Ocean going vessels and harbor craft: the over-water geographic domain is within the SJVAPCD boundary which is the San Joaquin river from the confluence of the San Joaquin and Mokelumne rivers to the Port.
- Cargo handling equipment: the geographic domain is within the Port boundary.
- Locomotives: the geographic domain is within the Port boundary and from the Port boundary to the two class one switching yards (approximately 5 miles from the Port).
- On-road vehicles, heavy-duty vehicles: the geographic domain is from the Port to the entrance or exit of the Interstate 5 or State Route 4 freeways.
- On-road vehicles, Port owned on-road vehicles: actual miles traveled which includes mostly on-Port operation.

Figure 1.1: Aerial Picture of the Port of Stockton

1.2 Regulatory Measures

This section summarizes the regulatory initiatives related to port activity from five emission source categories: OGVs, harbor craft, CHE, locomotives, and HDVs. The following tables present a list of currently adopted regulatory programs by each major source category that influenced emissions from the maritime industry in and around the Port.

Table 1.2: OGV Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
International Maritime Organization (IMO)	NO_x Emission Standard for Marine Engines *www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Nitrogen-oxides-%28NOx%29-%E2%80%93-Regulation-13.aspx*	NO_x	2000 – Tier I 2011 – Tier II 2016 – Tier III for ECA only	Auxiliary and propulsion engines over 130 kW output power on newly built vessels
IMO	Emissions Control Area, Low Sulfur Fuel Requirements for Marine Engines *www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-%28SOx%29-%E2%80%93-Regulation-14.aspx*	DPM, PM, and SO_x	2012 ECA – 1% Sulfur 2015 ECA – 0.1% Sulfur	Significantly reduce emissions due to low sulfur content in fuel by creating Emissions Control Area (ECA)
IMO	Initial IMO Strategy on reduction of GHG emissions from ships – Resolution MEPC.304(72) *www.unfccc.int/sites/default/files/resource/250_IMO%20submission_Talanoa%20Dialogue_April%202018.pdf*	GHG	2050 – 50%	Initial IMO Strategy on reduction of GHG emissions from ships by 50% in 2050 from 2008 level. Goal is to phase out GHG
IMO	Energy Efficiency Design Index (EEDI) for International Shipping *www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Technical-and-Operational-Measures.aspx*	CO_2 and other pollutants	2013	Increases the design efficiencies of ships relating to energy and emissions

Table 1.2: OGV Emission Regulations, Standards and Policies (cont'd)

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
Environmental Protection Agency (EPA)	Emission Standards for Marine Diesel Engines above 30 Liters per Cylinder (Category 3 Engines); Aligns with IMO Annex VI marine engine NO_x standards and low sulfur requirement *www.epa.gov/otaq/oceanvessels.htm#engine-fuel*	DPM, PM, NO_x, and SO_x	2000 – Tier I 2011 – Tier II 2016 – Tier III	Auxiliary and propulsion category 3 engines on US flagged new built vessels and requires use of low sulfur fuel
California Air Resources Board (CARB)	Regulation to Reduce Emissions from Diesel Auxiliary Engines on Ocean-Going Vessels While At-Berth at a California Port *www.arb.ca.gov/regact/2007/shorepwr07/shorepwr07.htm* and *www.arb.ca.gov/ports/shorepower/forms/regulatoryadvisory/regulatoryadvisory12232013.pdf*	DPM, PM, NO_x, SO_x, CO_2	2014 – 50% 2017 – 70% 2020 – 80%	Shore power (or equivalent) requirements for vessel operators based on fleet percentage visiting the ports.
CARB	Ocean-going Ship Onboard Incineration *www.arb.ca.gov/ports/shipincin/shipincin.htm*	DPM, PM, and HC	2007	All vessels cannot incinerate waste within 3 nm of the California coast

Table 1.3: Harbor Craft Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
EPA	Emission Standards for Harbor Craft Engines *www.epa.gov/regulations-emissions-vehicles-and-engines/domestic-regulations-emissions-marine-compression*	All	2009 – Tier 3 2014 – Tier 4 for 800 hp or greater	Commercial marine diesel engines with displacement less than 30 liters per cylinder
CARB	Low Sulfur Fuel Requirement for Harbor Craft *www.arb.ca.gov/regact/carblohc/carblohc.htm*	DPM, PM, NO_x, and SO_x	2006 – 15 ppm in SCAQMD area	Use of low sulfur diesel fuel in commercial harbor craft
CARB	Regulation to Reduce Emissions from Diesel Engines on Commercial Harbor Craft *www.arb.ca.gov/regact/2010/chc10/chc10.htm*	DPM, PM, and NO_x	2009 to 2020 - schedule varies depending on engine model year	Most harbor craft must meet more stringent emissions limits according to a compliance schedule

Table 1.4: Cargo Handling Equipment Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
EPA	Emission Standards for Non-Road Diesel Powered Equipment *www.epa.gov/otaq/standards/nonroad/nonroadci.htm*	All	2008 through 2015	All non-road equipment
CARB	Cargo Handling Equipment Regulation *www.arb.ca.gov/regact/2011/cargo11/cargo11.htm*	All	2007 through 2017; Opacity test compliance starting in 2016	All Cargo handling equipment
CARB	New Emission Standards, Test Procedures, for Large Spark Ignition (LSI) Engine Forklifts and Other Industrial Equipment *www.arb.ca.gov/regact/2008/lsi2008/lsi2008.htm*	All	2007 – first phase 2010 – second phase	Emission standards for large spark-ignition engines with 25 hp or greater
CARB	Fleet Requirements for Large Spark Ignition Engines *www.arb.ca.gov/regact/2010/offroadlsi10/lsifinalreg.pdf*	All	2009 through 2013	More stringent emissions requirements for fleets of large spark-ignition engines equipment

Table 1.5: Locomotives Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
EPA	Emission Standards for New and Remanufactured Locomotives and Locomotive Engines- Latest Regulation *www.epa.gov/otaq/standards/nonroad/locomotives.htm*	DPM and NO_x	2011 through 2013 – Tier 3 2015 – Tier 4	All new and remanufactured locomotive engines
EPA	Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel *www.epa.gov/otaq/fuels/dieselfuels/regulations.htm*	SO_x and PM	2010	All locomotive engines
CARB	Low Sulfur Fuel Requirement for Intrastate Locomotives *www.arb.ca.gov/msprog/offroad/loco/loco.htm#intrastate*	SO_x, NO_x, and PM	2007	Intrastate locomotives, mainly switchers

Table 1.6: Heavy-Duty Vehicles Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
CARB/ EPA	Emission Standards for New 2007+ On-Road Heavy-Duty Vehicles *www.arb.ca.gov/msprog/onroadhd/reducstd.htm*	NO_x and PM	2007 2010	All new on-road diesel heavy-duty vehicles
CARB	Heavy-Duty Vehicle On-Board Diagnostics (OBD and OBDII) Requirement *https://ww2.arb.ca.gov/our-work/programs/obd*	NO_x and PM	2010 +	All new on-road heavy-duty vehicles
CARB	ULSD Fuel Requirement *www.arb.ca.gov/regact/ulsd2003/ulsd2003.htm*	All	2006 - ULSD	All on-road heavy-duty vehicles
CARB	Drayage Truck and Bus Regulation (amended in 2011 and 2014) *www.arb.ca.gov/msprog/onroad/porttruck/drayagevtruckbus.pdf*	All	Phase-in started in 2009	All drayage trucks operating at California ports
CARB	Low NO_x Software Upgrade Program 2007 *www.arb.ca.gov/msprog/hdsoftware/hdsoftware.htm*	NO_x	Starting 2005	1993 to 1998 on-road heavy-duty vehicles that operate in California
CARB	Heavy-Duty Vehicle Greenhouse Gas Emission Reduction Regulation *https://ww2.arb.ca.gov/sites/default/files/classic//cc/hdghg/hdghg_mockup.htm*	CO_2	Phase 1 started in 2012	Heavy-duty tractors that pull 53-foot+ trailers in California
CARB	Assembly Bill 32 requiring GHG reductions targets and Governor's Executive Order B – 30-15 *www.arb.ca.gov/cc/ab32/ab32.htm*	CO_2	GHG emissions reduction goals in 2020	All operations in California

SECTION 2 SUMMARY OF RESULTS

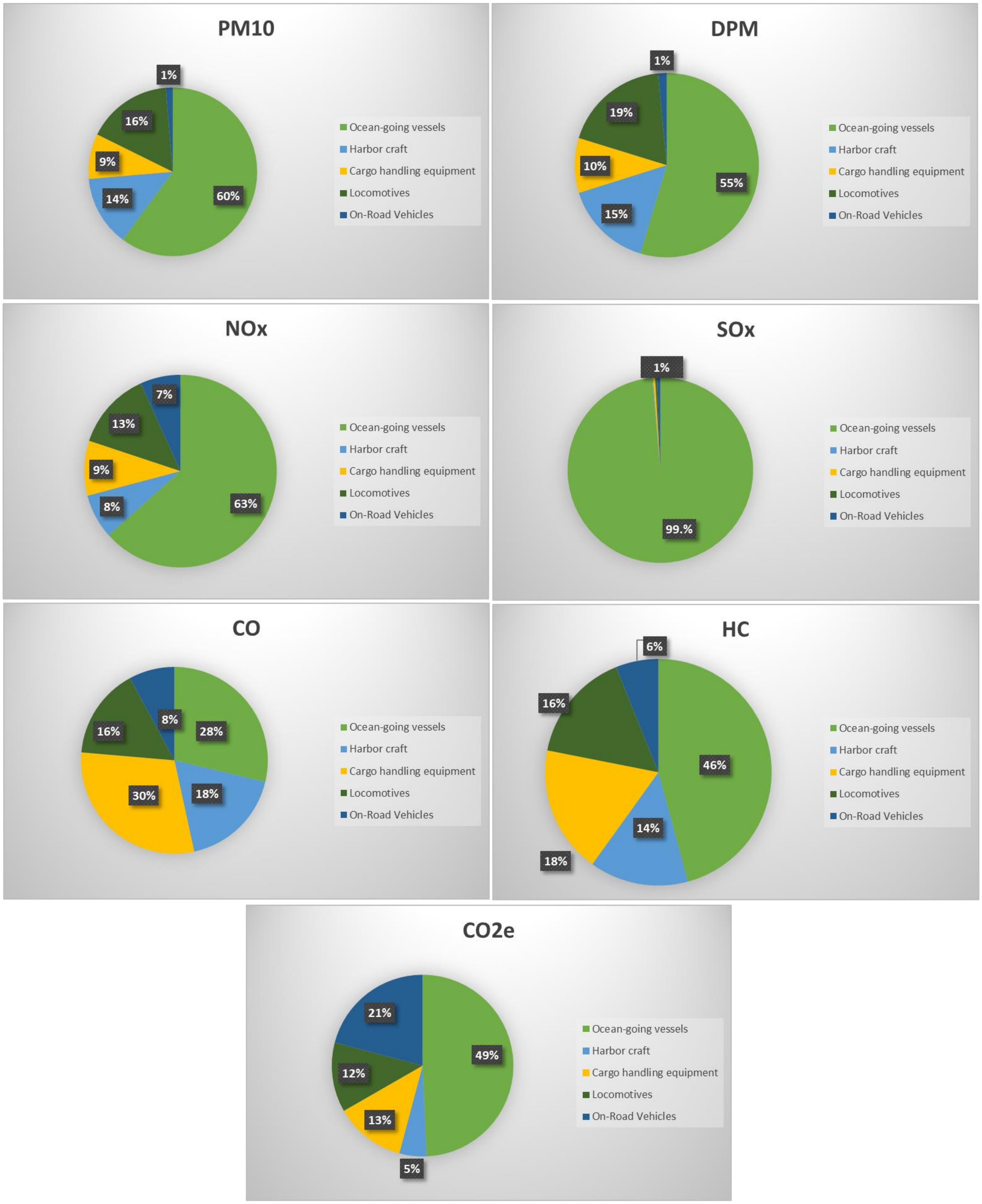
This section summarizes the air emissions for the Port of Stockton based on activity data for calendar year 2018. Greenhouse gas emissions in CO_2e are reported in units of metric tons (tonnes) per year; all other pollutants are shown in tons per year.

Table 2.1 presents the 2018 emissions estimates by category and Figure 2.1 presents the percent contribution of each category by pollutant. The OGV category emissions dominate the Port's total emissions ranging from 31% (CO) to 99% (SO_x) of the total depending on the pollutant. The other four categories contribute somewhat equally to the remaining emissions apart from PM emissions from the on-road vehicles which are substantially less than the other categories.

Table 2.1: 2018 Emissions

	PM10	PM2.5	DPM	NOx	SOx	CO	HC	CO2e
	tons	tons	tons	tons	tons	tons	tons	tonnes
Ocean-going vessels	2.9	2.8	2.3	127.7	6.9	11.5	4.7	9,646
Harbor craft	0.65	0.60	0.65	15.03	0.01	7.15	1.45	946
Cargo handling equipment	0.42	0.38	0.41	18.57	0.03	11.92	1.87	2,460
Locomotives	0.79	0.72	0.79	26.43	0.02	6.31	1.62	2,424
On-Road Vehicles	0.06	0.06	0.06	13.64	0.04	3.16	0.63	4,090
Total	**4.82**	**4.57**	**4.21**	**201.37**	**7.00**	**40.04**	**10.26**	**19,565**

Figure 2.1: 2018 Emissions Distribution for each Pollutant



The Port's Scope 1 and Scope 2 GHG emissions are shown in Table 2.2. Majority of the emissions are from the combustion of natural gas followed by mobile source tailpipe emissions and emissions from generating the electricity purchased and used by the Port.

Table 2.2: Port's 2018 Scope 1 & 2 GHG (CO_2e) Emissions, tonnes

Emissions Scope	Source		CO2e tonnes
Scope 1	Port Stationary Sources	Natural Gas Combustion	1,994
	Port Mobile Sources	Cargo Handling Eqipment and Passenger Vehicles (Light and Medium Duty Trucks and Automobiles) - Exhaust	1,133
Scope 2	Port Stationary Sources	Purchased Electricity	146
Total			3,272

SECTION 3 OCEAN-GOING VESSELS

This section presents emission estimates for the ocean-going vessels source category as well as source descriptions, data acquisition, and emissions estimation methodology.

3.1 Source Description

The vessel types that called the Port of Stockton and are included in this study are:

- **Bulk carrier** – vessels with open holds to carry various bulk dry goods, such as grain, salt, sugar, petroleum coke, and other fine-grained commodities.
- **General cargo** – vessels that are designed to carry a diverse range of cargo in their holds and on their decks, such as bulk metals, machinery, yachts, and palletized goods.
- **Tanker** –vessels that transport liquids in bulk, such as oil, chemicals, or other specialty goods, such as liquid fertilizers. Tankers are classified based on their size and can range from handysize (10,000 to 30,000 tons) to ultra-large (320,000+ tons). The tankers that visited the Port were the smaller category Chemical tankers and handysize tankers.

Figure 3.1: Typical Ocean-Going Vessels at the Port of Stockton

Emissions are estimated from the following sources on board ocean-going vessels (OGVs):

- Propulsion systems or propulsion engines that move the ship through the water;
- Auxiliary power systems or auxiliary engines (diesel generators) that provide electricity during ship operations; and
- Auxiliary boilers that produce hot water and steam for use in the engine room and for crew amenities.

Incinerators are not included in the emission estimates because incinerators are not used within the study area. CARB's regulation prohibits operating ship incinerators within three (3) nautical miles of the shore. Since the Port is an inland facility, vessels maneuvering within the study area would be subject to this regulation.

A vessel call is counted as a first arrival to a berth, excluding shifts. Vessel activities for vessels that called at the Port were identified as the following trip types:

- Arrivals – inbound trips from the inventory boundary to berth
- Departures – outbound trips from a berth to the inventory boundary
- Shifts – intra-port trips between terminals and ship repositioning

Vessel activity and emissions are estimated for two modes:

- Maneuvering – vessel operation from the inventory boundary to one of the Port's berths. It is assumed that the propulsion and auxiliary engines, and auxiliary boilers are operating.
- At Berth – The vessel has arrived at the berth for loading or unloading. Propulsion engines are shut off and auxiliary boilers are operating.

3.2 Data Acquisition

The following sources of data and operational knowledge about the Port's marine activities are used to compile the data necessary to estimate emissions from OGVs:

- Port vessel activity data
- IHS Markit (IHS) data
- Discussions with San Francisco Bar Pilots
- Starcrest's Vessel Boarding Program (VBP) data

Table 3.1 summarizes the vessel activities (arrival, departure, shift) provided by the Port for calendar year 2018. Figure 3.2 shows that the majority of the vessel calls are bulkers and tankers.

Table 3.1: Total OGV Activities in 2018

Category	Arrival	Departure	Shift	Total
Bulk	129	128	6	263
General Cargo	19	19	0	38
Tanker	65	64	10	139
2018 Total	**213**	**211**	**16**	**440**

Figure 3.2: Distribution of Arrivals by Vessel Type

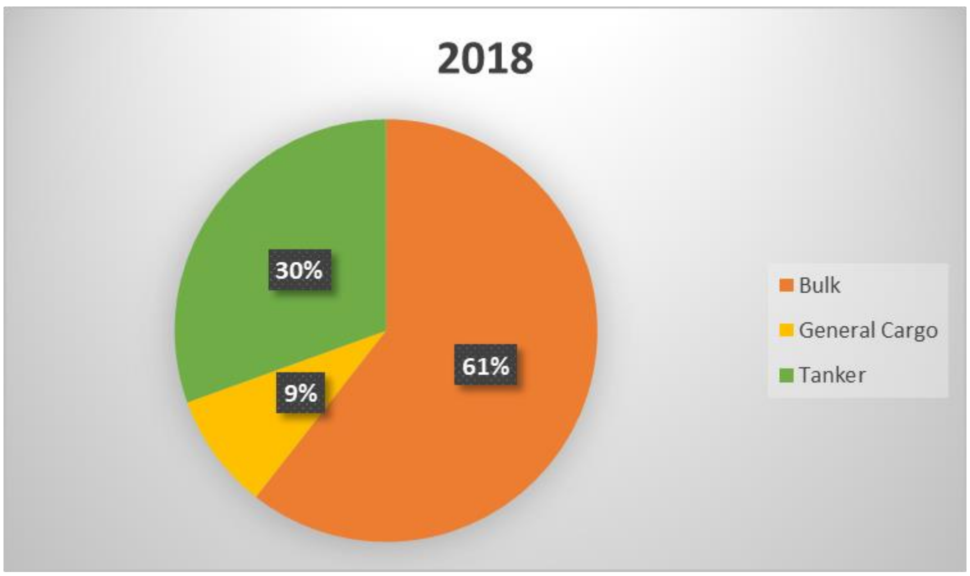


Table 3.2 shows the hotelling times in hours at berth. General Cargo has the longest average berth times followed by bulkers and then tankers. At-berth hours presented below are the total time spent by the vessel.

Table 3.2: Hotelling Times at Berth

Vessel Type	Min Hours	Max Hours	Avg Hours
2018			
Bulk	11	418	76
General Cargo	6	246	101
Tanker	6	223	42

3.3 Emission Estimation Methodology

Vessel activity data and the methods of estimating emissions are discussed below for propulsion engines, auxiliary engines, and auxiliary boilers. Differences in methods of emissions estimation for various modes of operation, maneuvering and at berth, are discussed where applicable. In general, emissions are estimated as a function of a vessel's engine energy demand with energy expressed in kW-hr multiplied by an emission factor, where the emission factor is expressed in terms of grams per kilowatt-hour (g/kW-hr). Emission factor adjustments (for different propulsion engine loads, different fuel usage, or emission controls) are then applied to reflect actual engine operations and associated emissions. Equations 3.1 and 3.2 report the basic equations used in estimating emissions by mode.

Equation 3.1

$$E_i = Energy_i \times EF \times FCF \times CF$$

Where:

E_i = Emissions by mode, grams
$Energy_i$ = Energy demand by mode, calculated using Equation 3.2 below as the energy output of the engine(s) or boiler(s), kW-hr
EF = Emission factor, expressed in terms of g/kWh, depends on engine type, IMO level of NO_x control (tier) and fuel used
FCF = Fuel correction factors are used to adjust from a base fuel associated with the EF and the fuel being used, dimensionless
CF = Control factor(s) for emission reduction technologies, dimensionless

The 'Energy' term of the equation is where most of the location-specific information is used. Energy by mode is calculated using Equation 3.2:

Equation 3.2

$$Energy_i = Load_i \times Activity_i$$

Where:

$Energy_i$ = Energy demand by mode, kW-hr
$Load_i$ = maximum continuous rated (MCR) propulsion engine power times load factor (LF which is an estimate of the percent of total power being used during operation), kW; reported auxiliary engine(s) operational load by mode i, kW; or auxiliary boiler operational load by mode i, kW
$Activity_i$ = time of activity for mode i, hours

3.4 Propulsion Engine Maximum Continuous Rated Power (MCR)

MCR power is defined as the manufacturer's tested maximum engine power and is used to determine propulsion engine load by mode. The international convention is to document MCR in kilowatts, and it is the highest power available from a ship engine during average cargo and sea conditions. For this study the 'Power' value in the IHS data is assumed to be the best proxy for MCR power.

3.5 Propulsion Engine Load Factor

The propulsion engine load factor is used to estimate how much of the propulsion engine(s') MCR is being used. The propulsion engine load factor is estimated using the Propeller Law, which states that propulsion engine load varies with the cube of the ratio of actual speed to the ship's maximum rated speed, as illustrated by the following equation.

Equation 3.3

$$LF = (Speed_{Actual} / Speed_{Maximum})^3$$

Where:

LF = load factor, dimensionless
$Speed_{Actual}$ = actual speed, knots
$Speed_{Maximum}$ = maximum speed, knots

For the purpose of estimating emissions, the lower limit of the load factor is set to 2% as the minimum load for a propulsion engine to work properly.

San Francisco Bar pilots report that vessels traveling in the narrow channels of the study area experience the phenomenon of "squat," in which vessels require additional power to overcome the increased water resistance caused by the narrow channel. It was assumed that the additional power required of vessels traveling at or above five knots in the San Joaquin River would increase the vessel's average propulsion engine load by 10%. Therefore, equation 3.4 was used when calculating the main engine load for vessels maneuvering at or greater than 5 knots in the study area.

Equation 3.4

$$LFx = LF + 10\%$$

Where:

LFx = calculated load factor for maneuvering zone segments where vessels travel at 5 knots or more
LF = load factor as calculated using Equation 3.3

3.6 Propulsion Engine Activity

Activity is measured in hours of operation. At-berth times were determined from the Port's arrival and departure data. Time in the maneuvering mode within the inventory domain is estimated using equation 3.5 which divides the segment distance traveled by ship speed. Speeds in the maneuvering area are based on discussions with the San Francisco Bar Pilots about typical vessel operation. Distances in the maneuvering area were calculated from GIS information. The inventory domain for OGV includes maneuvering:

- to and from the harbor along the San Joaquin River to the SJVAPCD boundary where ship speeds are assumed to be 6 knots and distance traveled is approximately 12 nautical miles, and
- to and from the entrance of the harbor to berth where ships are assumed to travel 1.5 nautical miles at a speed of 1-2 knots.
- vessel engine activity hours during maneuvering from the harbor entrance to berth was estimated to be 1.5 hrs for inbound vessels and 1.75 hrs for outbound vessels based on Equation 3.5. The departure time is higher than arrival because the time required to turn the vessel is attributed to departure, while in actual operation, it could occur either at arrival or departure.

Equation 3.5

$$Activity = D/Speed_{Actual}$$

Where:
Activity = activity, hours
D = distance, nautical miles
$Speed_{Actual}$ = actual ship speed, knots

3.7 Propulsion Engine Emission Factors

Diesel cycle engines are the most prevalent type of propulsion engines on vessels that visit the Port. The two predominant diesel propulsion engine types installed on vessels are:

- Slow speed diesel engines, having maximum engine speeds less than 130 rpm
- Medium speed diesel engines, having maximum engine speeds over 130 rpm (typically greater than 400 rpm) and less than 2,000 rpm.

The propulsion engine emission factors used in this study were reported in the ENTEC 2002 study,[6] except for PM, CO and greenhouse gas emission factors. The PM emission factors were provided by CARB[7]. An IVL Swedish Environmental Research Institute 2004 study[8] was the source for the PM emission factors for steamship and gas turbine vessels, as well as the CO and greenhouse gas emission factors for CO_2, and N_2O. Per IVL 2004 study data, CH_4 is assumed to be 2% of HC emission factors.

The SO_x emission factor is based on the following equations[9] for HFO fuel with 2.7% sulfur content:

Equation 3.6

$$SO_2\ EF = BSFC\ x\ 2\ x\ 0.97753\ x\ (Fuel\ Sulfur\ Fraction)$$

Where:
SO_2 EF = SO_x emission factor (g/kW/hr)
BSFC = brake specific fuel consumption in g/kW-hr
0.97753 is the fraction of fuel sulfur converted to SO_2 and 2 is the ratio of molecular weights of SO_2 and S.

[6] ENTEC, *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community, Final Report*, July 2002
[7] CARB, A Critical Review of Ocean-Going Vessel Particulate Matter Emission Factors, November 2007
[8] IVL, *Methodology for Calculating Emissions from Ships: Update on Emission Factors,* 2004. (IVL 2004)
[9] Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report, April 2009

The base emission factors are based on residual fuel oil/heavy fuel oil (HFO) with average sulfur content of 2.7%. IMO has established NO_x emission standards for marine diesel engines.[10] For regulatory purposes, all diesel cycle fuel oil/marine distillate fueled engines are divided into Tier 0 to Tier III as per the NO_x standards and by engine rated speed, in revolutions per minute or rpm, as listed below:

- Slow speed engines: less than 130 rpm
- Medium speed engines: between 130 and 2,000 rpm
- High speed engines: greater than or equal to 2,000 rpm

As of January 2015, all vessels are assumed to be compliant with the CARB fuel regulation (MDO/MDO 0.1% sulfur content and the IMO North American Emissions Control Area (ECA) requirement to use 0.1% sulfur (S) content fuel. The emission factors for base fuel (HFO with 2.7% sulfur content) and compliant fuel are shown in tables 3.3 and 3.4.

Table 3.3: Pollutant Emission Factors for Diesel Propulsion Engines, g/kWh[11]

Using 2.7% Sulfur HFO Fuel									
Engine Category	**IMO Tier**	**Model Year Range**	**PM_{10}**	**$PM_{2.5}$**	**DPM**	**NO_x**	**SOx**	**CO**	**HC**
Slow speed propulsion	Tier 0	1999 and older	1.50	1.20	1.50	18.1	10.5	1.4	0.6
Slow speed propulsion	Tier I	2000 to 2010	1.50	1.20	1.50	17.0	10.5	1.4	0.6
Slow speed propulsion	Tier II	2011 to 2015	1.50	1.20	1.50	15.3	10.5	1.4	0.6
Slow speed propulsion	Tier III	2016 and newer	1.50	1.20	1.50	3.6	10.5	1.4	0.6
Medium speed propulsion	Tier 0	1999 and older	1.50	1.20	1.50	14.0	11.5	1.1	0.5
Medium speed propulsion	Tier I	2000 to 2010	1.50	1.20	1.50	13.0	11.5	1.1	0.5
Medium speed propulsion	Tier II	2011 to 2015	1.50	1.20	1.50	11.2	11.5	1.1	0.5
Medium speed propulsion	Tier III	2016 and newer	1.50	1.20	1.50	2.8	11.5	1.1	0.5
Gas turbine	na	All	0.05	0.04	0.00	6.1	16.5	0.2	0.1
Steam propulsion engine and boiler	na	All	0.80	0.64	0.00	2.1	16.5	0.2	0.1
Using 0.1% S MGO Fuel									
Slow speed propulsion	Tier 0	1999 and older	0.255	0.240	0.255	17.01	0.389	1.4	0.6
Slow speed propulsion	Tier I	2000 to 2010	0.255	0.240	0.255	15.98	0.389	1.4	0.6
Slow speed propulsion	Tier II	2011 to 2015	0.255	0.240	0.255	14.38	0.389	1.4	0.6
Slow speed propulsion	Tier III	2016 and newer	0.255	0.240	0.255	3.38	0.389	1.4	0.6
Medium speed propulsion	Tier 0	1999 and older	0.255	0.240	0.255	13.16	0.426	1.1	0.5
Medium speed propulsion	Tier I	2000 to 2010	0.255	0.240	0.255	12.22	0.426	1.1	0.5
Medium speed propulsion	Tier II	2011 to 2015	0.255	0.240	0.255	10.53	0.426	1.1	0.5
Medium speed propulsion	Tier III	2016 and newer	0.255	0.240	0.255	2.63	0.426	1.1	0.5
Gas turbine	na	All	0.009	0.008	0.000	5.73	0.611	0.2	0.1
Steam propulsion engine and boiler	na	All	0.136	0.128	0.000	1.97	0.611	0.2	0.1

[10] See: *https://www.dieselnet.com/standards/inter/imo.php*

[11] Emission Factors for 0.1%S MGO fuel are calculated by multiplying the emission factors for 2.7%S HFO fuel by the appropriate fuel correction factor.

Table 3.4: GHG Emission Factors for Diesel Propulsion Engines, g/kWh

Using 2.7% Sulfur HFO Fuel					
Engine Category	**IMO Tier**	**Model Year Range**	**CO_2**	**N_2O**	**CH_4**
Slow speed propulsion	Tier 0	1999 and older	620	0.031	0.012
Slow speed propulsion	Tier I	2000 to 2010	620	0.031	0.012
Slow speed propulsion	Tier II	2011 to 2015	620	0.031	0.012
Slow speed propulsion	Tier III	2016 and newer	620	0.031	0.012
Medium speed propulsion	Tier 0	1999 and older	683	0.031	0.010
Medium speed propulsion	Tier I	2000 to 2010	683	0.031	0.010
Medium speed propulsion	Tier II	2011 to 2015	683	0.031	0.010
Medium speed propulsion	Tier III	2016 and newer	683	0.031	0.010
Gas turbine	na	All	970	0.08	0.002
Steam propulsion engine and boiler	na	All	970	0.08	0.002
Using 0.1% S MGO Fuel					
Slow speed propulsion	Tier 0	1999 and older	589	0.029	0.012
Slow speed propulsion	Tier I	2000 to 2010	589	0.029	0.012
Slow speed propulsion	Tier II	2011 to 2015	589	0.029	0.012
Slow speed propulsion	Tier III	2016 and newer	589	0.029	0.012
Medium speed propulsion	Tier 0	1999 and older	649	0.029	0.010
Medium speed propulsion	Tier I	2000 to 2010	649	0.029	0.010
Medium speed propulsion	Tier II	2011 to 2015	649	0.029	0.010
Medium speed propulsion	Tier III	2016 and newer	649	0.029	0.010
Gas turbine	na	All	922	0.075	0.002
Steam propulsion engine and boiler	na	All	922	0.075	0.002

The SO_x FCF for all fuel switching scenarios are basically the difference in S content of the baseline fuel and the actual fuel used. Equation 3.6 described earlier is used as the base to develop the SO_x FCFs for all S contents in the fuel. PM, $PM_{2.5}$, DPM, NO_x and CO_2 FCF for switching from HFO to MDO/MGO with 0.1% S level fuels were obtained from CARB during their regulatory activities related to fuel switching regulations as included in their OGV EI access model[12].

[12] *See: https://www.arb.ca.gov/ports/marinevess/ogv/ogv1085.htm*

Table 3.5 shows existing FCF for all pollutants and GHG.

Table 3.5: Fuel Correction Factors for Ocean Going Vessels, Dimensionless

Baseline Fuel and % S	Used Fuel and % S	PM_{10}	$PM_{2.5}$	DPM	NOx	SOx	CO	HC	CO_2	N_2O	CH_4
HFO (2.7%)	MGO (0.1%)	0.17	0.20	0.17	0.94	0.037	1.00	1.00	0.95	0.94	1.00

3.8 Propulsion Engines Low Load Emission Factor Adjustments

In general terms, diesel-cycle engines are not as efficient when operated at low loads compared with higher load operation. An EPA study[13] prepared by Energy and Environmental Analysis, Inc. (EEAI) established a formula for calculating emission factors for 2-stroke slow speed diesel engines at engine loads below 20%, conditions such as those encountered during harbor maneuvering and when traveling slowly at sea (e.g. in the reduced speed zone) This formula was later used and described in a study conducted for the EPA by ENVIRON.[14] While mass emissions in pounds per hour tend to go down as vessel speeds and engine loads decrease, the emission factors in g/kW-hr increase.

Equation 3.7 is the equation developed by EEAI to generate emission factors for the range of load factors from 2% to 20% for each pollutant:

Equation 3.7

$$\boldsymbol{y = a\,(fractional\ load)^{-x} + b}$$

Where:

y = emissions, g/kW-hr
a = coefficient, dimensionless
b = intercept, dimensionless
x = exponent, dimensionless
fractional load = propulsion engine load factor (2% - 20%), derived from the Propeller Law, percent

Table 3.6 presents the variables for equation 3.7.

Table 3.6: Low-Load Emission Factor Regression Equation Variables

Pollutant	Exponent (x)	Intercept (b)	Coefficient (a)
PM	1.5	0.2551	0.0059
NO_x	1.5	10.4496	0.1255
CO	1.0	0.1548	0.8378
HC	1.5	0.3859	0.0667

[13] EPA, *Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data,* February 2000
[14] EPA, *Commercial Marine Inventory Development,* July 2002

The base emission factors at 20% engine load used in the development of the low-load regression equation are not the currently accepted emission factors for OGV propulsion engines. Therefore, low-load adjustment (LLA) multipliers were developed by dividing the emission factors for each load increment between 2% and 20% by the emission factor at 20% load. These LLA multipliers are listed in Table 3.7. In keeping with the emission estimating practice of assuming a minimum propulsion engine load of 2%, the table of LLA factors does not include values for 1% load. During emission estimation, the LLA factors are multiplied by the latest emission factors for 2-stroke (slow speed) non-MAN diesel propulsion engines, adjusted for fuel differences between the actual fuel and the fuel used when the emission factors were developed. Adjustments to N_2O and CH_4 emission factors are made based on the NO_x and HC low load adjustments, respectively. Load adjustment factors for slow speed MAN diesel engines are discussed later in this section. The LLA adjustments are applied only to non-MAN engines at loads less than 20%. Low load emission factor adjustments do not apply to medium speed diesel engines, steamships or gas turbines because the EPA study referenced above only observed an increase in emissions from 2-stroke slow speed diesel engines.

Table 3.7: Low Load Adjustment Multipliers for Slow Speed non MAN Diesel Emission Factors[15]

Load	PM	NO_x	SO_2	CO	HC	CO_2	N_2O	CH_4
2%	7.29	4.63	3.30	9.68	21.18	3.28	4.63	21.18
3%	4.33	2.92	2.45	6.46	11.68	2.44	2.92	11.68
4%	3.09	2.21	2.02	4.86	7.71	2.01	2.21	7.71
5%	2.44	1.83	1.77	3.89	5.61	1.76	1.83	5.61
6%	2.04	1.60	1.60	3.25	4.35	1.59	1.60	4.35
7%	1.79	1.45	1.47	2.79	3.52	1.47	1.45	3.52
8%	1.61	1.35	1.38	2.45	2.95	1.38	1.35	2.95
9%	1.48	1.27	1.31	2.18	2.52	1.31	1.27	2.52
10%	1.38	1.22	1.26	1.96	2.18	1.25	1.22	2.18
11%	1.30	1.17	1.21	1.79	1.96	1.21	1.17	1.96
12%	1.24	1.14	1.17	1.64	1.76	1.17	1.14	1.76
13%	1.19	1.11	1.14	1.52	1.60	1.14	1.11	1.60
14%	1.15	1.08	1.11	1.41	1.47	1.11	1.08	1.47
15%	1.11	1.06	1.09	1.32	1.36	1.08	1.06	1.36
16%	1.08	1.05	1.06	1.24	1.26	1.06	1.05	1.26
17%	1.06	1.03	1.05	1.17	1.18	1.04	1.03	1.18
18%	1.04	1.02	1.03	1.11	1.11	1.03	1.02	1.11
19%	1.02	1.01	1.01	1.05	1.05	1.01	1.01	1.05
20%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

[15] The LLA multipliers for N_2O and CH_4 are based on NO_x and HC, respectively.

The low load emission factor is calculated for each pollutant using Equation 3.7.

Equation 3.7

$$\boldsymbol{EF = Adjusted\ EF \times LLA}$$

Where:

EF = calculated low load emission factor, expressed in terms of g/kW-hr
Adjusted EF = fuel adjusted emission factor for 2-stroke diesel propulsion engines, g/kW-hr
LLA = low load adjustment multiplier, dimensionless

The emission factors for MAN 2-stroke propulsion (main) engines were adjusted as a function of engine load using test data from the San Pedro Bay Ports' (SPBP) *MAN Slide Valve Low-Load Emissions Test Final Report* (Slide Valve Test)[16] completed under the SPBP Technology Advancement Program (TAP) in conjunction with MAN and Mitsui. The following enhancements are incorporated into the emissions estimates for applicable propulsion engines based on the findings of the study.

- Emission factor adjustment (EFA) is applied to pollutants for which test results were significantly different in magnitude than the base emission factors used in the inventory. A slide valve EFA (EFA_{SV}) is applied only to vessels equipped with slide valves (SV), which include 2004 or newer MAN 2-stroke engines and as identified in the HIS database as having slide valves. A conventional nozzle (C3) EFA (EFA_{C3}) is used for all other MAN 2-stroke engines, which are typically older than 2004 vessels. EFAs were developed by compositing the test data into the E3 duty cycle load weighting and comparing them to the E3-based EFs used in the inventories. The following EFAs are used:
  a. NO_x: $EFA_{SV} = 1.0$ $EFA_{C3} = 1.0$
  b. PM: $EFA_{SV} = 1.0$ $EFA_{C3} = 1.0$
  c. THC[17]: $EFA_{SV} = 0.43$ $EFA_{C3} = 1.0$
  d. CO: $EFA_{SV} = 0.59$ $EFA_{C3} = 0.44$
  e. CO_2: $EFA_{SV} = 1.0$ $EFA_{C3} = 1.0$
- Load adjustment factors (LAF) are calculated and applied to the EF x EFA across all loads (0% to 100%). The LAF is pollutant based and valve specific (SV or C3), using the same criteria as stated above for EFA. The adjusted equation for estimating OGV MAN propulsion engine emission factor is:

Equation 3.9

$$\boldsymbol{EF = Adjusted\ EF \times EFA \times LAFi}$$

Where:

EF = calculated low load emission factor, g/kW-hr
Adjusted EF = fuel adjusted emission factor for 2-stroke diesel propulsion engine. g/kW-hr
EFA = emission factor adjustment by pollutant or GHG, dimensionless
LAF_i = load adjustment factor, dimensionless

[16] As referenced in the Emission Estimating Methodology and Enhancements Section.
[17] Used for HC

Tables 3.8 and 3.9 present the LAFs used across the entire engine load range.

Table 3.8: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Slide Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
1%	0.36	0.36	0.36	1.90	1.10	0.12	1.36	1.10	1.90	1.36
2%	0.37	0.37	0.37	1.86	1.10	0.12	1.32	1.10	1.86	1.32
3%	0.38	0.38	0.38	1.82	1.09	0.12	1.28	1.09	1.82	1.28
4%	0.38	0.38	0.38	1.78	1.09	0.12	1.24	1.09	1.78	1.24
5%	0.39	0.39	0.39	1.74	1.09	0.12	1.20	1.09	1.74	1.20
6%	0.40	0.40	0.40	1.70	1.08	0.12	1.17	1.08	1.70	1.17
7%	0.41	0.41	0.41	1.67	1.08	0.12	1.14	1.08	1.67	1.14
8%	0.41	0.41	0.41	1.63	1.08	0.12	1.11	1.08	1.63	1.11
9%	0.42	0.42	0.42	1.60	1.07	0.12	1.08	1.07	1.60	1.08
10%	0.43	0.43	0.43	1.57	1.07	0.12	1.05	1.07	1.57	1.05
11%	0.44	0.44	0.44	1.53	1.07	0.26	1.02	1.07	1.53	1.02
12%	0.45	0.45	0.45	1.50	1.07	0.39	0.99	1.07	1.50	0.99
13%	0.45	0.45	0.45	1.47	1.06	0.52	0.97	1.06	1.47	0.97
14%	0.46	0.46	0.46	1.45	1.06	0.64	0.94	1.06	1.45	0.94
15%	0.47	0.47	0.47	1.42	1.06	0.75	0.92	1.06	1.42	0.92
16%	0.48	0.48	0.48	1.39	1.06	0.85	0.90	1.06	1.39	0.90
17%	0.49	0.49	0.49	1.37	1.05	0.95	0.88	1.05	1.37	0.88
18%	0.49	0.49	0.49	1.34	1.05	1.04	0.86	1.05	1.34	0.86
19%	0.50	0.50	0.50	1.32	1.05	1.12	0.84	1.05	1.32	0.84
20%	0.51	0.51	0.51	1.30	1.05	1.20	0.82	1.05	1.30	0.82
21%	0.52	0.52	0.52	1.28	1.04	1.27	0.81	1.04	1.28	0.81
22%	0.53	0.53	0.53	1.26	1.04	1.34	0.79	1.04	1.26	0.79
23%	0.54	0.54	0.54	1.24	1.04	1.40	0.78	1.04	1.24	0.78
24%	0.54	0.54	0.54	1.22	1.04	1.46	0.76	1.04	1.22	0.76
25%	0.55	0.55	0.55	1.20	1.03	1.51	0.75	1.03	1.20	0.75

Table 3.8: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Slide Valves (cont'd)

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
26%	0.56	0.56	0.56	1.19	1.03	1.55	0.74	1.03	1.19	0.74
27%	0.57	0.57	0.57	1.17	1.03	1.59	0.73	1.03	1.17	0.73
28%	0.58	0.58	0.58	1.16	1.03	1.63	0.72	1.03	1.16	0.72
29%	0.59	0.59	0.59	1.14	1.03	1.66	0.71	1.03	1.14	0.71
30%	0.60	0.60	0.60	1.13	1.02	1.68	0.70	1.02	1.13	0.70
31%	0.60	0.60	0.60	1.12	1.02	1.70	0.70	1.02	1.12	0.70
32%	0.61	0.61	0.61	1.10	1.02	1.72	0.69	1.02	1.10	0.69
33%	0.62	0.62	0.62	1.09	1.02	1.74	0.69	1.02	1.09	0.69
34%	0.63	0.63	0.63	1.08	1.02	1.75	0.68	1.02	1.08	0.68
35%	0.64	0.64	0.64	1.07	1.02	1.75	0.68	1.02	1.07	0.68
36%	0.65	0.65	0.65	1.06	1.01	1.75	0.68	1.01	1.06	0.68
37%	0.66	0.66	0.66	1.05	1.01	1.75	0.67	1.01	1.05	0.67
38%	0.67	0.67	0.67	1.05	1.01	1.75	0.67	1.01	1.05	0.67
39%	0.68	0.68	0.68	1.04	1.01	1.74	0.67	1.01	1.04	0.67
40%	0.69	0.69	0.69	1.03	1.01	1.73	0.67	1.01	1.03	0.67
41%	0.70	0.70	0.70	1.03	1.01	1.72	0.67	1.01	1.03	0.67
42%	0.70	0.70	0.70	1.02	1.01	1.71	0.68	1.01	1.02	0.68
43%	0.71	0.71	0.71	1.02	1.01	1.69	0.68	1.01	1.02	0.68
44%	0.72	0.72	0.72	1.01	1.00	1.67	0.68	1.00	1.01	0.68
45%	0.73	0.73	0.73	1.01	1.00	1.65	0.69	1.00	1.01	0.69
46%	0.74	0.74	0.74	1.00	1.00	1.62	0.69	1.00	1.00	0.69
47%	0.75	0.75	0.75	1.00	1.00	1.60	0.70	1.00	1.00	0.70
48%	0.76	0.76	0.76	1.00	1.00	1.57	0.70	1.00	1.00	0.70
49%	0.77	0.77	0.77	0.99	1.00	1.54	0.71	1.00	0.99	0.71
50%	0.78	0.78	0.78	0.99	1.00	1.51	0.71	1.00	0.99	0.71

Table 3.8: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Slide Valves (cont'd)

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
51%	0.79	0.79	0.79	0.99	1.00	1.48	0.72	1.00	0.99	0.72
52%	0.80	0.80	0.80	0.99	1.00	1.45	0.73	1.00	0.99	0.73
53%	0.81	0.81	0.81	0.99	1.00	1.41	0.74	1.00	0.99	0.74
54%	0.82	0.82	0.82	0.99	1.00	1.38	0.75	1.00	0.99	0.75
55%	0.83	0.83	0.83	0.98	0.99	1.35	0.75	0.99	0.98	0.75
56%	0.84	0.84	0.84	0.98	0.99	1.31	0.76	0.99	0.98	0.76
57%	0.85	0.85	0.85	0.98	0.99	1.27	0.77	0.99	0.98	0.77
58%	0.86	0.86	0.86	0.98	0.99	1.24	0.78	0.99	0.98	0.78
59%	0.87	0.87	0.87	0.98	0.99	1.20	0.80	0.99	0.98	0.80
60%	0.88	0.88	0.88	0.98	0.99	1.16	0.81	0.99	0.98	0.81
61%	0.89	0.89	0.89	0.98	0.99	1.13	0.82	0.99	0.98	0.82
62%	0.90	0.90	0.90	0.98	0.99	1.09	0.83	0.99	0.98	0.83
63%	0.91	0.91	0.91	0.99	0.99	1.06	0.84	0.99	0.99	0.84
64%	0.92	0.92	0.92	0.99	0.99	1.02	0.85	0.99	0.99	0.85
65%	0.93	0.93	0.93	0.99	0.99	0.98	0.87	0.99	0.99	0.87
66%	0.94	0.94	0.94	0.99	0.99	0.95	0.88	0.99	0.99	0.88
67%	0.95	0.95	0.95	0.99	0.99	0.92	0.89	0.99	0.99	0.89
68%	0.97	0.97	0.97	0.99	0.99	0.88	0.91	0.99	0.99	0.91
69%	0.98	0.98	0.98	0.99	0.99	0.85	0.92	0.99	0.99	0.92
70%	0.99	0.99	0.99	0.99	0.99	0.82	0.93	0.99	0.99	0.93
71%	1.00	1.00	1.00	0.99	0.99	0.79	0.95	0.99	0.99	0.95
72%	1.01	1.01	1.01	0.99	0.99	0.76	0.96	0.99	0.99	0.96
73%	1.02	1.02	1.02	0.99	0.99	0.74	0.98	0.99	0.99	0.98
74%	1.03	1.03	1.03	0.99	0.99	0.71	0.99	0.99	0.99	0.99
75%	1.04	1.04	1.04	0.99	0.99	0.69	1.00	0.99	0.99	1.00

Table 3.8: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Slide Valves (cont'd)

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
76%	1.05	1.05	1.05	0.99	0.99	0.66	1.02	0.99	0.99	1.02
77%	1.06	1.06	1.06	0.99	0.99	0.64	1.03	0.99	0.99	1.03
78%	1.07	1.07	1.07	0.99	0.99	0.63	1.05	0.99	0.99	1.05
79%	1.09	1.09	1.09	0.99	0.99	0.61	1.06	0.99	0.99	1.06
80%	1.10	1.10	1.10	0.99	0.99	0.60	1.08	0.99	0.99	1.08
81%	1.11	1.11	1.11	0.99	0.99	0.58	1.09	0.99	0.99	1.09
82%	1.12	1.12	1.12	0.99	0.99	0.57	1.10	0.99	0.99	1.10
83%	1.13	1.13	1.13	0.98	0.99	0.57	1.12	0.99	0.98	1.12
84%	1.14	1.14	1.14	0.98	0.99	0.56	1.13	0.99	0.98	1.13
85%	1.15	1.15	1.15	0.98	0.99	0.56	1.15	0.99	0.98	1.15
86%	1.16	1.16	1.16	0.98	0.99	0.56	1.16	0.99	0.98	1.16
87%	1.18	1.18	1.18	0.97	0.99	0.56	1.18	0.99	0.97	1.18
88%	1.19	1.19	1.19	0.97	0.99	0.57	1.19	0.99	0.97	1.19
89%	1.20	1.20	1.20	0.96	0.99	0.58	1.20	0.99	0.96	1.20
90%	1.21	1.21	1.21	0.96	0.99	0.59	1.22	0.99	0.96	1.22
91%	1.22	1.22	1.22	0.95	1.00	0.61	1.23	1.00	0.95	1.23
92%	1.23	1.23	1.23	0.95	1.00	0.63	1.24	1.00	0.95	1.24
93%	1.25	1.25	1.25	0.94	1.00	0.65	1.25	1.00	0.94	1.25
94%	1.26	1.26	1.26	0.93	1.00	0.67	1.27	1.00	0.93	1.27
95%	1.27	1.27	1.27	0.93	1.00	0.70	1.28	1.00	0.93	1.28
96%	1.28	1.28	1.28	0.92	1.00	0.73	1.29	1.00	0.92	1.29
97%	1.29	1.29	1.29	0.91	1.00	0.77	1.30	1.00	0.91	1.30
98%	1.31	1.31	1.31	0.90	1.00	0.81	1.31	1.00	0.90	1.31
99%	1.32	1.32	1.32	0.89	1.00	0.85	1.32	1.00	0.89	1.32
100%	1.33	1.33	1.33	0.88	1.00	0.90	1.34	1.00	0.88	1.34

Table 3.9: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Conventional Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
1%	0.84	0.84	0.84	1.91	1.11	1.38	2.53	1.11	1.91	2.53
2%	0.83	0.83	0.83	1.86	1.11	1.36	2.45	1.11	1.86	2.45
3%	0.83	0.83	0.83	1.82	1.10	1.34	2.37	1.10	1.82	2.37
4%	0.82	0.82	0.82	1.77	1.10	1.33	2.30	1.10	1.77	2.30
5%	0.82	0.82	0.82	1.72	1.10	1.31	2.23	1.10	1.72	2.23
6%	0.81	0.81	0.81	1.68	1.09	1.29	2.16	1.09	1.68	2.16
7%	0.81	0.81	0.81	1.64	1.09	1.28	2.10	1.09	1.64	2.10
8%	0.80	0.80	0.80	1.60	1.09	1.26	2.03	1.09	1.60	2.03
9%	0.80	0.80	0.80	1.56	1.08	1.25	1.97	1.08	1.56	1.97
10%	0.79	0.79	0.79	1.52	1.08	1.24	1.91	1.08	1.52	1.91
11%	0.79	0.79	0.79	1.49	1.08	1.22	1.86	1.08	1.49	1.86
12%	0.78	0.78	0.78	1.45	1.07	1.21	1.80	1.07	1.45	1.80
13%	0.78	0.78	0.78	1.42	1.07	1.20	1.75	1.07	1.42	1.75
14%	0.78	0.78	0.78	1.39	1.07	1.19	1.70	1.07	1.39	1.70
15%	0.77	0.77	0.77	1.36	1.06	1.18	1.65	1.06	1.36	1.65
16%	0.77	0.77	0.77	1.33	1.06	1.17	1.61	1.06	1.33	1.61
17%	0.77	0.77	0.77	1.30	1.06	1.16	1.56	1.06	1.30	1.56
18%	0.77	0.77	0.77	1.28	1.06	1.15	1.52	1.06	1.28	1.52
19%	0.76	0.76	0.76	1.25	1.05	1.14	1.48	1.05	1.25	1.48
20%	0.76	0.76	0.76	1.23	1.05	1.13	1.44	1.05	1.23	1.44
21%	0.76	0.76	0.76	1.20	1.05	1.13	1.41	1.05	1.20	1.41
22%	0.76	0.76	0.76	1.18	1.05	1.12	1.37	1.05	1.18	1.37
23%	0.76	0.76	0.76	1.16	1.04	1.11	1.34	1.04	1.16	1.34
24%	0.75	0.75	0.75	1.14	1.04	1.10	1.31	1.04	1.14	1.31
25%	0.75	0.75	0.75	1.12	1.04	1.10	1.28	1.04	1.12	1.28

Table 3.9: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Conventional Valves (cont'd)

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
26%	0.75	0.75	0.75	1.11	1.04	1.09	1.25	1.04	1.11	1.25
27%	0.75	0.75	0.75	1.09	1.04	1.08	1.22	1.04	1.09	1.22
28%	0.75	0.75	0.75	1.07	1.03	1.08	1.20	1.03	1.07	1.20
29%	0.75	0.75	0.75	1.06	1.03	1.07	1.17	1.03	1.06	1.17
30%	0.75	0.75	0.75	1.05	1.03	1.07	1.15	1.03	1.05	1.15
31%	0.75	0.75	0.75	1.03	1.03	1.06	1.13	1.03	1.03	1.13
32%	0.75	0.75	0.75	1.02	1.03	1.06	1.11	1.03	1.02	1.11
33%	0.75	0.75	0.75	1.01	1.02	1.05	1.09	1.02	1.01	1.09
34%	0.75	0.75	0.75	1.00	1.02	1.05	1.08	1.02	1.00	1.08
35%	0.76	0.76	0.76	0.99	1.02	1.04	1.06	1.02	0.99	1.06
36%	0.76	0.76	0.76	0.98	1.02	1.04	1.05	1.02	0.98	1.05
37%	0.76	0.76	0.76	0.98	1.02	1.03	1.04	1.02	0.98	1.04
38%	0.76	0.76	0.76	0.97	1.02	1.03	1.02	1.02	0.97	1.02
39%	0.76	0.76	0.76	0.96	1.01	1.02	1.01	1.01	0.96	1.01
40%	0.76	0.76	0.76	0.96	1.01	1.02	1.00	1.01	0.96	1.00
41%	0.77	0.77	0.77	0.95	1.01	1.01	0.99	1.01	0.95	0.99
42%	0.77	0.77	0.77	0.95	1.01	1.01	0.99	1.01	0.95	0.99
43%	0.77	0.77	0.77	0.94	1.01	1.01	0.98	1.01	0.94	0.98
44%	0.78	0.78	0.78	0.94	1.01	1.00	0.97	1.01	0.94	0.97
45%	0.78	0.78	0.78	0.94	1.01	1.00	0.97	1.01	0.94	0.97
46%	0.78	0.78	0.78	0.94	1.01	0.99	0.96	1.01	0.94	0.96
47%	0.79	0.79	0.79	0.94	1.00	0.99	0.96	1.00	0.94	0.96
48%	0.79	0.79	0.79	0.93	1.00	0.98	0.96	1.00	0.93	0.96
49%	0.79	0.79	0.79	0.93	1.00	0.98	0.96	1.00	0.93	0.96
50%	0.80	0.80	0.80	0.93	1.00	0.98	0.96	1.00	0.93	0.96

Table 3.9: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Conventional Valves (cont'd)

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
51%	0.80	0.80	0.80	0.94	1.00	0.97	0.95	1.00	0.94	0.95
52%	0.81	0.81	0.81	0.94	1.00	0.97	0.95	1.00	0.94	0.95
53%	0.81	0.81	0.81	0.94	1.00	0.96	0.95	1.00	0.94	0.95
54%	0.82	0.82	0.82	0.94	1.00	0.96	0.95	1.00	0.94	0.95
55%	0.82	0.82	0.82	0.94	1.00	0.96	0.96	1.00	0.94	0.96
56%	0.83	0.83	0.83	0.94	1.00	0.95	0.96	1.00	0.94	0.96
57%	0.84	0.84	0.84	0.95	1.00	0.95	0.96	1.00	0.95	0.96
58%	0.84	0.84	0.84	0.95	1.00	0.95	0.96	1.00	0.95	0.96
59%	0.85	0.85	0.85	0.95	1.00	0.94	0.96	1.00	0.95	0.96
60%	0.86	0.86	0.86	0.95	0.99	0.94	0.97	0.99	0.95	0.97
61%	0.86	0.86	0.86	0.96	0.99	0.93	0.97	0.99	0.96	0.97
62%	0.87	0.87	0.87	0.96	0.99	0.93	0.97	0.99	0.96	0.97
63%	0.88	0.88	0.88	0.96	0.99	0.93	0.98	0.99	0.96	0.98
64%	0.89	0.89	0.89	0.97	0.99	0.93	0.98	0.99	0.97	0.98
65%	0.89	0.89	0.89	0.97	0.99	0.92	0.98	0.99	0.97	0.98
66%	0.90	0.90	0.90	0.98	0.99	0.92	0.99	0.99	0.98	0.99
67%	0.91	0.91	0.91	0.98	0.99	0.92	0.99	0.99	0.98	0.99
68%	0.92	0.92	0.92	0.98	0.99	0.91	0.99	0.99	0.98	0.99
69%	0.93	0.93	0.93	0.99	0.99	0.91	1.00	0.99	0.99	1.00
70%	0.94	0.94	0.94	0.99	0.99	0.91	1.00	0.99	0.99	1.00
71%	0.94	0.94	0.94	0.99	0.99	0.91	1.00	0.99	0.99	1.00
72%	0.95	0.95	0.95	1.00	0.99	0.91	1.01	0.99	1.00	1.01
73%	0.96	0.96	0.96	1.00	0.99	0.91	1.01	0.99	1.00	1.01
74%	0.97	0.97	0.97	1.00	0.99	0.91	1.01	0.99	1.00	1.01
75%	0.98	0.98	0.98	1.01	0.99	0.90	1.01	0.99	1.01	1.01

Table 3.9: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Conventional Valves (cont'd)

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
76%	0.99	0.99	0.99	1.01	0.99	0.90	1.01	0.99	1.01	1.01
77%	1.00	1.00	1.00	1.01	0.99	0.90	1.01	0.99	1.01	1.01
78%	1.01	1.01	1.01	1.01	0.99	0.91	1.01	0.99	1.01	1.01
79%	1.03	1.03	1.03	1.02	0.99	0.91	1.01	0.99	1.02	1.01
80%	1.04	1.04	1.04	1.02	0.99	0.91	1.01	0.99	1.02	1.01
81%	1.05	1.05	1.05	1.02	0.99	0.91	1.01	0.99	1.02	1.01
82%	1.06	1.06	1.06	1.02	0.99	0.91	1.01	0.99	1.02	1.01
83%	1.07	1.07	1.07	1.02	0.99	0.92	1.01	0.99	1.02	1.01
84%	1.08	1.08	1.08	1.02	0.99	0.92	1.00	0.99	1.02	1.00
85%	1.10	1.10	1.10	1.02	0.99	0.92	1.00	0.99	1.02	1.00
86%	1.11	1.11	1.11	1.02	0.99	0.93	0.99	0.99	1.02	0.99
87%	1.12	1.12	1.12	1.02	0.99	0.93	0.99	0.99	1.02	0.99
88%	1.13	1.13	1.13	1.02	0.99	0.94	0.98	0.99	1.02	0.98
89%	1.15	1.15	1.15	1.01	0.99	0.95	0.97	0.99	1.01	0.97
90%	1.16	1.16	1.16	1.01	0.99	0.95	0.97	0.99	1.01	0.97
91%	1.17	1.17	1.17	1.01	0.99	0.96	0.96	0.99	1.01	0.96
92%	1.19	1.19	1.19	1.00	0.99	0.97	0.94	0.99	1.00	0.94
93%	1.20	1.20	1.20	1.00	0.99	0.98	0.93	0.99	1.00	0.93
94%	1.22	1.22	1.22	0.99	0.99	0.99	0.92	0.99	0.99	0.92
95%	1.23	1.23	1.23	0.99	0.99	1.01	0.91	0.99	0.99	0.91
96%	1.24	1.24	1.24	0.98	0.99	1.02	0.89	0.99	0.98	0.89
97%	1.26	1.26	1.26	0.97	1.00	1.03	0.87	1.00	0.97	0.87
98%	1.28	1.28	1.28	0.97	1.00	1.05	0.86	1.00	0.97	0.86
99%	1.29	1.29	1.29	0.96	1.00	1.07	0.84	1.00	0.96	0.84
100%	1.31	1.31	1.31	0.95	1.00	1.08	0.82	1.00	0.95	0.82

3.9 Auxiliary Engine Emission Factors and Load Defaults

Vessels visiting the Port of Stockton are equipped with the following types of auxiliary engines:

- Medium speed diesel engines (most common), having maximum engine speeds over 130 rpm (typically greater than 400 rpm) and less than 2,000 rpm.
- High speed diesel engines, having maximum engine speeds equal to or greater than 2,000 rpm.

The basic emission factors (based on 2.7% sulfur content) were obtained from the ENTEC 2002 study, except for PM, CO and greenhouse gas emission factors. The PM emission factors were provided by CARB. IVL Swedish Environmental Research Institute's 2004 study was the source for the PM emission factors for gas turbine and steamship vessels, as well as the CO and greenhouse gas emission factors for CO_2, and N_2O. Per IVL 2004 study data, CH_4 were assumed to be 2% of HC emission factors[18]. The emission factors for base fuel (HFO with 2.7% sulfur content) and fuel currently being required by CARB regulation (MDO/MGO 0.1% sulfur content) and the IMO North American Emissions Control Area (ECA) requirements to use 0.1% sulfur content fuel are shown in tables 3.10 and 3.11. Like the propulsion engine emission factors, the 2.7% sulfur HFO base emission factors are multiplied by the appropriate pollutant FCF (see Table 3.1) to calculate the 0.1% S MGO emission factors. SO_x emission factors are based on equations described in earlier sections. As of January 2014, the auxiliary engines are using 0.1% S fuel due to the CARB and ECA requirements.

Table 3.10: Pollutant Emission Factors for Auxiliary Engines, g/kW-hr

Engine Category	IMO Tier	Model Year Range	PM_{10}	$PM_{2.5}$	DPM	NOx	SOx	CO	HC
Using 2.7% Sulfur HFO Fuel									
Medium speed auxiliary	Tier 0	1999 and older	1.50	1.20	1.50	14.70	12.3	1.1	0.4
Medium speed auxiliary	Tier I	2000 to 2010	1.50	1.20	1.50	13.00	12.3	1.1	0.4
Medium speed auxiliary	Tier II	2011 to 2015	1.50	1.20	1.50	11.20	12.3	1.1	0.4
Medium speed auxiliary	Tier III	2016 and newer	1.50	1.20	1.50	2.80	12.3	1.1	0.4
High speed auxiliary	Tier 0	1999 and older	1.50	1.20	1.50	11.60	12.3	0.9	0.4
High speed auxiliary	Tier I	2000 to 2010	1.50	1.20	1.50	10.40	12.3	0.9	0.4
High speed auxiliary	Tier II	2011 to 2015	1.50	1.20	1.50	8.20	12.3	0.9	0.4
High speed auxiliary	Tier III	2016 and newer	1.50	1.20	1.50	2.10	12.3	0.9	0.4
Using 0.1% S MGO Fuel									
Medium speed auxiliary	Tier 0	1999 and older	0.255	0.240	0.255	13.82	0.455	1.4	0.6
Medium speed auxiliary	Tier I	2000 to 2010	0.255	0.240	0.255	12.22	0.455	1.4	0.6
Medium speed auxiliary	Tier II	2011 to 2015	0.255	0.240	0.255	10.53	0.455	1.4	0.6
Medium speed auxiliary	Tier III	2016 and newer	0.255	0.240	0.255	2.63	0.455	1.4	0.6
High speed auxiliary	Tier 0	1999 and older	0.255	0.240	0.255	10.90	0.455	1.1	0.5
High speed auxiliary	Tier I	2000 to 2010	0.255	0.240	0.255	9.78	0.455	1.1	0.5
High speed auxiliary	Tier II	2011 to 2015	0.255	0.240	0.255	7.71	0.455	1.1	0.5
High speed auxiliary	Tier III	2016 and newer	0.255	0.240	0.255	1.97	0.455	1.1	0.5

[18] HC emission factors are HC/1.21

Table 3.11: GHG Emission Factors for Auxiliary Engines, g/kW-hr

Using 2.7% Sulfur HFO Fuel					
Engine Category	**IMO Tier**	**Model Year Range**	**CO_2**	**N_2O**	**CH_4**
Medium speed auxiliary	Tier 0	1999 and older	722	0.031	0.008
Medium speed auxiliary	Tier I	2000 to 2010	722	0.031	0.008
Medium speed auxiliary	Tier II	2011 to 2015	722	0.031	0.008
Medium speed auxiliary	Tier III	2016 and newer (	722	0.031	0.008
High speed auxiliary	Tier 0	1999 and older	690	0.031	0.008
High speed auxiliary	Tier I	2000 to 2010	690	0.031	0.008
High speed auxiliary	Tier II	2011 to 2015	690	0.031	0.008
High speed auxiliary	Tier III	2016 and newer	690	0.031	0.008
Using 0.1% S MGO Fuel					
Medium speed auxiliary	Tier 0	1999 and older	686	0.029	0.012
Medium speed auxiliary	Tier I	2000 to 2010	686	0.029	0.012
Medium speed auxiliary	Tier II	2011 to 2015	686	0.029	0.012
Medium speed auxiliary	Tier III	2016 and newer	686	0.029	0.012
High speed auxiliary	Tier 0	1999 and older	656	0.029	0.010
High speed auxiliary	Tier I	2000 to 2010	656	0.029	0.010
High speed auxiliary	Tier II	2011 to 2015	656	0.029	0.010
High speed auxiliary	Tier III	2016 and newer	656	0.029	0.010

The IHS Markit (IHS) database contains limited installed power information for auxiliary engines and no information on use by mode. Due to the lack of information in IHS, the primary data source for auxiliary load data is from Starcrest's Vessel Boarding Program (VBP) program where vessels are boarded at various ports and information related to engine load is collected on vessel operations by mode. Vessel data for sister-ships of the boarded vessels are also collected and utilized. When estimating auxiliary engine emissions, VBP operational data is first applied on a vessel by vessel basis if the vessel was boarded or it is a sister-ship to a boarded vessel. If the vessel is not in the VBP database, average auxiliary engine load defaults are derived from the VBP data and applied by vessel type. The fleet mix that called the Port in 2018 was compared to other ports and it was determined that an average of the latest published Port of Los Angeles and the Port of Long Beach default loads would be suitable surrogates when VBP data is not available. An average of auxiliary engine default loads from the Port of Los Angeles's 2019 Emissions Inventory,[19] and the Port of Long Beach's 2019 Emissions Inventory,[20] which was also based on VBP data, were used.

[19] See: *https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory*
[20] See: *https://www.polb.com/environment/air/#emissions-inventory*

Table 3.12 presents the auxiliary engine load defaults by vessel type, by mode, used to estimate emissions for 2018.

Table 3.12: 2018 Average Auxiliary Engine Load Defaults, kW

Vessel Type	Maneuvering	Berth Hotelling
Bulk	749	180
Bulk - Self Discharging	807	179
General Cargo	1250	647
Tanker -Handysize	685	713
Tanker - Chemical	862	892

3.10 Auxiliary Boiler Emission Factors and Load Defaults

In addition to the auxiliary engines that are used to generate electricity for on-board uses, most vessels have one or more auxiliary boilers used for fuel heating and for producing hot water and steam. Emission factors for the steam boilers listed in tables 3.13 and 3.14 are the same as for steam powered propulsion engines.

Table 3.13: Pollutant Emission Factors for Auxiliary Boilers, g/kW-hr

Engine Category	IMO Tier	Model Year Range	PM_{10}	$PM_{2.5}$	DPM	NOx	SOx	CO	HC
Using 2.7% Sulfur HFO Fuel									
Steam boiler	na	All	0.80	0.64	0.00	2.1	16.5	0.2	0.1
Using 0.1% S MGO Fuel									
Steam boiler	na	All	0.136	0.128	0.000	1.97	0.611	0.2	0.1

Table 3.14: GHG Emission Factors for Auxiliary Boilers, g/kW-hr

Engine Category	IMO Tier	Model Year Range	CO_2	N_2O	CH_4
Using 2.7% Sulfur HFO Fuel					
Steam boiler	na	All	970	0.08	0.002
Using 0.1% S MGO Fuel					
Steam boiler	na	All	922	0.075	0.002

The auxiliary boiler fuel consumption data collected from vessels during the VBP is converted to equivalent kilowatts using specific fuel consumption (SFC) factors found in the 2002 Entec report. The average SFC value for distillate fuel is 290 grams of fuel per kW-hour, and 305 grams of fuel per kW-hour for residual fuel. The average kW for auxiliary boilers using distillate fuel is calculated using the following equation.

Equation 3.10

$$\boldsymbol{Average\ kW = ((daily\ fuel/24) \times 1{,}000{,}000)/290}$$

Where:

Average kW = average energy output of boilers, kW
daily fuel = boiler fuel consumption, tonnes per day

As with auxiliary engines, the IHS database does not provide boiler engine load or fuel consumption data. The primary source of auxiliary boiler fuel consumption data is from the VBP, and direct values for vessels boarded are used on an individual basis for vessels boarded and their sister ships. For vessels not boarded or vessels that did not have any sister vessels boarded through the VBP, average loads presented in the Port of Los Angeles and the Port of Long Beach 2019 Annual Emissions Inventories reports was applied.

Table 3.15 presents the load defaults for the auxiliary boilers by vessel type and by mode for 2018.

Table 3.15: 2018 Auxiliary Boiler Load Defaults by Mode, kW

Vessel Type	Maneuvering	Berth Hotelling
Bulk	94	125
Bulk - Self Discharging	103	132
General Cargo	124	160
Tanker -Handysize	144	2586
Tanker - Chemical	136	568

3.11 OGV Emission Estimates

Tables 3.16 presents the estimated OGV emissions for 2018. The criteria pollutant emissions are in tons per year (tpy), while the greenhouse gas (CO_2e) emissions are in tonnes (metric tons) per year.

Table 3.16: Ocean-Going Vessel Emissions, tons or tonnes per year

Year	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
2018	2.9	2.8	2.3	127.7	6.9	11.5	4.7	9,646

Table 3.17 presents the estimated OGV emissions by operating mode for 2018.

Table 3.17: Ocean-Going Vessel Emissions by Operating Mode, tons or tonnes per year

Operating Mode	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Hotelling at berth	2.2	2.1	1.6	82.6	5.6	7.9	3.0	7,762
Maneuvering	0.7	0.7	0.7	45.1	1.4	3.6	1.7	1,854
2018 Total	**2.9**	**2.8**	**2.3**	**127.7**	**6.9**	**11.5**	**4.7**	**9,646**

Table 3.18 presents the estimated OGV emissions by emission source type for 2018.

Table 3.18: Ocean-Going Vessel Emissions by Emission Source Type, tons or tonnes per year

Source Type	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Auxiliary Engine	2.0	1.9	2.0	90.2	3.5	8.5	3.1	4,886
Auxiliary Boiler	0.6	0.6	0.0	9.0	2.8	0.9	0.5	3,914
Main Engine	0.3	0.3	0.3	28.5	0.6	2.0	1.1	846
2018 Total	**2.9**	**2.8**	**2.3**	**127.7**	**6.9**	**11.5**	**4.7**	**9,646**

Table 3.19 presents the estimated OGV emissions by vessel type for 2018.

Table 3.19: Ocean-Going Vessel Emissions by Vessel Type, tons or tonnes per year

Vessel Type	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Bulk	1.1	1.0	0.9	52.6	2.5	4.5	1.9	3,545
General Cargo	0.5	0.4	0.4	19.7	1.0	1.9	0.7	1,343
Tanker	1.4	1.3	1.0	55.5	3.4	5.1	2.1	4,758
Total	**2.9**	**2.8**	**2.3**	**127.7**	**6.9**	**11.5**	**4.7**	**9,646**

Table 3.20 lists the vessel movements (arrival, departure, and shifts), total energy consumption for all engines, auxiliary boilers, and the OGV IMO engine Tier distribution for all vessel visits in 2018. Most vessels visiting the Port met the cleaner Tier I or Tier II standards with no vessels meeting the cleanest Tier III standard.

Table 3.20: Ocean-Going Vessel Movements, Energy Consumption, and Tier Level Comparison

Year	Vessel Movements	Energy Consumption (kW-hrs)	Engine Tier Distribution Tier 0	Tier I	Tier II	Tier III
2018	440	12,428,702	5%	54%	41%	0%

SECTION 4 HARBOR CRAFT

This section presents emission estimates for the commercial harbor craft source category and includes source descriptions, data acquisition, and emissions estimation methodology.

4.1 Source Description

Harbor craft are commercial vessels that spend their time within or near the port and harbor. The harbor craft emissions inventory consists of Assist tugboats. Assist tugboats help ships maneuver in the harbor during arrival, departure, and shifts from berth. In general, the assist tugboats escort the ships from near the entrance of the harbor to the berth upon arrival and form the berth to the harbor entrance on departure. They also help vessels in making turns and docking/undocking.

Table 4.1 includes the harbor craft engine population and other characteristics used to estimate emissions from the 6 assist tugs operating in the Port during 2018. Figure 4.1 is a picture of an assist tug that operates at the Port.

Table 4.1: Harbor Craft Engine Characteristics

Equipment	Engine	Power (hp)			Model Year			Annual Activity Hours		
	Count	Min	Max	Average	Min	Max	Average	Min	Max	Average
2018										
Propulsion	12	725	1,300	946	1965	2015	1990	35	837	409
Auxiliary	12	40	120	77	1960	2009	1990	0	550	325

Figure 4.1: Assist Tugboats at the Port of Stockton

4.2 Data Acquisition

Data for the harbor craft inventory was collected from the vessel owners and/or operators.

4.3 Emission Estimation Methodology

Harbor craft emissions are estimated for each engine individually, based on the engine's model year, power rating, and annual hours of operation. The Port of Stockton harbor craft emission calculation methodology is similar to the methodology used by the CARB to estimate emissions for commercial harbor craft emissions operating in California.[21] The basic equation used to estimate emissions from harbor craft engines is shown below in Equation 4.1.

Equation 4.1

$$E = Power \times Activity \times LF \times EF \times FCF \times CF$$

Where:

E = emissions, grams/year
Power = maximum rated power of the engine, hp or kW
Activity = engine activity, hours/year
LF = load factor (ratio of average power used during normal operations as compared to maximum rated power), dimensionless
EF = emission factor, grams of pollutant per unit of work, g/hp-hr or g/kW-hr
FCF = fuel correction factors are used to adjust EF associated with a base fuel to the fuel being used to reflect changes in fuel properties that have occurred over time, dimensionless
CF = control factor to reflect changes in emissions due to installation of emission reduction technologies not originally reflected in the emission factors, dimensionless

Power
Power is defined as the manufacturer's maximum rated power for an engine. Power and activity information is obtained during data acquisition process.

Activity
The number of hours each engine operated within the emissions inventory domain on the six assist tugs operating at the Port in 2018 were obtained from the owners/operators of the vessels.

Load Factors
Engine load factors are used in emission calculations to reflect the fact that, on average, engines are operated at power levels lower than their maximum power rating. The load factor for the main and auxiliary engines for the assist tugs was estimated to be 0.31 and 0.43, respectively. The engine load factors are from CARB's emission estimation methodology report[22], except for the main engine load factor which is based on actual engine load readings collected in the San Pedro Bay[23].

---

[21] CARB, *Commercial Harbor Craft Regulatory Activities*, Appendix B: Emissions Estimation Methodology for Commercial Harbor Craft Operating in California. See: *https://www.arb.ca.gov/regact/2007/chc07/appb.pdf*. Viewed April 2011.
[22] CARB, *Emissions Estimation Methodology for Commercial Harbor Craft Operating in California*, Appendix B.
[23] Port of Los Angeles*, 2001 Baseline Air Emissions Inventory,* Prepared by Starcrest Consulting Group, LLC, July 2005.

Emission Factors

Harbor craft emission factors included in equation 4.2 have two components: zero-hour (ZH) rate and deterioration rate. These are obtained from CARB's latest emission estimation methodology report that was also the source of load factors mentioned above.

The ZH rate is a function of model year and horsepower rating for the engine, in the absence of any malfunction or tampering of engine components. The deterioration rate (DR) takes into account the change in the engine's ZH as the equipment is used, due to wear of various engine parts or reduced efficiency of emission control devices. DR is expressed as a function of cumulative hours reflecting the engine usage in terms of the total number of hours accumulated on the engine at the time of emissions rate calculation.

The cumulative hours reflect the engine's total operating hours at the time emissions are calculated. The emission factor is calculated as:

Equation 4.2

$$\boldsymbol{EF = ZH + (DR \times Cumulative\ Hours)}$$

Where:

EF = emission factor. g/hp-hr or g/kW-hr
ZH = zero-hour emission rate for a given horsepower category and model year when the engine is new and the emissions control systems are functioning normally, g/hp-hr or g/kW-hr
DR = deterioration rate (rate of change of emissions as a function of equipment age), g/hp-hr^2 or g/kW-hr^2
Cumulative hours = total number of hours the engine has been in use and calculated as annual operating hours times age of the engine, hours

The equation for the deterioration rate is shown in Equation 4.3.

Equation 4.3

$$\boldsymbol{DR = (DF \times ZH)\ /\ cumulative\ hours\ at\ the\ end\ of\ useful\ life}$$

Where:

DF = deterioration factor; percent increase in emissions at the end of the useful life, %
Cumulative hours at the end of useful life = annual operating hours times useful life in years, hours

Table 4.2: Engine Deterioration Factors for Harbor Craft Diesel Engines

Horsepower Range	PM	NO_x	CO	HC
25 – 50	0.31	0.06	0.41	0.51
51 – 250	0.44	0.14	0.16	0.28
> 251	0.67	0.21	0.25	0.44

CARB defines the useful life of harbor craft as the age at which 50% of the engines are retired from the fleet; it is assumed that 100% of the engines will be retired at the age of twice the useful life and for the assist tug are 21 and 23 years for the main and auxiliary engines, respectively.

Fuel Correction Factors

Emission factors developed for harbor craft are based on diesel fuel with sulfur contents that are different than is currently used. It was assumed that ULSD was used by all harbor craft in 2018. To account for the required use of ULSD in harbor craft engines, the fuel correction factors in Table 4.3 are used in equation 4.1. The fuel correction factor for SO_x reflects the change from diesel fuel with an average sulfur content of 350 parts per million (ppm) to ULSD (15 ppm).

Table 4.3: Harbor Craft ULSD Fuel Correction Factors

Equipment MY	PM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
1995 and older	0.720	0.930	0.043	1	0.72	1	0.930	0.72
1996 to 2010	0.800	0.948	0.043	1	0.72	1	0.948	0.72
2011 and newer	0.852	0.948	0.043	1	0.72	1	0.948	0.72

4.4 Harbor Craft Emission Estimates

Harbor craft emissions were estimated using the same methodology described above and activity data collected for 2018. Table 4.4 summarizes the 2018 emissions.

Table 4.4: Harbor Craft Emission Estimates, tons or tonnes per year

Year	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
2018	0.65	0.60	0.65	15.03	0.01	7.15	1.45	946

Table 4.5 shows the total energy in kilowatt hours (kW-hrs) used, and the Tier distribution of the engines used by the harbor craft sector for 2018. The Tier distribution shows that the fleet is comprised of vessels with a substantial fraction of engines that are older meeting less stringent standards. However, Table 4.6 shows the energy use by engine tier and shows that most of the work (60%) was done by harbor craft equipped with cleaner Tier 2 and Tier 3 engines.

Table 4.5: Harbor Craft Energy Consumption

Year	Vessel Count	Energy Consumption (kW-hrs)	Engine Tier Distribution Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
2018	6	1,297,557	50%	8%	25%	17%	0%

Table 4.6: Harbor Craft Engine Count and Energy Usage by Tier

Tier	Engine Count	Energy Distribution
Tier 0	50%	16%
Tier 1	8%	24%
Tier 2	25%	19%
Tier 3	17%	41%
Tier 4	0%	0%

SECTION 5 CARGO HANDLING EQUIPMENT

This section presents emission estimates for the cargo handling equipment source category and includes source descriptions, data acquisition, and emissions estimation methodology.

5.1 Source Description

The CHE category includes equipment that moves cargo to and from marine vessels, railcars, and on-road trucks at berth. Table 5.1 shows the list of the cargo handling equipment (CHE) and engine characteristics included in the emission inventory for the Port of Stockton. Some of the equipment types used at the Port did not match the CARB CHE categories and in those instances, the equipment was matched to CARB categories that had similar operational profiles. For example, Trackmobile equipment were assumed to have similar characteristics to those of CARB's rail pusher category. Equipment not included in the table because they were too few include a gasoline-powered manlift, and diesel-powered skid steer loader and sweeper. Figure 5.1 shows a typical forklift being operated at the Port.

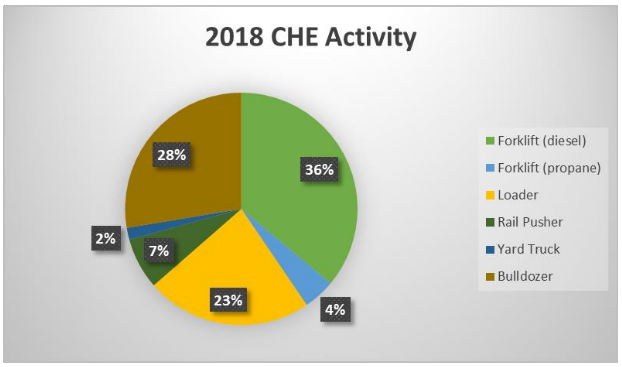
Figure 5.1: Forklift Operating at the Port

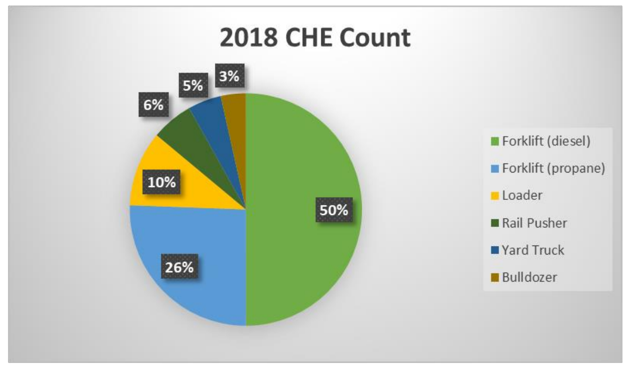
Table 5.1: CHE Characteristics

Equipment	Engine Type	Count	Power (hp)			Model Year			Annual Activity Hours		
			Min	Max	Average	Min	Max	Average	Min	Max	Average
Forklift	Diesel	43	119	265	159	1981	2019	2001	50	1,500	692
Forklift	Propane	22	41	430	69	2000	2012	2004	0	1,500	434
Loader	Diesel	9	170	420	291	2001	2019	2009	500	1,000	607
Rail Pusher (Trackmobile)	Diesel and Propane	5	95	155	135	1982	2008	1996	100	1,500	750
Yard Truck	Diesel	4	200	200	200	2007	2007	2007	200	200	200
Bulldozer		3	354	410	391	2011	2013	2012	1,300	1,750	1,600

Figure 5.2 shows the distribution of the 2018 CHE activity, in kW-hr, and by equipment type. Almost 80% of the CHE fleet are forklifts, followed by loaders, rail pushers, and yard trucks. However, for the activity, forklifts contribute 36% of the activity with bulldozers and loaders making up most of the remaining activity.

Figure 5.2: Distribution of 2018 Activity (kW-hr) and Equipment Count





5.2 Data Acquisition

The following is the list of information sought from equipment owners or operators during data collection:

- Equipment type
- Equipment identification number
- Equipment make and model
- Engine make and model
- Rated horsepower (or kilowatts)
- Equipment and engine model year
- Type of fuel used (ULSD, gasoline or propane)
- Electric equipment, if any
- Annual hours of operation (some terminals use hour meters)
- Installed Emissions reduction technologies, if any

5.3 Emission Estimation Methodology

The emissions calculation methodology used to estimate CHE emissions is consistent with CARB's latest methodology for estimating emissions from CHE.[24] The basic equation used to estimate CHE emissions is as follows.

Equation 5.1

$$\boldsymbol{E = Power \times Activity \times LF \times EF \times FCF \times CF}$$

Where:

E = emissions, grams/year
Power = maximum rated power of the engine, hp or kW
Activity = equipment's engine activity, hr/year
LF = load factor (ratio of average load used during normal operations as compared to full load at maximum rated horsepower), dimensionless
EF = emission factor, grams of pollutant per unit of work, g/hp-hr or g/kW-hr
FCF = fuel correction factors are used to adjust EF associated with a base fuel to the fuel being used to reflect changes in fuel properties that have occurred over time, dimensionless
CF = control factor to reflect changes in emissions due to installation of emission reduction technologies not originally reflected in the emission factors, dimensionless

Power

Power is defined as the manufacturer's maximum rated power for an engine. Power and activity information is obtained during data acquisition process. Averages by CHE engine and fuel type are used as defaults for the missing information (see Table 5.1)

Activity

It is the annual usage in hours of the equipment obtained during data acquisition process. Averages by CHE engine and fuel type are used as defaults where information was missing.

[24] CARB, Appendix B: *Emission Estimation Methodology for Cargo Handling Equipment Operating at Ports and Intermodal Rail Yards in California*.

Load Factors

Because engines are not continually operated at their maximum horsepower rating during normal operation, the engine load factor represents the average percentage of power that is applied during the engine's operation. Load factors for CHE were primarily obtained from CARB's CHE methodology; however, the load factors for yard tractors were revised based on studies conducted by the ports of Long Beach and Los Angeles in consultation with CARB.[25] Table 5.2 lists the load factors for specified CHE.

Table 5.2: Cargo Handling Equipment Engine Load Factors

CHE Type	Load Factor
Forklift	0.30
Loader	0.55
Rail Pusher (Trackmobile)	0.51
Yard Truck	0.39
Bulldozer	0.55

Emission Factors

The emission factor is a function of the zero-hour emission rate by fuel type (diesel, propane or liquefied natural gas), by CHE engine type (off-road or on-road), for the CHE engine model year (in the absence of any malfunction or tampering of engine components that can change emissions), deterioration rate, and cumulative hours. The deterioration rate reflects the fact that the engine's zero-hour emission rates change as the equipment is used, due to wear of various engine parts or reduced efficiency of emission control devices. The cumulative hours reflect the CHE engine's total operating hours. The emission factor is calculated as:

Equation 5.2

$$\boldsymbol{EF = ZH + (DR \times Cumulative\ Hours)}$$

Where:

EF = emission factor, g/hp-hr or g/kW-hr
ZH = zero-hour emission rate by fuel type by CHE engine type for a given horsepower category and model year, g/hp-hr or g/kW-hr
DR = deterioration rate (rate of change of emissions as a function of CHE engine age), $g/hp\text{-}hr^2$ or $g/kW\text{-}hr^2$
Cumulative hours = number of hours the CHE engine has been in use and calculated as annual operating hours times the age of the CHE engine, hours

ZH rates and DR by horsepower and engine year reflect diesel engines certified to off-road and on-road emission standards, as well as gasoline and propane engines certified to large spark ignited engine emission standards[26]. The ZH emission and DR are consistent with those in CARB's latest emissions calculations methodology for cargo handling equipment and the OFFROAD 2007 model.

[25] Port of Long Beach and Port of Los Angeles, *San Pedro Bay Ports Yard Tractor Load Factor Study and San Pedro Bay Ports Rubber-Tired Gantry Crane*, Prepared by Starcrest Consulting Group, LLC.
[26] See: *https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-nonroad-engines-and-vehicles*

Fuel Correction Factors

Emission factors developed for CHE are based on diesel fuel with sulfur content that are different than the sulfur content currently used. It was assumed that ULSD fuel was used in 2018. To account for the required use of ULSD in CHE, the fuel correction factors in Table 5.3 are used in equation 5.1.

Table 5.3: Fuel Correction Factors for ULSD

Equipment Model Year	PM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
1995 and older	0.720	0.930	0.110	1.000	0.720	1.000	0.930	0.720
1996 to 2010	0.800	0.948	0.110	1.000	0.720	1.000	0.948	0.720
2011 and newer	0.852	0.948	0.110	1.000	0.720	1.000	0.948	0.720

5.4 Cargo Handling Equipment Emission Estimates

Emissions were estimated for 2018 based on activity provided by the equipment operator for 2018. Table 5.4 summarizes the emissions.

Table 5.4: CHE Emission Estimates, tons or tonnes per year

Year	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
2018	0.42	0.38	0.41	18.57	0.03	11.92	1.87	2,460

Table 5.5 summarizes the CHE emissions by equipment type. In 2018, the forklift category emissions are the largest followed by the Loader, Rail Pushers and Bulldozer categories.

Table 5.5: CHE Emissions by Equipment Type, tons or tonnes per year

2018 Emissions	Fuel Type	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Forklift	Diesel	0.25	0.23	0.25	11.12	0.01	5.19	0.89	782
Forklift	Propane	0.01	0.01	0.00	1.35	0.00	2.99	0.44	113
Loader	Diesel	0.04	0.04	0.04	2.34	0.01	1.09	0.16	500
Rail Pusher (Trackmobile)	Diesel and Propane	0.10	0.09	0.10	1.87	0.00	1.15	0.16	156
Yard Truck	Diesel	0.00	0.00	0.00	0.07	0.00	0.07	0.00	36
Bulldozer	Diesel	0.01	0.01	0.01	1.68	0.01	1.27	0.22	659
Other	Gasoline and Diesel	0.00	0.00	0.00	0.14	0.00	0.15	0.01	214
Total		**0.42**	**0.38**	**0.41**	**18.57**	**0.03**	**11.92**	**1.87**	**2,460**

Table 5.6 lists the CHE count, energy consumption in kW-hrs, and off-road diesel engine Tier distribution for the 56 off-road diesel engines in the fleet. In addition to the 56 off-road diesel engines, the fleet equipment power includes 4 model year 2006 on-road diesel engine, 23 propane engine, 1 gasoline engine, and 2 electric engines. For the off-road diesel equipment, a substantial fraction is equipped with older engines meeting less stringent emission standards.

Table 5.6: CHE Energy Consumption and Off-Road Tier Distribution

Year	Equipment Count	Energy Consumption (kW-hrs)	Offroad Diesel Tier Distribution Tier 0	Tier 1	Tier 2	Tier 3	Tier 4i	Tier 4f
2018	91	2,937,782	30%	14%	16%	18%	7%	14%

Table 5.7 shows the count and energy use distribution of off-road diesel engine emission tier levels. Almost two thirds of the work done by the CHE category was done by equipment with cleaner Tier 3 or Tier 4 engines.

Table 5.7: CHE Off-Road Diesel Engine Count and Energy Distribution by Tier

Tier	Engine Count	Energy Distribution
T0	28%	18%
T1	13%	13%
T2	15%	6%
T3	16%	17%
T4 int	13%	8%
T4 fin	15%	38%

SECTION 6 RAILROAD LOCOMOTIVES

This section presents emission estimates for the railroad locomotives emission source category. The section discusses emission source description, data acquisition, emissions estimation methodology, and the locomotive emission estimates.

6.1 Source Description

Two types of locomotives are used by railroads – switching and line-haul. Switching locomotives are smaller locomotives that are used to move railcars and smaller trains short distances. Switching locomotives are ones designed specifically for switching service or are older line-haul locomotives that have been retired from line-haul service and redeployed in switching service. Line-haul locomotives are the largest and are used in service moving the long interstate trains. The Port is served by two large railroads Union Pacific (UP) and BNSF) and a smaller shortline railroad (Central California Traction Company (CCTC). [27] The Port's rail system consists of 55 miles of track. In 2018, CCTC operated five switching locomotives and a stevedoring company operated one switching locomotive within the Port. The CCTC locomotives were three Tier 0 SW 1500s and two Tier 4 Brookville Genset locomotives. The stevedoring company locomotive met Tier 4 emission standards. Both UP and BNSF railroads also provided service to the Port using line haul locomotives from their off-port rail yards located approximately 5 miles away, with both providing one train per day and trains delivering corn (3 to 4 trains per month) or coal (2 trains per week) to the Port. Figure 6.1 below shows a switching locomotive operating at the Port.

Figure 6.1: Switching Locomotive Operating at the Port

[27] See: *https://www.cctrailroad.com/about-us/*

6.2 Data and Information Acquisition

Information on the switching locomotives was provided by CCTC and the stevedoring company. In addition to locomotive make and model, the companies provided annual fuel consumption or annual hours of operation for each locomotive in 2018. Fuel consumption is a good measure of the amount of work performed by locomotive equipment and is important data for estimating emissions. Line-haul locomotive information was obtained from CCTC and publicly available information on UP and BNSF operations.

6.3 Emission Estimation Methodology

Switching Locomotives

The following text provides a description of the methods used to estimate emissions from the switching locomotives operating at the Port. Emissions have been estimated using the fuel consumption data provided by the locomotive's operators to calculate activity in horsepower-hours, and emission factors in terms of grams of emissions per horsepower-hour (g/hp-hr). Using the following equation, fuel consumption is converted to horsepower-hours using the brake specific fuel consumption (BSFC) conversion factor that equates horsepower-hours to gallons of fuel (hp-hr/gal).[28]

Equation 6.1

$$\textit{Annual work in hphr per year} = \frac{gallons}{year} \times \frac{15.2\ hphr}{gallon}$$

The calculation of emissions from horsepower-hours uses the following equation.

Equation 6.2

$$E = EF \times Energy$$

Where:

E = emissions, grams per year
Energy = annual work, hp-hrs/yr
EF = emission factor, grams pollutant per horsepower-hour

The EPA emission factors for locomotives cover particulate, NO_x, CO, and HC emissions in g/hp-hr. SO_x emission factors have been developed to reflect the use of 15 ppm ULSD using a mass balance approach, assuming that all of the sulfur in the fuel is converted to SO_2 and emitted during the combustion process. While the mass balance approach calculates SO_2 specifically, it is a reasonable approximation of SO_x. The following example shows the calculation of the SO_x emission factor.

Equation 6.3

$$\frac{15\ g\ S}{1{,}000{,}000\ g\ fuel} \times \frac{3{,}200\ g\ fuel}{gal\ fuel} \times \frac{2\ g\ SO_2}{g\ S} \times \frac{gal\ fuel}{15.2\ hp\ hr} = 0.006\ g\ SO_2/hphr$$

In this calculation, 15 ppm S is written as 15 g S per million g of fuel. The value of 15.2 hp-hr/gallon of fuel is the average BSFC for switching locomotives. Two grams of SO_2 is emitted for each gram of sulfur in the fuel because the atomic weight of sulfur is 32 while the molecular weight of SO_2 is 64, meaning that the mass of SO_2 is two times that of sulfur.

[28] U.S. EPA, *Emission Factors for Locomotives*: EPA-420-F-09-025, Office of Transportation and Air Quality, April 2009

Greenhouse gas emission factors from EPA references[29] have been used to estimate emissions of the greenhouse gases CO_2, CH_4, and N_2O from locomotives. Additionally, all particulate emissions are assumed to be PM_{10} and DPM. $PM_{2.5}$ emissions have been estimated as 92% of PM_{10} emissions to be consistent with the $PM_{2.5}$ ratio used by CARB in estimating $PM_{2.5}$ emissions from other types of nonroad engines.

Table 6.1 lists the emission factors, as g/hp-hr, used in calculating locomotive emissions.

Table 6.1: Emission Factors for Switch Locomotives, g/hp-hr

Locomotive Tier level	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
Tier 0	0.44	0.40	0.44	12.6	0.006	1.83	1.01	670	0.017	0.05
Tier 4	0.015	0.014	0.015	1	0.006	1.83	0.08	670	0.017	0.050

Line-haul Locomotives

Emissions from line-haul locomotives operating in the Port have been estimated on an activity basis from information obtained from the CCTC staff. Line-haul trains travel from the UP and BNSF rail yards located approximately 5 miles from the Port. Upon entering Port property, they travel an additional mile to the Port's switchyards. Both UP and BNSF send one train daily to the Port. In addition, trains delivering coal (twice weekly) and corn (3 to 4 per month for 10 months) visit the Port, traveling the same distances as the daily trains.

Four components of locomotive activity are used to develop the off-and on-port emission estimates: number of trains, average weight of each train, distances traveled within and outside the Port, and the amount of fuel used per ton-mile of train activity. The number of trains is determined from the CCTC information. The gross weight of a typical train, including locomotives, railcars, and freight, is estimated at 9,646 tons based on information reported by UP and BNSF to the U.S. Surface Transportation Board (an element of the US Department of Transportation) in an annual report known as the "R-1."[30] The distance assumptions are two miles round-trip on-Port travel and 10 miles round-trip off-Port travel for each train as it moves from the UP or BNSF yard to the Port and back. Table 6.2 shows the number of trains and train-miles traveled in 2018.

Table 6.2: Train Count and Miles Traveled Assumptions

Train Type	Train count	Miles per visit	Train miles/year
Routine freight	730	12	8,760
Coal	104	12	1,248
Corn	35	12	420
All train types			**10,428**

[29] EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016,* April 2018

[30] Union Pacific, *Class I Railroad Annual Report R-1 to the Surface Transportation Board for the Year Ending Dec. 31, 2018* and BNSF, *Class I Railroad Annual Report R-1 to the Surface Transportation Board for the Year Ending Dec. 31, 2018, https://prod.stb.gov/reports-data/economic-data/annual-report-financial-data/*

Table 6.3 shows the gross ton-miles in millions calculated by multiplying the number of trains, the gross weight per train, and the miles traveled. This table also shows the estimated total fuel usage, estimated by multiplying the gross ton-miles by the average fuel consumption of the two Class 1 railroads. This average fuel consumption has been derived from information reported by the railroads in their R1 reports. Among the details in this report are the total gallons of diesel fuel used in freight service and the total freight moved in thousand gross ton-miles. The total fuel reported by both railroads was divided by the total gross ton-miles to derive the average factor of 1.005 gallons of fuel per thousand gross ton-miles used in the 2018 emissions inventory. Also listed in Table 6.3 is the estimated total of out-of-port horsepower-hours, calculated by multiplying the estimated fuel use by the line-haul locomotive fuel use conversion factor of 20.8 hp-hr/gal.

Table 6.3: Gross Ton-Mile, Fuel Use, and hp-hr Estimate

Train Type	Train-miles per year	GTM per year	gallons per year	hphr per year
Routine freight	8,760	84,495,623	84,918	1,766,294
Coal	1,248	12,037,733	12,098	251,638
Corn	420	4,051,160	4,071	84,698
All train types	**10,428**	**100,584,516**	**101,087**	**2,102,630**

Emission estimates for off-port line haul locomotive activity are calculated by multiplying the estimate of overall horsepower-hours by the emission factors in terms of g/hp-hr. Table 6.4 shows the line-haul fleet average emission factors for 2018.[31]

Table 6.4: Fleet Average Line-Haul Locomotive Emissions Factors, g/bhp-hr

Emission Factors	PM_{10}	$PM_{2.5}$	DPM	NOx	SOx	CO	HC	CO_2e
EF	0.130	0.119	0.130	5.19	0.005	1.28	0.20	494

6.4 Emission Estimates

The estimated locomotive emissions associated with the Port in 2018 are presented in Table 6.5. Since locomotives are diesel fueled, DPM is the same as PM_{10}.

Table 6.5: Estimated Emissions from Locomotives (tons or tonnes per year)

Locomotive Type	PM_{10}	$PM_{2.5}$	DPM	NOx	SOx	CO	HC	CO_2e
Line-haul	0.30	0.28	0.30	12.03	0.01	2.97	0.47	1173
Switch	0.49	0.44	0.49	14.40	0.01	3.34	1.15	1250
Total	**0.79**	**0.72**	**0.79**	**26.43**	**0.02**	**6.31**	**1.62**	**2424**

[31] U.S. EPA, *Emission Factors for Locomotives*: EPA-420-F-09-025, Office of Transportation and Air Quality, April 2009

SECTION 7 ON-ROAD VEHICLES

This section presents emission estimates for heavy-duty vehicles (HDV) that visit the Port and light-duty vehicles (LDV) that are owned by the Port. The section discusses emission source descriptions, data and information acquisition, emission estimation methodology, and the emission estimates.

7.1 Source Descriptions

Heavy-duty trucks move cargo to and from the terminals and facilities that serve as the bridge between land and sea transportation. They are primarily driven on the public roads near the port and on highways within the inventory domain as they arrive from or depart to locations outside the domain. The most common configuration of HDVs in maritime freight service is the articulated tractor-trailer (truck and semi-trailer) having five axles, including the trailer axles. Common trailer types in the study area include standard 53-foot trailers, as well as tankers and flatbeds. Figure 7.1 shows a typical truck servicing the Port. In addition to HDVs, lighter-duty vehicles such as light-duty trucks and passenger cars owned and operated by the Port have been included as a separate category.

Figure 7.1: Trucks Operating at the Port

7.2 Data and Information Acquisition

HDV and LDV emission estimates are based on the number of miles traveled within the inventory domain, which is a function of the number of trips made to and from the Port and the distance traveled within the domain on each trip. Distances have been estimated for travel within the inventory domain. The other major variable that contributes to the emission estimates is the distribution of model years of the trucks making the trips, since emission standards cause newer trucks to emit lower levels of some pollutants than earlier model year trucks.

Information on the number of truck trips was provided by the Port's tenants, gleaned from traffic studies, and estimated from publicly available information. The average distances traveled in the inventory domain was estimated using publicly available mapping applications. Information was not available about the model years of the vehicles visiting the Port, so the San Joaquin County averages from the EMFAC 2017 model were assumed to represent the model year distribution of vehicles calling at the Port.

Emissions from the LDV category are based on the number of units (vehicles), annual miles traveled, average travel speed, and model year of the vehicles. The vehicle make, model, model year, and annual miles traveled were provided by the Port. The vehicle average speed was assumed to be the posted speed limit on the Port of 25 mph as most of the miles driven by all category of vehicles were driven in the Port.

Table 7.1 summarizes the activity data and assumptions underlying the estimates for the trucks and port owned light and medium duty vehicles. Overall, trucks visited the port over 233,000 times and traveled an average of 8 miles on surface streets where the posted speed limit is 25 mph. For the light and medium duty vehicle fleet, the Port owns 76 vehicles and their total annual mileage in 2018 was 546,020 miles. The average speed was assumed to be the Port speed limit of 25 mph as the vehicles traveled mainly on the Port.

Table 7.1: On-Road Vehicle Activity Summary

Parameter	Value	Units
Trucks		
Trips	233,000	trips
Miles per round trip	8.0	miles
Total annual miles	1,864,000	miles
Average speed	25	mph
Cars and light and medium duty trucks		
Vehicle count	76	vehicles
Average annual miles	546,020	miles
Average speed	25	mph

7.3 Emission Estimation Methodology

In general, emissions from on-road vehicles are estimated using the general equation:

Equation 7.1

$$\boldsymbol{E = EF \times A}$$

Where:

E = mass of emissions per defined period (such as a year)
EF = emission factor (mass per unit of distance or time)
A = activity (distance driven during the defined period)

Emissions are estimated by multiplying the emission factor by the distance driven. The units of distance in this inventory are miles and the emission factors are expressed as grams of emissions per mile of travel (g/mile). Annual emissions are expressed in short tons for the criteria pollutants and metric tons (tonnes) for greenhouse gases.

The emission factors for on-road vehicles have been obtained from CARB's EMFAC2017 model,[32] which provides emission factors for on-road vehicles of all types. EMFAC emission factors were obtained for calendar year 2018 and for the appropriate vehicle types as discussed above. Emission factors specific to San Joaquin County were specified in the EMFAC2017 data request.

An additional component of HDV emissions occurs when HDVs equipped with catalytic convertors to control NO_x emissions are started after being shut off for a period sufficient for the catalyst to cool. Extra NO_x emissions occur until the catalyst gets to full working temperature. EMFAC results are used to estimate the average amount of NO_x emitted from HDV starts during each trip (tons of NO_x per trip), and annual NO_x emissions are calculated by multiplying tons of NO_x per trip by the total number of trips during the year.

Table 7.2 lists the emission factors used to estimate emissions and are EMFAC aggregates (defaults) as Port specific model year data was not available. Speeds for heavy-duty trucks are specific estimates for on-Port operation (assumed to be the posted speed limit of 25 mph) and for Port owned light and medium duty trucks and automobiles.

Table 7.2: Emission factors by vehicle type

Vehicle Category	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2e
Heavy Duty Trucks, g/mi	0.031	0.029	0.031	6.59	0.019	1.03	0.26	2,089
Port Light and Medium duty fleet, g/mile	0.0032	0.0029	0.0004	0.16	0.0035	1.74	0.15	359

[32] See: *https://www.arb.ca.gov/emfac/2017/*

7.4 Emission Estimates

The estimated emissions from on-road vehicles in 2018 are summarized in Table 7.3

Table 7.3: Emission Estimates for Terminal Vehicles

	Emissions (tons or tonnes per year)							
Vehicle Category	**PM_{10}**	**$PM_{2.5}$**	**DPM**	**NO_x**	**SO_x**	**CO**	**HC**	**CO_2e**
Heavy Duty Trucks	0.0629	0.0601	0.0629	13.5383	0.0387	2.1159	0.5363	3,894
Port Light and Medium duty fleet	0.0019	0.0018	0.0002	0.0970	0.0021	1.0453	0.0894	196
Total	**0.0648**	**0.0619**	**0.0631**	**13.6354**	**0.0408**	**3.1612**	**0.6257**	**4,090**

SECTION 8 STATIONARY SOURCES GHG EMISSIONS

8.1 Source Description

In addition to the greenhouse gas (GHG) emissions estimated for the mobile sources operating in and around the Port, the stationary source GHG emissions were determined for 2018 for the Port's stationary sources (buildings). GHG emissions resulting from activities at the buildings on Port property such as natural gas combustion and electricity use were estimated using methodologies or methodologies equivalent to those outlined in the current accepted global accounting and reporting standards for GHG inventories (the GHG protocol[33] and the World Ports Climate Initiative[34]). These standards recommend that the emissions be categorized into three "scopes" that account for where they are generated.

- Scope 1 emissions are direct emissions from sources operated by the Port and include for example, emissions from a building's natural gas-fired furnaces or from vehicles owned and operated by the Port.
- Scope 2 emissions are indirect emissions occurring because of the generation of purchased electricity, steam, heating and cooling for buildings operated by the Port.
- Scope 3 emissions are those generated by sources operated by others due to activities associated with the Port and can include for example, exhaust emissions released in the inventory domain from mobile sources such as ocean-going vessels and electricity purchased by the Port's tenants.

  Note - Scope 3 emissions were not included in this inventory.

8.2 Data Acquisition

Electricity and natural gas use were obtained from Port utility records 2018. Utility records for electricity, and natural gas were supplied for the Port and the Port's tenants. The collected information was used with the GHG Protocol standard methodologies to estimate the emissions which are further described below.

[33] World Resources Institute and World Business Council for Sustainable Development, GHG Protocol. See: *https://www.ghgprotocol.org/about-us*

[34] World Ports Climate Initiative, Carbon Footprinting Guidance Document. See: *https://www.wpci.iaphworldports.org /carbon-footprinting/*

8.3 Emission Estimation Methodology

The GHG Protocol summarizes the accepted methodologies for estimating GHG emissions and lists the activity data and emission factors in the Protocol's Appendix C.[35] Generally, GHG emissions are calculated using the following formula:

Equation 8.1

$$\boldsymbol{GHG\ Emissions = Emission\ Factor\ \times Activity}$$

The emission factor and activity are specific to the source type. For example, the natural gas combustion emission factor would be in units of mass of pollutant per unit of natural gas fuel or kg CO_2 per cubic foot of natural gas. The activity would then be the number of cubic feet of natural gas burned in the year. The GHG Protocol requires that emission factors be relevant to the inventory domain (e.g., GHG emissions from electricity use should use emission factors specific to the fuel mix used to generate the electricity for the local utility – Pacific Gas and Electric). They should be specific to the activity being measured and sourced from a credible government, industry, or academic source.

Building energy use includes emissions from the generation of electricity and combustion of natural gas mainly used for building HVAC systems. Annual electricity and natural gas consumption for the Port was obtained from Pacific Gas and Electric (PGE) utility bills. The emission factors for electricity generation were obtained from PGE's voluntary greenhouse gas reporting[36] and for natural gas combustion from U.S. EPA.[37] The emission factors for both the natural gas combustion and electricity utilities are shown in Table 8.1. The U.S. national average emission factor for electrical generation is shown for comparison.[38]

Table 8.1: Electricity Consumption and Natural Gas Combustion CO_2e Emission Factors

Year	National Average (lb/MWhr)	Pacific Gas ad Electric (lb/MWhr)	Natural Gas Combustion (kg/MBtu)
2018	953	207	53.11

The Port's mobile source GHG emissions include emissions from cargo handling equipment and passenger vehicle fleets. The passenger vehicle fleet is composed of automobiles and light and medium duty trucks. The GHG emissions methodologies were discussed in earlier chapters.

[35] World Resources Institute and World Business Council for Sustainable Development, GHG Protocol. See: *https://www.ghgprotocol.org/about-us*
[36] Pacific Gas and Electric Benchmarking Greenhouse Gas Emissions for Delivered Electricity. See: *https://www.pgecorp.com/corp_responsibility/reports/2019/en02_climate_change.html*
[37] U.S. EPA Center for Climate Corporate Leadership GHG Emission Factors Hub. See: *https://www.epa.gov/sites/production/files/2018-03/emission-factors_mar_2018_0.xlsx*
[38] U.S. EPA eGRID model. See: *https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid*

8.4 GHG Scope 1 and 2 Emission Estimates

The GHG emissions, tonnes of CO_2e, for the Port's 2018 Scope 1 and 2 GHG emissions are listed in Table 8.2. The Port's GHG emissions are dominated by those from the combustion of natural gas followed by those from the mobile sources' tailpipe emissions and emissions from generating the electricity used at the Port.

Table 8.2: GHG Emission by Scope and Source Category

Port of Stockton's 2018 Scope 1 and 2 GHG Emissions (CO2e tonnes)			
Emissions Scope	**Source**		**Emissions**
Scope 1	Port Stationary Sources	Natural Gas Combustion	1,994
	Port Mobile Sources	Cargo Handling Eqipment and Passenger Vehicles (Light and Medium Duty Trucks and Automobiles) - Exhaust	1,133
Scope 2	Port Stationary Sources	Purchased Electricity	146
Total			3,272