Port of San Francisco
Seaport Air Emissions Inventory 2013

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February 2015
03-34869D

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GLOSSARY OF TERMS

Adjustment factors: Used to adjust emission factors or engine load factors or other situations for non-standard conditions.

Anchorage: Vessels anchored off-shore waiting for berth or next assignment.

Assist mode: Period when a tugboat is engaged in assisting a ship to/from its berth or maneuvering in the harbor.

Auxiliary engine: Used to drive on-board electrical generators to provide electric power or to operate equipment on board the vessel.

Auxiliary power: Typically electric power generated via the auxiliary engine.

Barge: A flat-bottomed craft built mainly for water transport of heavy goods. Most barges are not self-propelled and need to be moved by tugboats or towboats.

Berth: A location alongside a pier to moor vessels.

Brake-specific fuel consumption (BSFC): This is the measure of the engines efficiency in terms of the fuel consumption rate (weight of fuel burned per hour) divided by the engine load or output (e.g. kilowatts). For marine engines a different term, standard fuel oil consumption (SFOC), is sometimes used to describe the identical efficiency measure.

Cargo handling equipment: Shore-based offroad equipment used for bulk materials transfer cargo or containers. Cargo handling equipment is used to move containers or bulk materials from one mode of transportation to another. Typical cargo handling equipment found at ports include yard trucks, rubber-tired gantry (RTG) cranes, top and side picks, front end leaders forklifts, and other general industrial equipment.

CNG: Compressed natural gas

Cruise mode: The vessel mode while traveling in the open ocean or in an area without speed restrictions.

Dead weight tonnage (DWT): The weight of the ship, all her stores and fuel, pumps and boilers, crews quarters with crew and the cargo. In other words, how much water the vessel displaces when loaded.

Diesel-electric: Ship propulsion designs where sets of diesel engines generate electric power to drive propellers and primarily used on most cruise ships.

Emission factor: The average emission rate of a given pollutant for a given source, relative to a unit of activity. Typical examples are grams per kilowatt of actual power or grams per hour of engine operation.

Emissions inventory: A listing of all the pollutant emissions included in the study.

Excursion: For-hire vessels for entertainment and sight-seeing.

Gas turbines: An alternative engine type to internal combustion diesel engines used on some cruise ships.

g/kW-hr: This is the unit for reporting emission or fuel consumption factors, and means the grams per kilowatt-hour of work performed. Work and energy are used synonymously in this context.

Harbor Craft: The smaller vessels conducting business in the bay, including excursion vessels, pilot boats, assist tugs, and towing tugs.

Heavy Duty On-Road Vehicles: The large diesel powered trucks bringing cargo to and from the Port. Large passenger buses bringing tourists to and from cruise terminals are also included in this category.

Hotelling: On-board activities while a ship is in port and at its berth or at anchor.

Installed power: The engine power available on the vessel. The term most often refers only to the propulsion power available on the vessel, but could incorporate auxiliary engine power as well.

Knot: A nautical unit of speed meaning one nautical mile per hour and is equal to about 1.15 statute miles per hour.

Link: A defined portion of a vessel's, train's, or truck's travel. For example a link was established extending from the North Buoy out in the ocean to the location where the pilot boards the vessel. A series of links defines all of the movements within a defined area or a trip.

Load: The actual power output of the vessel's engines or generator. The load is typically the rated maximum power of the engine multiplied by the load factor if not measured directly.

Load factor: Average engine load expressed as a fraction or percentage of rated power.

LPG: Liquid petroleum gas, or primarily propane.

Maximum power: A power rating usually provided by the engine manufacturer that states the maximum continuous power available for an engine.

Medium speed engine: A 4-stroke engine used for auxiliary power and rarely, for propulsion. Medium speed engines typically have rated speeds of greater than 250 revolutions per minute.

Mode: Defines a specific set of activities, for example, a tug's transit mode includes travel time to/from a port berth while escorting a vessel.

NOx: nitrogen oxides and includes all nitrogen oxide compounds.

Ocean-going vessels (OGV): Vessels equipped for travel across the open oceans. These do not include the vessels used exclusively in the harbor, which are covered in this report under commercial harbor craft. In this report, OGV are restricted to the deep draft vessels.

Off-Road activity: Activity that occurs off of established roadways. Activity within a marine terminal yard is considered off-road activity.

On-road activity: Activity that occurs on established roadways.

Operation mode: the current mode of operation for a ship – for example, cruising, maneuvering, or hotelling.

PM_{10}: particulate matter emissions less than 10 micrometers in diameter.

$PM_{2.5}$: particulate matter emissions less than 2.5 micrometers in diameter

Pilot Boats: Vessels used to transport the Bay Pilots to and from the large vessels entering or exiting the Bay.

Port of Call: A specified port where a ship docks.

Propulsion engine: Shipboard engine used to propel the ship.

Propulsion power demand: Power used to drive the propeller and the ship.

Rated power: A guideline set by the manufacturer as a maximum power that the engine can produce continuously.

Reduce Speed Zone (RSZ): OGV transit modes below cruise speed due to speed limits.

ROG: reactive organic gas; all hydrocarbon compounds that can assist in producing ozone (smog). Includes hydrocarbons (HC) plus aldehyde and alcohol compounds minus methane, often used interchangeably with HC although they are not quite the same.

SOx: Oxides of sulfur. Interchangeable term with sulfur dioxide but include some other minor forms of sulfur oxides.

Spatial allocation: Areas on a map allocating a specific set of activities.

Spatial scope: A specified area on a map that defines the area covered in study.

Slow speed engine: Typically a 2-stroke engine or an engine that runs below 250 rpm.

Steam boiler: Boiler used to create steam or hot water using external combustion.

Time in mode: The amount of time a vessel remains in a specified mode, for example the amount of time a ship spends in the reduced speed zone.

Tons: Represents short tons (2,000 lbs) unless otherwise noted.

Tonnes: metric tons (1,000 kg)

Tug class: A tugboat's bollard pull class designation.

Two-stroke engine: Engine designed so that it completes the four processes of internal combustion (intake, compression, power, exhaust) in only two strokes of the piston.

EXECUTIVE SUMMARY

Introduction

The Port of San Francisco (Port) Seaport Air Emissions Inventory (emissions inventory) identifies and quantifies air emissions from the Port's maritime activities for the calendar year 2013, organized by the major source categories as follows:

- Ocean-Going Marine Vessels (OGV)
- Harbor Craft (HC)
- Cargo Handling Equipment (CHE)
- Heavy Duty On-Road Vehicles (HDV – trucks, buses)
- Rail Locomotives (RL)

The Introduction describes in more detail the approach, which was to provide the Port an update and comparison to the emission inventory conducted for the Port's 2005 activity (Moffat and Nichol and ENVIRON, 2010).

Overview of the Port

The Port of San Francisco manages about 7.5 miles of coastline, from the Hyde Street Pier in the north, across the Fisherman's Wharf area, the Ferry Building, the base of the Bay Bridge, the baseball stadium, and then south through the waterfront industrial areas up through the Islais Creek area ending at Berth 96. The Port has over 500 tenants, conducting a wide variety of businesses. Most of the Port's tenants, although located near the water, have no waterside activity and therefore are not considered maritime businesses. Examples of these businesses include parking lots, restaurants, retailers, shops, a baseball stadium, offices, etc. The Port has small boat marinas and a ferry terminal. However, consistent with the Port's 2005 inventory, these are not included in the inventory.

The Port's businesses that are considered maritime in nature include cruise line business, cargo business, excursion ferries, harbor services, ship repair, and a short line railroad. These businesses utilize the equipment included in the emissions inventory: Ocean-Going Marine Vessels (OGV), Harbor Craft (HC), Cargo Handling Equipment (CHE), Heavy Duty On-Road Vehicles (HDV, i.e., trucks and buses), and Rail Locomotives (RL).

In 2013, the Port received three types of ocean-going vessel traffic, cruise ships, cargo ships, and ships to dry dock for maintenance. The cruise ships docked at Berth 35 during 2013, cargo ships to Piers 80, 92, and 94, and ships to maintenance at Pier 70 for 2013.

Several Port tenants operate vessels classified as harbor craft. The SF Bar Pilots and three excursion vessel companies operate from the Port. There is a commercial and charter boat fishing fleet and fish processing tenants who were not included in the 2005 emission inventory approach and, therefore, to be consistent, were not included in this inventory. An assist tug

company is home-berthed in San Francisco but serves ships calling to ports around the Bay, and some terminals also receive cargo via tug and barge calls to the Port. Finally, the Jeremiah O' Brien historic vessel has occasional outings on the Bay. Shore cargo handling equipment is used to move bulk and other freight or otherwise serve ships and barges. Freight is moved to and from the Port via trucks, and the San Francisco Bay Railroad provides rail service.

Purpose and Scope

This is an inventory of the air emissions generated by maritime activities conducted through and by the Port of Francisco tenants. On the water side, the spatial domain of the inventory includes Port-related marine vessel transit, from dockside out through the Golden Gate Bridge and to the first outer buoys beyond the Sea Buoy, approximately 25 – 30 miles away from the Port. On the landside, the spatial scope of the inventory includes activity between Pier 43½ and Pier 96 and truck travel to the nearest freeway. This emission inventory used the same scope as the previous 2005 emission inventory.

The inventory provides estimates for emissions of five "criteria" air pollutants, reported as tons per year. The pollutants are:

- Reactive organic gases (ROG)
- Carbon monoxide (CO)
- Nitrogen oxides (NOx)
- Particulate matter, including diesel particulate matter (PM)
- Sulfur oxides (SOx)

Particulate matter emissions estimated in this report are primarily diesel particulate matter (DPM). DPM has been designated a toxic air contaminant by the California Air Resources Board (ARB). A fraction of particulate matter emissions come from steam boilers, gas turbines and LPG or CNG-powered engines, and thus are not classified as DPM. Total particulate is divided into two size ranges: PM_{10} (particles with aerodynamic diameter 10 microns or less) and $PM_{2.5}$ (particles with aerodynamic diameter 2.5 microns or less).

In addition, three greenhouse gas (GHG) components (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) were estimated. These components were combined in a CO_2 equivalent (CO_2e) estimate using the relative global warming potential of each component.

Shoreside Power Considerations

Shoreside power for cruise ships was first brought online at the Port's Pier 27 in late 2010, becoming the first such operable system in California. Unfortunately, the system had to be temporarily mothballed in early 2012 for the construction of the new James C. Herman Cruise Terminal at Pier 27. Shoreside power was brought back online in mid-2014. Therefore, the inventory year 2013 does not include any reduction of cruise ship emissions through the use of shoreside power. A separate estimate of the emission reductions expected from the system in

2014 is included, as an example of the additional emission reductions likely to be achieved by the system now that it is in regular operation.

Shoreside power was installed at the Pier 70 shipyard and brought online in late 2012. Due to the way shipyard emissions were evaluated in 2005, and in order to keep the 2013 inventory consistent with that older methodology, the emissions and the emission reductions from the use shoreside power at the shipyard is also not reflected in the summary 2013 inventory. A separate estimate of the ship emissions while at the ship yard, and emission reductions achieved by shoreside power was made, so that future inventories will be able to capture the emissions and as well as the emission reductions realized.

Summary of Results

A summary of the emission estimates for 2013 is provided here and is compared with the 2005 emission inventory. In general, the maritime activity levels for the Port in 2013 were similar to the levels in 2005.

For OGV calling in 2013, the numbers of both cruise and bulk cargo ship calls were lower than in 2005, but the vessels calling in 2013 were larger and had significantly higher installed power. The primary ship type was cruise ships, which berthed on average longer than was estimated for 2005. The number of passengers[1] in 2013 was 256,410 from 64 calls compared with 211,646 passengers from 74 calls in 2005. Cargo ship calls however were significantly lower in 2013 (36 calls) than in 2005 (92 calls) resulting in lower emissions despite larger freight ships calling in 2013. Shore operations were similar in both years but some facilities experienced less activity, including Pier 80 and Pier 96 general cargo freight ship calls, which had 2 calls in 2013 compared to 17 in 2005, and only one tanker call at Pier 92 compared with 10 calls in 2005.

The results of the Port emission inventory for 2013 are summarized in Table ES-1 and Figure ES-1. For reference, the results of the 2005 inventory are included in Table ES-2. The 2013 and 2005 results are compared graphically in Figure ES-2. Table ES-3 presents the results of the 2013 GHG emissions estimates.

In most cases, the 2013 NOx, PM, and SO_2 emissions were lower than 2005 due to the introduction of low sulfur fuel for OGV, lower NOx and PM emitting engines for Harbor Craft (despite higher activity levels), and less activity and cleaner engines for CHE and trucking. The small increase in ROG and CO from 2005 can be attributed to an increase in the ARB emission factors for OGV, higher activity levels for excursion vessels in 2013, and greater use of higher CO emitting LPG and CNG cargo handling and other off-road equipment.

[1] http://www.sf-port.org/index.aspx?page=163

Table ES-1. Port of San Francisco 2013 Emission Inventory. (tons)

Source Category	ROG	CO	NOx	PM_{10}	SO_2
Ocean-Going Vessels (OGV)	12.02	21.11	246.79	6.30	27.69
Harbor Craft (HC)	37.59	149.02	290.61	11.80	0.25
Cargo Handling Equipment (CHE)	0.99	106.27	7.42	0.31	0.01
Heavy Duty On-Road Vehicles (HDV)	0.87	1.83	7.84	0.19	0.01
Rail Locomotives (RL)	0.20	0.28	0.59	0.08	0.00
Total	**51.67**	**278.50**	**553.25**	**18.68**	**27.96**
Relative to 2005	18%	105%	-16%	-56%	-86%

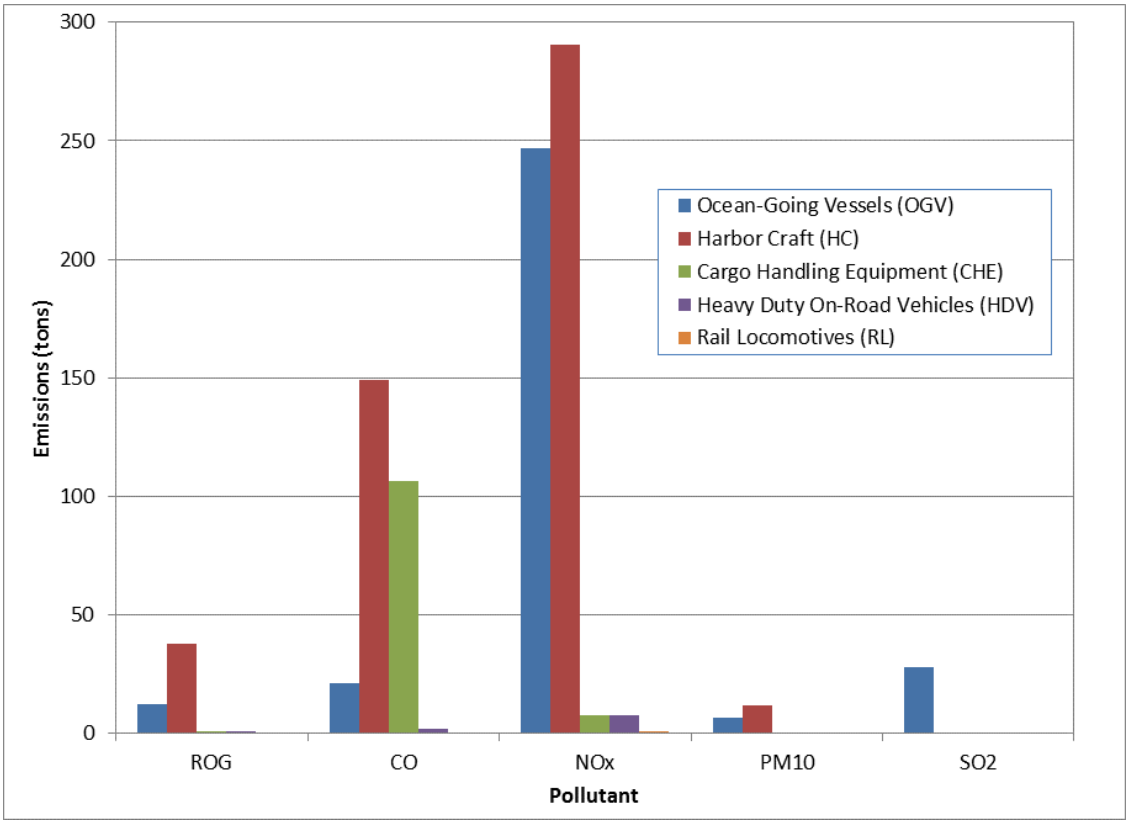

Figure ES-1. Port of San Francisco 2013 Emission Inventory by source category.

Table ES-2. Port of San Francisco 2005 Emission Inventory. (tons)

Source Category	ROG	CO	NOx	PM_{10}	SO_2
Ocean-Going Vessels (OGV)	7.6	19.9	246.1	25.5	195.5
Harbor Craft (HC)	31.1	96.4	361.8	14.8	4.1
Cargo Handling Equipment (CHE)	3.1	13.0	40.3	1.5	0.3
Heavy Duty On-Road Vehicles (HDV)	2.1	6.5	13.6	0.8	0.1
Transportation Refrigeration Units (TRU)	0	0.1	0	0	0
Rail Locomotives (RL)	0	0.1	0.2	0	0
Total	**43.9**	**135.9**	**662.0**	**42.6**	**200.0**

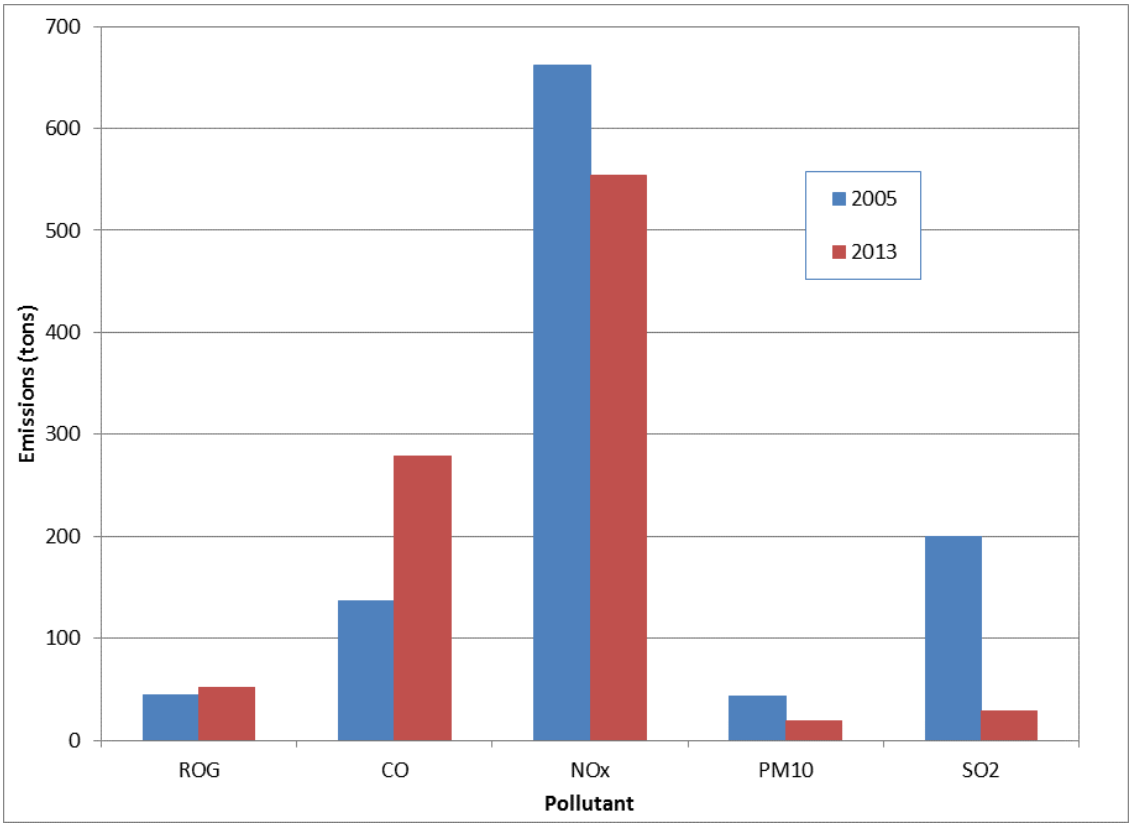

Figure ES-2. Port of San Francisco 2005 and 2013 Emission Inventory Comparison.

Table ES-3. Port of San Francisco 2013 GHG Emission Inventory. (tons).

Source Category	CH_4	N_2O	CO_2	CO_2e
Ocean-Going Vessels (OGV)	1.66	0.36	14,052	14,198
Harbor Craft (HC)	3.38	0.90	26,437	26,787
Cargo Handling Equipment (CHE)	0.36	0.01	722	732
Heavy Duty On-Road Vehicles (HDV)	0.04	0.00	1,275	1,276
Rail Locomotives (RL)	0.01	0.00	78	79
Total	**5.45**	**1.27**	**42,563**	**43,071**

1.0 INTRODUCTION

1.1 Purpose and Background

The Port of San Francisco (Port) has prepared this maritime air emissions inventory for the purpose of identifying and quantifying the air emissions from maritime-related activities during calendar year 2013 (the "2013 inventory"). This emissions inventory updates the Port's 2005 Seaport Air Emissions Inventory (the "2005 inventory") that identified and quantified air emissions from the Port's maritime activities, organized by major source categories as follows:

- Ocean-Going Marine Vessels (OGV)
- Harbor Craft (HC)
- Cargo Handling Equipment (CHE)
- Heavy Duty On-Road Vehicles (HDV – trucks, buses)
- Transportation Refrigeration Units (TRU)
- Rail Locomotives (RL)

In 2010, the Bay Planning Coalition (BPC), the Port of San Francisco, and the Bay Area Air Quality Management District (BAAQMD) jointly prepared and published a maritime emissions inventory for calendar year 2005. The BAAQMD contributed in-kind services by performing the harbor craft and locomotive emissions estimates, and all other categories were determined by the contractors of the 2005 report. (Moffatt & Nichol and ENVIRON, 2010)

The Port of San Francisco voluntarily chose to prepare the 2005 air emissions inventory of its marine operations, along with the other major public seaports in the San Francisco Bay Area. The other ports were Benicia, Redwood City, and Richmond. Also in the Bay Area, the Port of Oakland conducted their 2005 inventory (ENVIRON 2008), and completed an update for 2012 (ENVIRON 2013). Because the Port of Oakland had already completed an inventory for 2005, BAAQMD and the other ports chose 2005 for the inventory year so that the data would be generally comparable and overall Bay Area maritime emissions could be evaluated.

This current emissions inventory update highlights the Port's commitment to improve understanding of the nature, location and magnitude of emissions from its maritime-related operations and how emission reduction programs, changes to its operations, and other factors have affected the air emissions at the Port. An emissions inventory is best understood as an estimate of the quantity of pollutants that a group of sources produce in a given area, over a prescribed period of time. Emissions inventories should be used with care and in conjunction with other information and tools to evaluate and assess air quality problems.

1.2 Considerations When Using Emissions Inventories

Emissions inventories are used for multiple purposes: to analyze air quality, to develop pollutant control strategies or plans, and to track and communicate progress toward air quality goals. Emissions inventories are essential tools, but they have some inherent shortcomings that

are often overlooked and lead to misconceptions about their use and value. The term "inventory" is something of a misnomer because it implies greater precision in "counting" emissions than is really the case. An emissions inventory is better understood as an estimate of the quantity of pollutants that a group of sources produce in a given area, over a prescribed period of time. The methods of making estimates are usually very technical in nature, a characteristic that makes the limitations of emissions inventories less transparent to the general public.

The accuracy of emissions estimates varies due to a number of factors. Even a well-conducted, detailed and carefully constructed inventory, such as this one, does not have access to direct emissions measurements from the specific, individual sources being studied. As a result, it is necessary to rely on surrogate information to characterize sources, describe source activities, and specify pollutant emission rates.

Emissions estimation methodologies are continuously in flux, changing and evolving over time as better and more accurate information becomes available. Historically, emissions inventory updates have revealed previously overlooked information about sources and source activity that has substantially changed overall emissions estimates. For example, because of new information made available, such as provided in the Port's 2005 Air Emission Inventory, the California Air Resources Board (ARB) updated the ocean-going vessel auxiliary boiler activity rates. As a result, emissions inventories conducted even a few years apart may not be directly comparable.

Another important consideration in interpreting emissions inventories is the somewhat counter-intuitive fact that there can be a poor correlation between the magnitude of emissions and an air quality impact. The importance of a given ton of emissions may differ from another ton because of the location at which it is emitted, because of the meteorological conditions that affect its dispersion, and in some cases because of the chemical reactions that occur in the atmosphere. Emissions inventories should be used with care and in conjunction with other information and tools to evaluate and assess air quality problems.

1.3 Regulations and Port's Clean Air Program Affecting Port Source Categories

1.3.1 Overview

The air emissions source categories at the Port are affected by international, federal, state, and Port emission control programs. International and federal regulations address the emission standards for new engines, while state programs address the fuel, retrofits, and fleet composition. Port programs target operations at the berth, on terminals, and in transit. The summary of the regulations affecting the Port air emission source categories provided here is meant to provide a general understanding and the primary effect of the emission reduction standards and programs since 2005. The details of each regulation or agreement can be found in the referenced documents.

1.3.2 Ocean Going Vessel Regulations

Regulations to reduce emissions from ocean-going vessels fall into two categories: new (or rebuilt) engine performance standards and 2) fuel standards.

Engine Performance Standards

The United States (US) has signed onto the international emission standards for marine engines, called MARPOL Annex VI regulations. The MARPOL (2008) regulations provide for NOx emission standards for marine engines worldwide and Emission Control Area (ECA) fuel sulfur limits. Emissions standards for marine engines were introduced as a phased, progressive approach consisting of different tiers with increasing levels of emissions reduction. The first set of NO_x emission standards for new marine engines include Tier 1 for 2000 model year OGV. Model year 1990 – 1999 engines must meet Tier 1 standards when rebuilt after 2011 but did not appreciably affect NOx emission rates. Tier 2 NOx emission standards beginning with the 2011 model year provide measureable NOx reductions, and Tier 3 standards beginning in 2016 will provide dramatically lower NOx emissions.

Fuel Standards

The United States and Canada jointly petitioned for and an ECA was declared for US and Canadian waters that will limit marine fuel sulfur content to 0.1% or lower beginning in 2015 out to 200 nm from shore on the entire west coast.

In addition, the state of California (ARB, 2011a) limited marine diesel and auxiliary boiler fuel sulfur content to 0.5% beginning June 28, 2009 and 0.1% by January 1, 2014 within 24 nautical miles from the California coast.

The impact these rules had on the Port's emissions inventory was dramatic in terms of PM and SO_2 emission rates for 2012 because the fuel sulfur was reduced from nominally 27,000 ppm to 3,000 ppm on average. By 2014, the fuel sulfur used in OGVs will be reduced to 0.1% or below generating further reductions in the future. In addition, the Port began to see OGVs in 2012 with Tier 2 engines lowering NOx emission rates, and further reductions are expected in the future as ships are replaced.

1.3.3 Ocean-Going Vessel At Berth Regulation

California approved a regulation that limits the time during which auxiliary diesel engines are operated on frequently calling ocean-going vessel fleets while such ships are docked at-berth in a California port. The 'at berth' regulation is also called the shoreside power rule because the primary technology used to comply with the regulation is for the ship to use shore power instead of on-board auxiliary diesel engines. The regulation was approved in 2009 and the first compliance date whereby vessel fleets began utilizing shorepower was January 1, 2014.

The applicable fleets are ships calling a California port including any U.S. or foreign-flagged container vessel, passenger vessel, or refrigerated cargo vessel. The following exceptions are noted in the at-berth regulation:

1. A fleet composed solely of container or refrigerated cargo vessels that visits the same California port fewer than 25 times total in a calendar year; and
2. A fleet composed solely of passenger vessels that visits the same California port fewer than 5 times total in a calendar year.

The requirements of the rule are that in 2014 at least 50 percent of a fleet's visits to the port shall meet the onboard auxiliary diesel engine operational time limit of three hours for most ships, and the fleet's onboard auxiliary-diesel-engine power generation while docked at the berth shall be reduced by at least 50 percent from the fleet's baseline power generation. In 2017, the requirements increase to 70 percent of the fleet's visits, and 80 percent in 2020.

1.3.4 Commercial Harbor Craft

New harbor craft marine diesel engines are regulated by EPA who has set emission standards that meet or exceed the international regulations. EPA has staged the emission standards for commercial marine diesel engines by Tier level. Implementation years for new engines depend upon the power level of the engine, cylinder displacement, and power density in terms of power per displacement. The international standards described for OGV engines were considered 'Tier 1' emission controls, and EPA (2008a) has approved Tier 2, 3, and 4 emission standards that are more stringent than the international standards. Any engines with greater than 30 liters per cylinder must meet the international regulations described for OGV engines.

EPA Tier 2, 3, and 4 emissions standards limit new harbor craft engine NOx and PM emissions. The EPA regulations include some exceptions and special cases, however most vessel engines must comply with the one set of emission limits. The Tier 2 emissions began in 2004 and will be followed by Tier 3 and 4 emissions standards starting in 2013 that will further reduce NOx and PM emissions.

During 2007, the State of California (ARB, 2011b) adopted and then later amended regulatory limits on DPM, NOx, and SOx emissions from diesel propulsion and auxiliary engines on commercial harbor craft such as towboats and tugboats operated within 24 nm of the California coast. This regulation requires that new and in-use diesel-fueled harbor craft comply with the low sulfur fuel use requirement when operating within regulated California waters. It also sets emission standards for new engines equivalent to the federal emission standards, as well as requirements and a schedule for the replacement or otherwise bringing into compliance pre-Tier 1 and Tier 1 engines for in-use fleets (ferries, excursion vessels, tugboats, towboats, push boats and multipurpose harbor craft) to be equivalent or better than the Tier 2 emission standard for new engines. The in-use fleet standards began taking effect in 2009, limiting the use of 1975 and earlier model year engines and will continue to encourage greater use of Tier 2 or better engines through 2023 when all engines operating more than 300 hours per year will meet Tier 2 or better emissions levels.

The emission standards and the California fleet replacement requirements have led to updates to new engines and retirements of older engines and vessels. The emission rates for PM and NOx from the new engines are considerably lower due to these regulations. With the California fleet upgrade compliance continuing through 2022, the emissions from harbor craft will continue to decline in the future.

1.3.5 Off-Road and Cargo Handling Equipment Regulations

Diesel off-road engines are the primary type used in the Port's cargo handling and other off-road equipment. Emission regulations for new diesel (compression-ignition) engines in off-road equipment have been approved with emission regulations implemented for new engines (EPA, 1998). These regulations supplemented the original (renamed Tier 1) regulations for compression-ignition engines under 50 horsepower (EPA, 1994). The regulations have different implementation years and emission levels depending upon the rated power of the engine with increasingly more stringent NOx and PM emissions standards through 2015 when fully implemented.

In addition, the State of California (ARB, 2012a) has approved regulations mandating retrofit or new engine purchases for cargo handling equipment. The regulations seek to replace or retrofit such that engines meet the Tier 4 off-road engine emission standards.

Yard trucks (also called hostlers) with fleets of four or more must upgrade to low Tier 4 NOx and PM emission levels until fully implemented by 2015. Yard trucks may be upgraded using the highest level 3 verified diesel emission control strategy (VDECS) available, which is usually a diesel particulate filter (DPF), or a new engine model that meets or exceeds the Tier 4 off-road emission standard. Compliance may also be demonstrated using on-road trucks that meet or exceed the Tier 4 off-road emission standard.

For other CHE, the requirement is also to fully meet Tier 4 emission standards by 2013.

The impact of these regulations has been to dramatically lower emissions, especially PM, from off-road equipment used at the Port with further reductions expected in the future.

1.3.6 Locomotive Regulations and Voluntary Commitment

EPA (1997) finalized the first set of locomotive standards that provided three tiers of emission standards, which included provisions for a retrofit of older locomotives to provide greater emission reductions earlier than waiting for fleets to replace older engines. The standards for new locomotives were phased in with three steps to allow retooling of the manufacturing process. The first set of standards, Tier 0, applied to locomotives originally manufactured from 1973 to 2001; this standard includes a retrofit requirement for older engines during remanufacturing. The second standard, Tier 1, applied to model years 2002 to 2004; and a third standard, Tier 2, applied to model years 2005 and beyond. EPA (2008b) approved additional emission standards for later models of locomotives and instituted emission standards when Tier 0, 1, and 2 engines are rebuilt, and lower new engine NOx and PM emissions levels meeting Tier 3 standards for 2012 and Tier 4 standards for 2015.

The primary effect of the early locomotive emission standards and the agreements has been to reduce NOx emission rates since the 2006 inventory if new locomotives are purchased replacing older ones. The later emission standards including ongoing locomotive rebuilds will produce greater particulate emission rate reductions moving into the future.

1.3.7 On-Road Truck Regulations

EPA (2001) approved emission standards for new on-road heavy-duty vehicle emission standards that were phased in starting with the model year 2007 and fully implemented for the 2010 and later model year vehicles. The 2007 emission standard reduced the PM emissions standard by 90% from previous model years. The final 2010 emission standard reduced NOx emissions more than 90% when fully implemented, and applicable to 50% of the fleet starting with the 2007 model year. The primary methods used to achieve these emission levels were the use of DPF for PM control and selective catalytic reduction (SCR) for NOx control. The final 2010 emission standards result in almost a 99% reduction in NOx and PM emissions from uncontrolled levels.

In addition, California ARB (2011c) approved a regulation, commonly referred to as the Drayage Truck Rule, to upgrade drayage truck fleets. Starting in 2012, trucks with engine model year 1996 or newer were required to install the best available DPF. As of January 1, 2014, all engines were required to be 2007 or newer to operate at ports and intermodal rail yards. All drayage trucks will need to use engines meeting the 2010 emission standards by 2023.

The drayage truck compliance with the ARB rulemaking mandating fleet turnover and PM filter installation was nearly complete in 2012, substantially reducing particulate matter emissions rates since the 2006 inventory. The additional mandate for 2010 engines will reduce NOx emission rates from these vehicles through 2023.

1.4 Important Features of the Port of Francisco Seaport Air Emissions Inventory

Some features of the Port emissions inventory that should be kept in mind throughout this report are described below.

1.4.1 Scope

The Port of San Francisco manages about 7.5 miles of coastline, from the Hyde Street Pier in the north, across the Fisherman's Wharf area, the Ferry Building, the base of the Bay Bridge, the baseball stadium, and then south through the waterfront industrial areas up through the Islais Creek area ending at Berth 96. The Port has over 500 tenants, conducting a wide variety of businesses. Most of the Port's tenants, although located near the water, have no waterside activity and therefore are not considered maritime businesses. Examples of these businesses include parking lots, restaurants, retailers, shops, a baseball stadium, offices, etc. The Port has small boat marinas and a ferry terminal. However, consistent with the Port's 2005 inventory, these are not included in the inventory.

The Port's businesses that are considered maritime in nature include cruise line business, cargo business, excursion ferries, harbor services, ship repair, and a short line railroad. These businesses utilize the equipment included in the emissions inventory: Ocean-Going Marine Vessels (OGV), Harbor Craft (HC), Cargo Handling Equipment (CHE), Heavy Duty On-Road Vehicles (HDV, i.e., trucks and buses), and Rail Locomotives (RL).

In 2013, the Port received three types of ocean-going vessel traffic, cruise ships, cargo ships, and ships to dry dock for maintenance. The cruise ships docked at Berth 35 during 2013, cargo ships to Piers 80, 92, and 94, and ships to maintenance at Pier 70 for 2013.

Several Port tenants operate vessels classified as harbor craft. The SF Bar Pilots and three excursion vessel companies operate from the Port. There is a commercial and charter boat fishing fleet and fish processing tenants who were not included in the 2005 emission inventory approach and, therefore, to be consistent, were not included in this inventory. An assist tug company is home-berthed in San Francisco but serves ships calling to ports around the Bay, and some terminals also receive cargo via tug and barge calls to the Port. Finally, the Jeremiah O' Brien historic vessel has occasional outings on the Bay. Shore cargo handling equipment is used to move bulk and other freight or otherwise serve ships and barges. Freight is moved to and from the Port via trucks, and the San Francisco Bay Railroad provides rail service.

The inventory estimates emissions from the Port's tenants' and other maritime operations that occurred in the calendar year 2013 using the same geographic scope as the 2005 inventory. It is not intended to represent emissions in other years, or emissions outside the geographic domains identified for each major source category, as described below in "Technical Approach". Tenants for which emissions were estimated include bulk and break bulk freight and a rail yard. Non-tenant maritime operations for which emissions were estimated include freight and cruise ships, trucks, tugs and other work vessels, and excursion vessel operators.

This is an inventory of the air emissions generated by maritime activities conducted through and by the Port of Francisco tenants. On the water side, the spatial domain of the inventory includes Port-related marine vessel transiting, from dockside out through the Golden Gate Bridge and to the first outer buoys beyond the Sea Buoy, approximately 25 – 30 miles away from the Port as shown in Figure 1-1. On the landside, the spatial scope of the inventory includes activity between Pier 43½ and Pier 96 and truck travel to the nearest freeway as shown in Figure 1-2. This emission inventory used the same scope as the previous 2005 emission inventory.

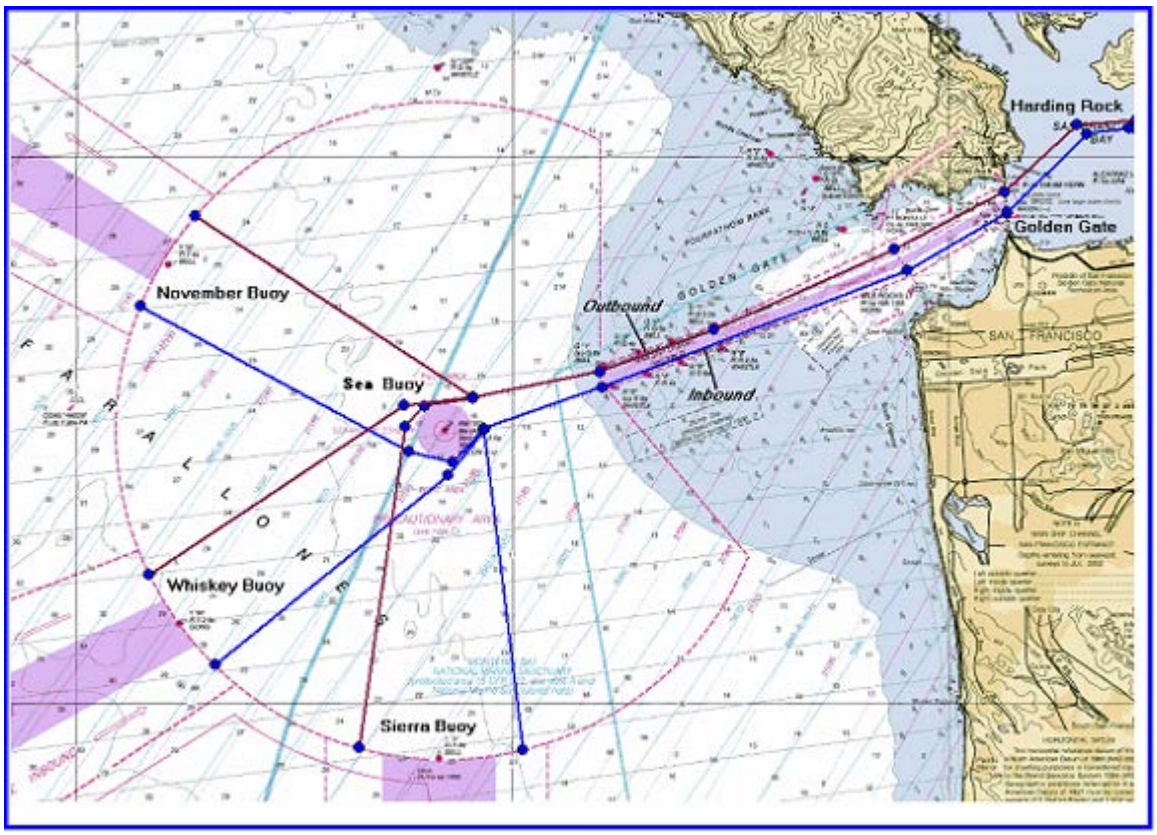

Figure 1-1. Waterside Emission Inventory Scope.

Figure 1-2. Port of San Francisco Planning and Development Project Map. (POSF, 2014)

Tenants included in this inventory were determined using the same methods used for the 2005 inventory; tenants were not included in the inventory if they were not directly related to maritime activities at the Port. The diagram in Figure 1-3 lists the Port tenants affiliated with the maritime activity and indicates the tenants that were not included in this inventory.

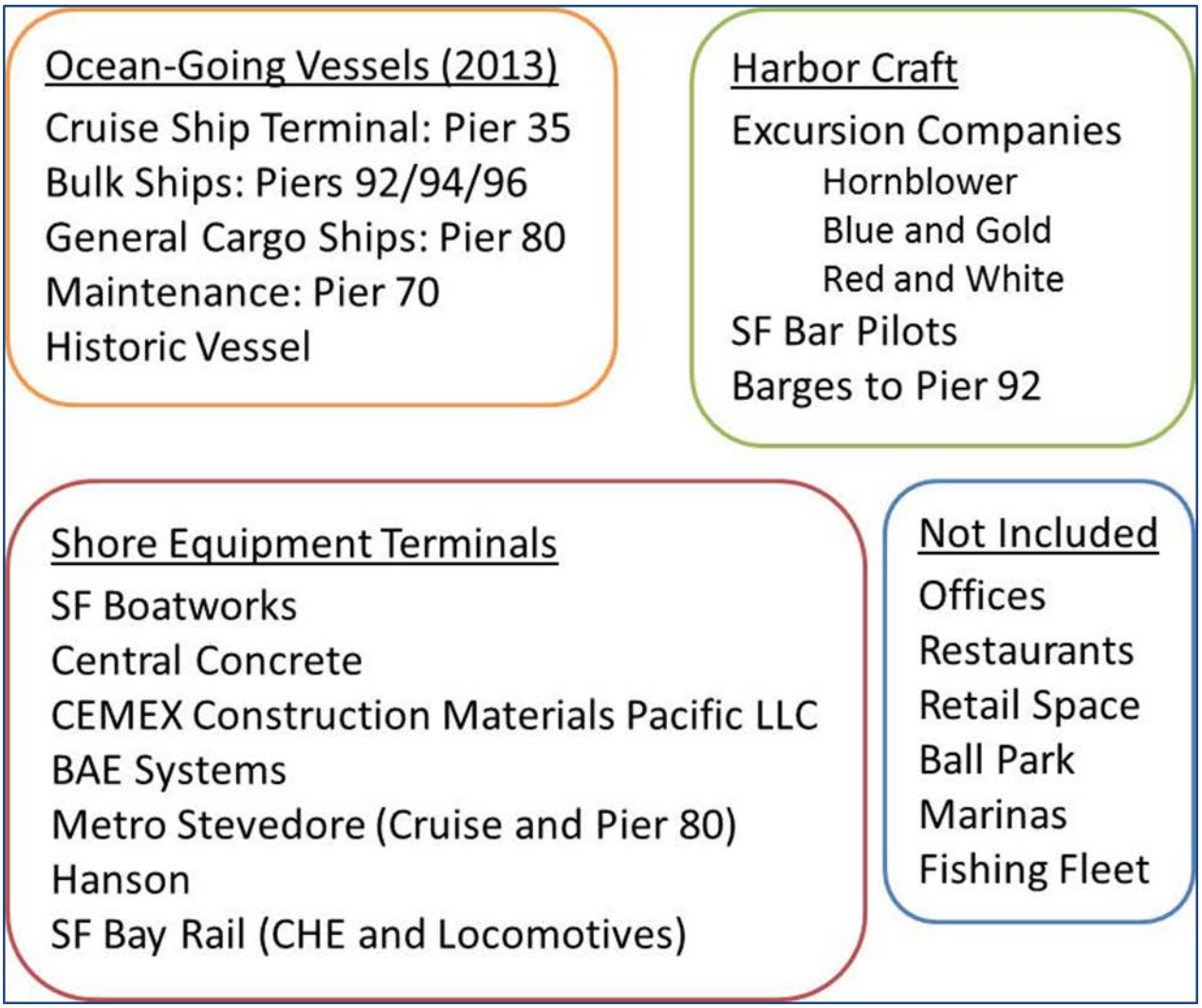

Figure 1-3. Port tenants.

1.4.2 Sources

The inventory focuses on the largest sources of air emissions from maritime operations, which, except for ship boilers and various gasoline and compressed gas fueled off-road equipment, are all powered by diesel engines. The source categories include ocean-going vessels, harbor craft assisting those vessels, vessels moving barges or for excursions, cargo handling equipment at marine terminals and the one Port rail yard, and locomotives and trucks engaged in transport of freight. The inventory does not address other sources, such as gasoline-powered, light-duty vehicles, that operated at the Port.

1.5 Criteria Air Pollutants

The inventory provides estimates for emissions of five "criteria" air pollutants described here, reported as tons per year.[2]

Reactive Organic Gases	Generally colorless gases that are emitted during combustion or through evaporation. They react with other chemicals in the ambient air to form ozone or particulate matter, both of which can have adverse health effects at higher concentrations
Carbon Monoxide	Colorless gas that is a product of incomplete combustion. Has an adverse health effect at higher concentrations.
Nitrogen Oxides	Nitrogen oxides include nitric oxide and nitrogen dioxide. Nitrogen dioxide is a light brown gas formed during combustion from reactions with nitrogen in the fuel or the combustion air. Nitrogen dioxide has adverse health effects at higher concentrations. Both nitrogen dioxide and nitric oxide participate in the formation of ozone and particulate matter in the ambient air.
Particulate Matter	Solid or liquid particles that form from a variety of chemical reactions during the combustion process. Solid particulate may also be emitted from activities that involve abrasion or friction, such as brake and tire wear. Have adverse health effects at higher concentrations. Particulates are divided into those less than 10 microns, PM_{10}, and those less than 2.5 microns, $PM_{2.5}$ aerodynamic diameter. Diesel particulate matter (DPM) is defined as particulates from diesel engine exhaust.
Sulfur Oxides	Sulfur bearing gases, primarily SO_2, that form during combustion of a fuel that contains sulfur. Has adverse health effects at higher concentrations and participates in the formation of sulfate particulate matter in the ambient air.

1.5.1 Particulate Matter

The particulate matter estimated in this report is primarily diesel particulate matter (DPM), which is defined as a toxic air contaminant by the ARB. Some ocean-going vessels use boilers to supply steam power for propulsion engines, and all vessels operate auxiliary boilers for hot water on board. In addition, some particulate emissions were from non-diesel gasoline or LPG fueled cargo handling equipment, as noted in Section 4. The particulate emissions were estimated from emission factors as PM_{10}; $PM_{2.5}$ was calculated as a fraction of PM_{10} which varied by source category.

[2] The term "criteria" pollutant is applied to pollutants for which an ambient air quality standard has been set, or which are chemical precursors to pollutants for which an ambient air quality standard has been set.

1.6 Greenhouse Gases

The greenhouse gas (GHG) emission inventory includes estimates of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from each source category. Fuel combustion is the source of CO_2, while CH_4 results from incomplete combustion and N_2O is generated during the high temperature combustion. A combined carbon dioxide equivalent (CO_2e) estimate was prepared by adding 21 times the CH_4 and 310 times N_2O emissions to the CO_2 emissions to account for the greater greenhouse gas potential of these two emissions. (IPCC, 1995)

1.7 Technical Approach

This report outlines the maritime emissions inventory from mobile sources and includes the input data and methodology used in estimating emissions. The emissions inventory includes the following major source categories:

- Deep-Draft Ocean-Going Vessels (OGV)
- Commercial Harbor Craft (assist tugs, tug and barge, excursion, and others)
- Cargo Handling (CHE) and Other Off-road Equipment
- Trucks
- Locomotives

This inventory of the air emissions by and large used the same scope and emission estimation methods as the 2005 emission inventory. This inventory approached each source category with more refinement of the activity, especially for harbor craft and shore equipment. A summary of the approach and comparison to the approach and input data used in the 2005 inventory is outlined here.

- Deep-Draft Ocean-Going Vessels (OGV)
  - Low sulfur fuel usage (affects ROG, PM, and SOx emission rates)
  - 2013 Calls and Vessel Characteristics
- Commercial Harbor Craft (More refined estimates)
  - Assist tugs (Marine Exchange assists for each call by company)
  - Tug and barge (similar approach as 2005)
  - Excursion (specific hours and vessel characteristics)
  - SF Bar Pilots (specific hours and vessel characteristics)
- Cargo Handling (CHE) and Other Off-road Equipment
  - OFFROAD2011 for non-CHE emission factors available
- Trucks (similar to 2005)
- Locomotives (similar to 2005)

1.8 Report Organization

This emissions inventory report is organized into an Executive Summary, seven sections, and the appendices.

- The Executive Summary briefly describes the methodologies used to estimate air emissions for all Port activities, and includes a summary of the results.
- Section 1 contains this introduction to the report.
- Section 2 describes deep-draft ocean-going marine vessels including cruise and freight ships.
  - A separate estimate of the emissions for ships while at the Pier 70 shipyard, and
  - Emission reductions from the use of shoreside power at both Pier 70 and the Pier 27 cruise ship terminal.
- Section 3 describes assist tug, tug and barge, excursion and other commercial work boats.
- Section 4 describes cargo handling and other off-road equipment.
- Section 5 describes the Port on-road truck activity associated with container movements.
- Section 6 describes locomotive emissions.
- Section 7 contains the summary and results of the report, a comparison with the 2005 seaport emission inventory, and emissions at and emission reductions expected from the shoreside power systems at the Pier 27 cruise terminal and the Pier 70 shipyard.
- Section 8 provides the references used in developing the emissions inventory.

2.0 OCEAN-GOING MARINE VESSELS (OGV)

2.1 Deep-Draft Ocean-Going Marine Vessel Activity and Inventory

This section documents the emission estimation methods and results for large deep-draft ocean-going vessels (OGV) calling at Port of San Francisco. ENVIRON followed the latest ARB emission estimation methodology for ocean-going vessels (ARB, 2011a), as was consistent with the methods used in the 2005 emission inventory.

OGVs use propulsion engines for transiting, auxiliary engines for onboard electrical power and small boilers to meet steam and hot water needs. Each vessel has unique characteristics of design speed, engine type and power that affect the estimates of time and engine load for each vessel call.

The Marine Exchange of the San Francisco Bay Region provided the ship calls that berthed at the Port and are provided in Appendix A. The Marine Exchange identified the ship and time and location at various points during its visit to the Bay. The time at berth when the ship initially berthed was identified as when the first line from the shore to the ship was secured, and the end of the berthing period by when the last line was off the ship. Ships calling to anchorage in the Bay were also identified by time of arrival and departure from that location.

Of the 103 commercial deep draft vessel calls to the Port of Francisco terminals in 2013, 64 were cruise ships calling to Pier 35 with 31 bulk carriers primarily to Pier 94, four general cargo vessels to Pier 80, one container/general cargo vessel to Pier 80, one tanker to Pier 92, and two cruise ships to the Pier 70 BAE Systems Ship Repair facility (BAE) to lie up for maintenance. In addition, one container ship shifted to Pier 35, two container ship shifts to and from Pier 70 and the Port of Oakland, and five Navy ships called to the Pier 70 in 2013 with one of those leaving in 2014, compared with nine vessels to Pier 70 during 2005 that were all assumed to be cruise ships. The list of Port calls is provided in Table 2-1.

Table 2-1. Ocean Going Vessels – Calls.

Vessel Type	Calls	Average Age
Bulk Carriers/General Cargo/Tanker	36	2006 (31 Calls from Tier II, >2010)
Cruise	64 (plus 2 for Maintenance)	1998
Tanker	1	1984
Container	1 shift to Pier 35 plus 2 shifts to and from Oakland and Pier 70)	1980
Navy	4 Inbound and Outbound and 1 ship Inbound to Pier 70	1997

Of the 37 bulk/general cargo carrier and tanker calls to the Port, 29 calls also included additional trips to the Ports of Redwood City, Richmond, and/or Stockton. The additional transit distance and emissions to these other ports were not included in the Port's inventory but the full inbound and outbound transit was included.

ENVIRON separately addressed three additional vessels calls when no freight moved over the Port's terminal. One container ship called to Pier 35 on its way from the Port of Oakland to sea, so the transit emissions from this vessel were assigned to the Port of Oakland and only the hotelling emissions at Pier 35 were assigned to the Port. Also, a container ship called to the Pier 70 BAE Systems Ship Repair facility (BAE) twice to tie up waiting for its next assignment, but that ship carried freight to and from other Bay Area ports (C&H Sugar and the Port of Oakland) before and after laying up at the Port, so only the emissions for the additional in-Bay transit to and from anchorage for that ship were assigned to the Port.

Lastly, hotelling emissions were adjusted for several calls. Of the 31 bulk carrier calls, 28 arrived to anchorage prior to calling at the Port, and the anchoring hotelling emissions were added to the Port's inventory. However, the Pier 70 BAE maintenance facility hotelling emissions for the two cruise ship maintenance and two laid up container ship calls were not included in this inventory because the auxiliary engine and boiler loads could not be determined during this period and exclusion of these activities was consistent with the 2005 emission inventory approach.

2.2 Emissions Calculation

The equation below is the basic equation used to estimate emissions. The inputs are the engine rated power, typical load factor, and time at that load. Emissions for propulsion engines, auxiliary engines, and boilers were determined separately using emission factors provided by ARB (2011a). The rated power is the maximum power that the engine can produce continuously.

$$\text{Emissions (per hour)} = \text{Engine Power} \times \text{Load Factor} \times \text{Emission Factor} \quad (2\text{-}1)$$

$$\text{Emissions total} = \sum \{\text{Emissions per hour} \times \text{hours per mode}\}_{\text{modes and vessel calls}} \quad (2\text{-}2)$$

The time in each mode was calculated using the link lengths and estimated speeds. The load factor depends on the vessel's maximum speed and the actual vessel speed in each mode.

2.2.1 Propulsion Power and Load

Propulsion power and design speed were derived from the Fairplay database, which reports design features for each vessel. To obtain estimates of maximum power and speed, main engine power and vessel design speed were used directly, consistent with ARB's methodology (ARB, 2011a). The vessel design speed was assumed to be the cruise speed.

The load factors for the propulsion power over any given link were determined from the classic Stokes Law cubic relationship for speed and load. The proportional relationship of load to the vessel speed can be expressed as in the following equation where the 100% load factor would correspond to the vessel operating at its maximum speed.

$$\text{Load Factor} = (\text{Vessel Speed} / \text{Vessel Maximum Speed})^3 \quad (2\text{-}3)$$

The designed cruise speed of the vessel was estimated to be 0.937 of the maximum speed. Thus the load factor at the cruise speed is 0.823. For other transiting modes the load was calculated directly from the equation shown above and is unique to each vessel's reported design speed.

2.2.2 Auxiliary Power and Load

The auxiliary power was primarily derived from auxiliary generator capacity taken from the Fairplay database and supplemented by other available data and estimates. ENVIRON used the load factors shown in Table 2-2 to describe the vessel activity. These load factors were taken from ARB (2011a) and are the same as used in the 2005 inventory.

Table 2-2. Ocean Going Vessels – Auxiliary engine load factors estimates.

Ship-Type	Cruise	Reduced Speed Zone (RSZ)	Maneuvering	Hotel
Bulk Carrier	17%	17%	45%	10%
Container Ship	13%	13%	50%	18%
Cruise Ships (diesel-electric)	80%	80%	64%	16%
General Cargo	17%	17%	45%	10%
Tanker	0%	0%	33%	22%

Source: ARB, 2011a.

2.2.3 Input Data

2.2.3.1 Vessel Calls

The Marine Exchange of the San Francisco Bay Region provided the vessel calls to the Port. The data included the date and time the ship arrived, departed, or shifted. The time stamps were provided for when the pilot boarded and left the vessel, passed the Golden Gate, and often the first and last line at the dock. The first and last line at the dock provide the at-berth hotelling time for each call, and only ships at the shipyard at Pier 70, used shore power instead of on-board auxiliary engines. For vessels that shifted, such as between anchorage and the Port, the beginning and end time for each shift was provided. Appendix A shows the calls to the Port with the arrival (first line) and departure (last line) date and time.

2.2.3.2 Vessel Characteristics

The vessel characteristics include the type of vessel, the build year, design speed, propulsion engine power and stroke (2 or 4 stroke), and auxiliary generator capacity. The IHS Fairplay database was available to provide the input data. The ship characteristics are shown provided in Appendix B.

2.2.3.3 Transit Legs

Generally, vessel activity is classified into four modes of operation: cruise, reduced speed zone (RSZ), maneuvering, and hotelling as follows:

- Cruise mode occurs in the open ocean where there are fewer navigational challenges and where ships typically operate at their design speed.
- RSZ mode occurs where ships are required to slow down and stay within prescribed lanes as shown in Figure 2-1. For ships arriving in the SF Bay, the RSZ mode occurs after a SF Bar Pilot boards and takes command of the vessel at the Sea Buoy until the vessel slows to a very low maneuvering speed near the Port defined for the purposes of this inventory as starting at the Bay Bridge. The RSZ mode for departing ships is the inverse of that for arriving ships.
- Maneuvering mode is defined as occurring near the berth.
- Lastly, the hotelling or 'at berth' mode occurs when the vessel is stopped at berth or lying at anchor south of the Bay Bridge.

The Port's piers where OGV called range about five miles from north at Pier 35 to south at Pier 94. The transit legs account for the travel distance unique to each pier assigning an estimate distance based on Google Earth leg assignments. North of Pier 35 all vessels were assumed to use the same route to and from sea through the Golden Gate (GG) to/from the sea buoy (Buoy), and North, South, and West navigation routes. The speed and distance assignments are shown in Tables 2-3 and 2-4, with the outer legs highlighted in Figure 2-1.

Table 2-3. Pier leg distances and speeds to and from Golden Gate.

Pier	Distance (nm)	Speed (knots)	Pier Description
P27	4.05	13.5	PIER 27
P27A	4.05	13.5	PIER 27A, S.F.
P27B	4.05	13.5	PIER 27B, S.F.
P30	5.64	13.5	PIER 30/32, S.F.
P35	3.73	13.5	PIER 35, PASS. TERM.
P35N	3.73	13.5	PIER 35N, S.F.
P35S	3.73	13.5	PIER 35S, S.F.
P50	6.57	13.5	PIER 50, S.F.
P70	7.22	13.5	SAN FRANCISCO DRY DOCK
P80	7.95	13.5	PIER 80, S.F.
P80A	7.95	13.5	METRO PORTS
P80B	7.95	13.5	METRO PORTS
P80C	7.95	13.5	METRO PORTS
P84	7.95	13.5	PIER 84, S.F.
P92	7.95	13.5	Pier 92
P94	8.25	13.5	Pier 94
P27	4.05	13.5	PIER 27

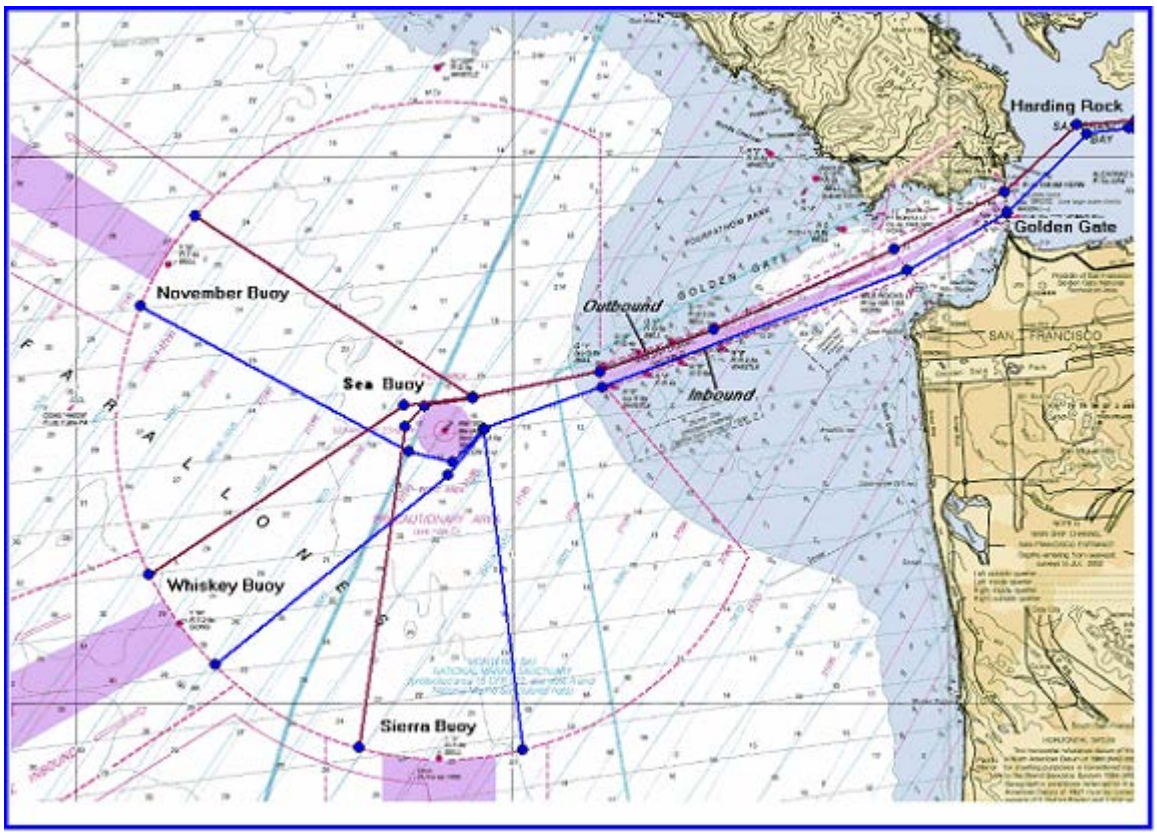

Figure 2-1. Outer OGV legs west, south, north to sea buoy and sea buoy to Golden Gate.

Table 2-4. Leg distances and speeds outside of Golden Gate (GG).

Leg	Direction	Distance (nm)	Speed (knots)
W to Buoy	Inbound W	6.7	Unrestricted
S to Buoy	Inbound S	6	Unrestricted
N to Buoy	Inbound N	7.4	Unrestricted
Pilot on board	Inbound	1.5	9
Buoy to GG	Inbound	8.72	13.5
GG to Buoy	Outbound	8.91	13.5
Pilot off ship	Outbound	1.5	9
Buoy to W	Outbound W	6.81	Unrestricted
Buoy to S	Outbound S	7.34	Unrestricted
Buoy to N	Outbound N	6.1	Unrestricted

This study used the previous study (Moffat & Nichol and ENVIRON, 2010) maneuvering time of 30 minutes total as 15 minutes inbound and 15 minutes outbound.

2.2.4 Emissions Factors

Emission factors depend on the type of engine and fuel used in the vessel for propulsion or auxiliary engines. Three types of engines were used for propulsion power on ships; slow speed engines (2-stroke and typically lower than 250 rpm), medium speed engines (4-stroke), and steam boilers coupled with steam turbines. ENVIRON determined from Fairplay data (Fairplay, 2009) the propulsion engines used on vessels calling to the Port. Emission factors for these engines are shown in Table 2-5. In the ARB reference (ARB 2011a[3]), it was noted that 0.3% sulfur fuel represented an average in-use fuel sulfur level, and the PM emission factor was estimated as the average of the 0.5% and 0.1% sulfur emission factor.

Table 2-5. Ocean Going Vessels – Emission factors (g/kW-hr) for Precontrol, Tier I, and Tier II[a] engines as noted. (Source: ARB, 2011a).

Engine Type	Fuel Type	ROG	CO	NO_x	PM_{10}	$PM_{2.5}$
Slow Speed	Marine Distillate (0.1% S)	0.78	1.10	17.0	0.25	0.23
Slow Speed	Marine Distillate (0.5% S) [Marine Distillate (0.3% S)]	0.78	1.10	17.0 14.4 Tier II	0.375 [0.3125]	0.345 [0.2875]
Slow Speed	Heavy Fuel Oil	0.69	1.38	18.1	1.50	1.46
Medium Speed	Marine Distillate (0.1% S)	0.65	1.10	13.2	0.25	0.23
Medium Speed	Marine Distillate (0.5% S) [Marine Distillate (0.3% S)]	0.65	1.10	13.2 10.9 Tier II	0.375 [0.3125]	0.345 [0.2875]
Medium Speed	Heavy Fuel Oil	0.57	1.10	14.0	1.50	1.46
Steam	Residual Oil	0.1	0.2	2.1	1.50	1.46
Auxiliary	Marine Distillate (0.1% S)	0.52	1.10	13.9	0.25	0.23
Auxiliary	Marine Distillate (0.5% S) [Marine Distillate (0.3% S)]	0.52	1.10	13.9 11.54 Tier I 9.2 Tier II	0.375 [0.3125]	0.345 [0.2875]
Auxiliary	Residual Oil	0.46	1.10	14.7	1.5	1.46

[a] – Tier I (for ships built in 2000 – 2010), Tier II (2011 – 2015)

NO_x emissions from marine engines are regulated by model year with Tier I beginning with the 2000 model year, Tier II for model year 2011 and Tier III with model year 2016 (for vessels operating in the North American Emission Control Area). Minimum marine engine emission standards for foreign flagged vessels are specified in MARPOL (2008) Annex 13 which defines the model year as, "Ships constructed means ships the keels of which are laid or which are at a similar stage of construction." Though not all of the ships have 'keel laid' as an entry in the Fairplay database, all ships have a date of delivery listed. This date was used together with the average time from the keel laid to delivery date for container ships calling the Port (where both dates were provided) of 158 days to estimate the model year of the vessel. Tier I and II NO_x emission rates were derived from ARB (2011a). Fortunately there were not any calls where the uncertainty in the vessel date affected the estimated emission factor.

Emission rates assuming 0.3% fuel sulfur content were used based on ARB's expectation of vessel operator's response to the California fuel sulfur requirements. Emission factors provided for 0.5% and 0.1% sulfur were averaged to determine the PM and SO2 emission factors used in

[3] http://www.arb.ca.gov/regact/2011/ogv11/ogv11isor.pdf

this inventory. Steamships, which are not required to use low sulfur fuels, were assumed to use residual oil in the main propulsion boilers, but no steamships other than the Jeremiah O'Brien called to the Port during 2013.

Greenhouse gas emission rates are provided in Table 2-6. (ARB, 2011a)

Table 2-6. Greenhouse gas emission factors (g/kW-hr).

Source	Fuel	CH_4	N_2O	CO_2
Main 2-Stroke	MGO	0.078	0.018	588
Main 2-Stroke	Residual	0.078	0.018	620
Main 4-Stroke	MGO	0.09	0.018	645
Main 4-Stroke	Residual	0.09	0.018	677
Gas Turbine	MGO	0	0.018	970
Auxiliary Engine	MGO	0.09	0.018	690
Auxiliary Engine	Residual	0.09	0.018	722
Boiler	MGO	0.032	0.013	921.5
Steam	Residual	0.032	0.013	970

2.2.4.1 Low Load Adjustment Factors

Emission factors for OGV engines were derived from data collected at high operational loads. Adjustment factors are applied to obtain emission factors applicable to operation at very low loads where the engine does not operate as efficiently. As recommended by ARB (see ENVIRON, 2008), ENVIRON applied low load adjustment factors for propulsion engines consistent with those used in the calendar year 2008 Port of Los Angeles emission inventory (Starcrest, 2005) for HC, CO, NO_x and SO_x. These adjustment factors are listed in Table 2-7. Low load adjustment factors for PM listed in Table 2-8 are from ENVIRON (2008).

Table 2-7. Ocean Going Vessels – Low load adjustment factors for propulsion engines.

Load %	HC	CO	NO_x	SO_x	PM
1	N/A	N/A	N/A	N/A	9.82
2	21.18	9.68	4.63	1.00	5.60
3	11.68	6.46	2.92	1.00	4.03
4	7.71	4.86	2.21	1.00	3.19
5	5.61	3.89	1.83	1.00	2.66
6	4.35	3.25	1.60	1.00	2.29
7	3.52	2.79	1.45	1.00	2.02
8	2.95	2.45	1.35	1.00	1.82
9	2.52	2.18	1.27	1.00	1.65
10	2.18	1.96	1.22	1.00	1.52
11	1.96	1.79	1.17	1.00	1.40
12	1.76	1.64	1.14	1.00	1.31
13	1.60	1.52	1.11	1.00	1.22
14	1.47	1.41	1.08	1.00	1.15
15	1.36	1.32	1.06	1.00	1.09
16	1.26	1.24	1.05	1.00	1.03
17	1.18	1.17	1.03	1.00	1.00

Load %	HC	CO	NO_x	SO_x	PM
18	1.11	1.11	1.02	1.00	1.00
19	1.05	1.05	1.01	1.00	1.00
20	1.00	1.00	1.00	1.00	1.00

Source: Table 3.8 from Starcrest, 2009 except PM values from ARB (2006a).

The low load adjustments in Table 2-7 were applied to propulsion engines when in the RSZ and maneuvering modes. Low load adjustment factors only affect propulsion engine emissions because no single auxiliary engine operates below 20% load at any time. Each vessel has a set of three or more auxiliary engines to provide auxiliary power, so individual engines are shut-down when the load decreases leaving the remaining working engines operating above 20% load.

A 2% average propulsion engine load was assumed for the maneuvering mode. For the RSZ mode (between the Bay Bridge and the Sea Buoy), a load factor was calculated specifically for each vessel as the cube root of the ratio of the assumed RSZ mode speed (13.5 knots) to the maximum speed of the vessel.

2.2.4.2 Boiler Emissions

In-use boiler power estimates of 506 kW for container ships, 109 kW for bulk cargo vessels, 106 kW for general cargo, and 1000 kW for cruise ships were assumed based on ARB (2011). Boiler emission factors shown in Table 2-8 were used; these are consistent with emission factors used in ARB (2011a).

Table 2-8. Auxiliary boiler emission rates (g/kW-hr).

Fuel Type	ROG	CO	NO_x	PM_{10}	SO_x	CO_2	CH_4	N_2O
Residual	0.11	0.20	2.1	0.80	16.50	970	0.032	0.013
0.5% Sulfur	0.11	0.20	1.995	0.20	2.99	921.5	0.032	0.013
0.1% Sulfur	0.11	0.20	1.995	0.133	0.58	921.5	0.032	0.013

Source: ARB, 2011a

2.3 Emission Results

The emission result totals are shown in Tables 2-9 and Figure 2-2 and by ship type and mode (transiting includes cruise, reduce speed zone, and maneuvering) in Tables 2-10 and 2-11 and in Figures 2-3 and 2-4. Table 2-12 presents the greenhouse gas (GHG) emission estimates. The cruise ships dominated the emissions generated by OGV. Emission reductions are expected once shore power for cruise ships becomes available and further reduction in fuel sulfur required, with both starting in 2014.

Table 2-9. OGV emissions by ship type in 2013. (tons)

Operating Mode	ROG	CO	NOx	$PM_{2.5}$	PM_{10}/DPM	SOx	CO_2e
Cruise	10.21	18.39	215.73	4.95	5.15	22.87	12,401
Cargo	1.57	2.30	26.74	0.61	0.64	2.61	1,388
Anchorage, Shifts, Container Ships to Pier 35, Pier 70, and Jeremiah O'Brien	0.24	0.42	4.32	0.26	0.10	2.21	409
Total	**12.02**	**21.11**	**246.79**	**5.82**	**5.88**	**27.69**	**14,198**

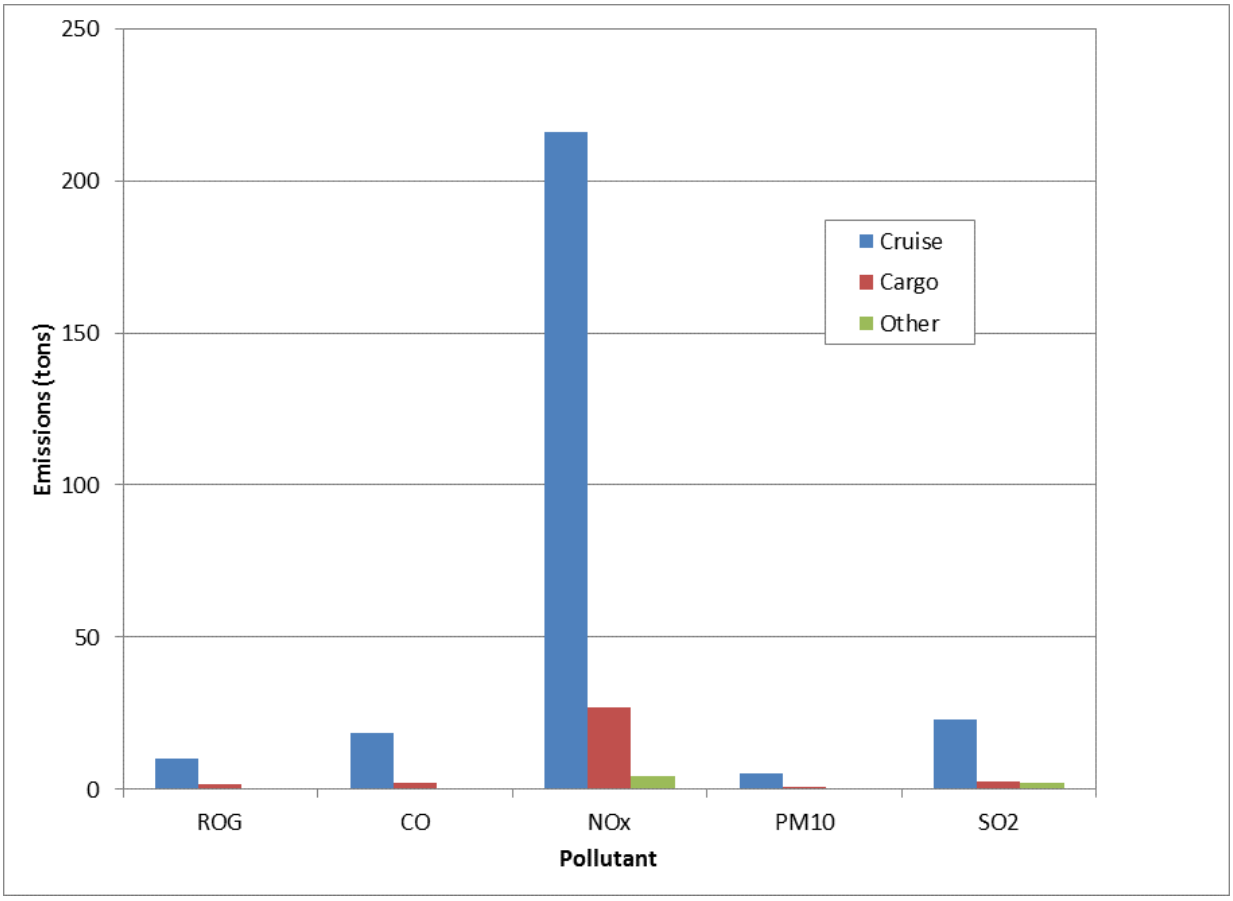

Figure 2-2. OGV emissions by ship type in 2013.

Table 2-10. Cruise ships emissions in 2013. (tons)

Operating Mode	ROG	CO	NOx	$PM_{2.5}$	PM_{10}/DPM	SOx	CO_2e
Transiting (Cruise, RSZ, and Maneuvering)	5.12	7.66	90.06	2.03	2.16	9.00	4,739
Berthing	5.09	10.73	125.67	2.92	2.99	13.86	7,662
Total	**10.21**	**18.39**	**215.73**	**4.95**	**5.15**	**22.87**	**12,401**

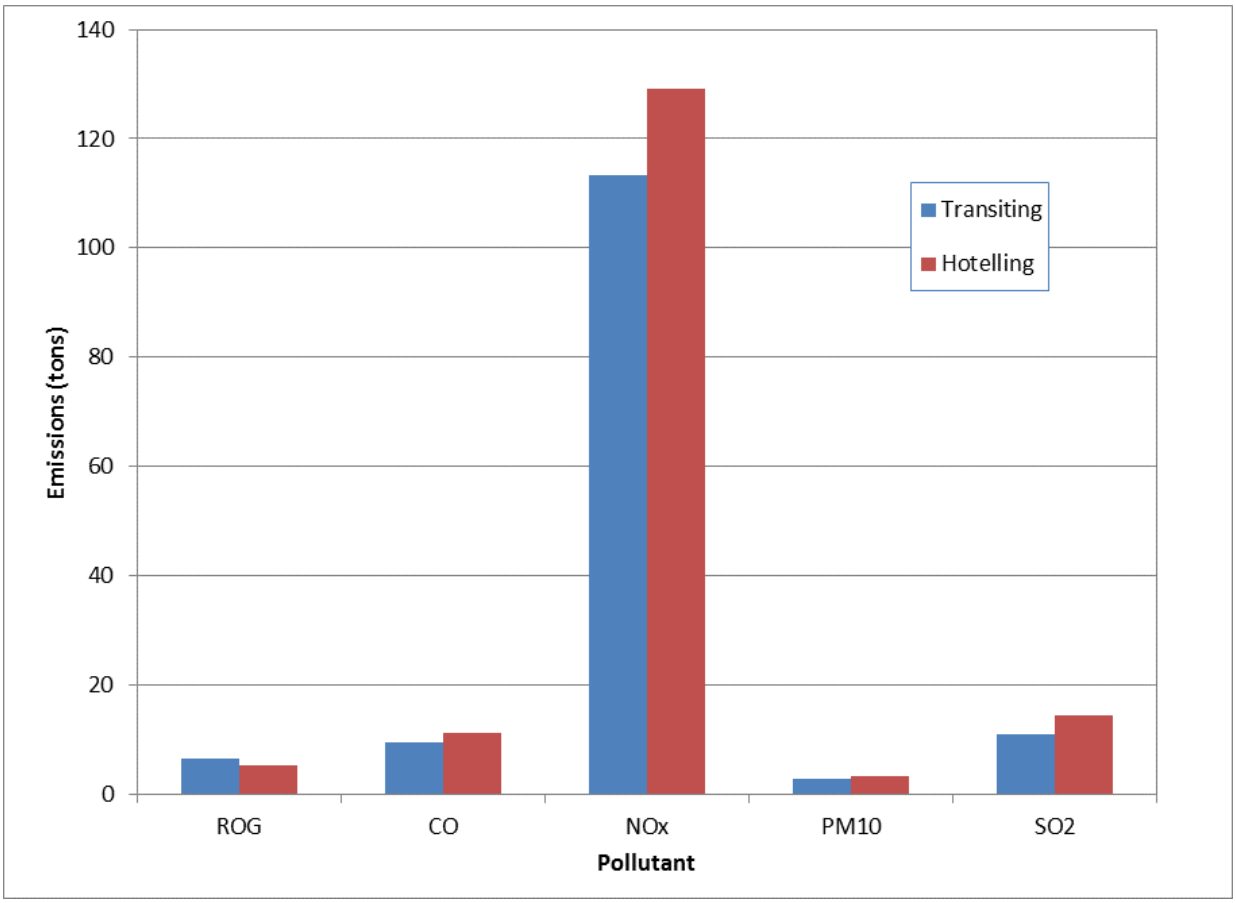

Figure 2-3. Cruise ships emissions in 2013.

Table 2-11. Cargo ships emissions in 2013. (tons)

Operating Mode	ROG	CO	NOx	$PM_{2.5}$	PM_{10}/DPM	SOx	CO_2e
Transiting	1.39	1.94	23.23	0.50	0.54	1.99	1,050
Berthing	0.11	0.37	3.51	0.11	0.10	0.62	338
Total	**1.57**	**2.30**	**26.74**	**0.61**	**0.64**	**2.61**	**1,388**

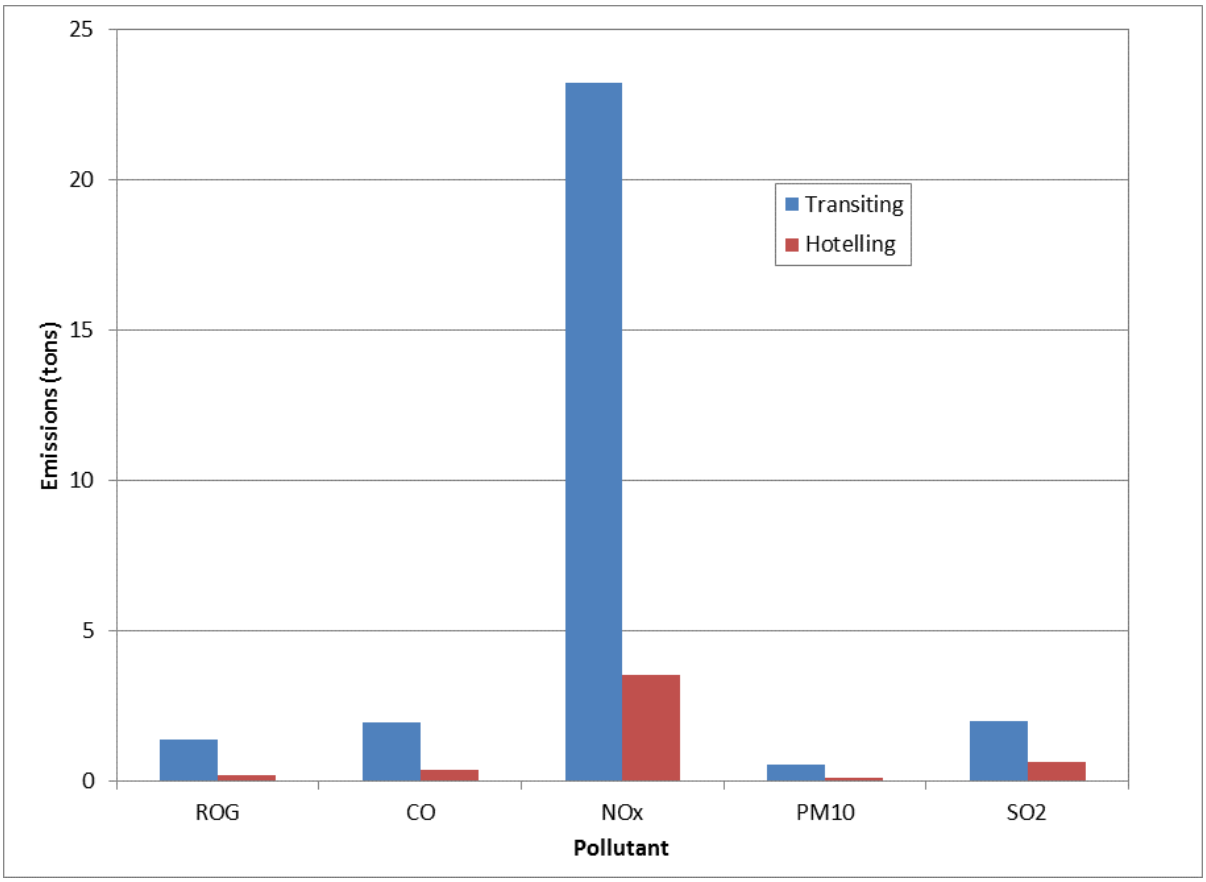

Figure 2-4. Cargo ships emissions in 2013.

Table 2-12. OGV GHG emissions in 2013. (tons)

Operating Mode	CH_4	N_2O	CO_2	CO_2e
Transiting	0.70	0.16	5,726	5,789
Berthing	0.93	0.19	7,920	8,000
Anchorage, Shifts of Container Ship to Pier 35 and Pier 70, direct to Pier 70 and Jeremiah O'Brien	0.03	0.01	406	409
Total	**1.65**	**0.36**	**14,017**	**14,198**

2.4 Shore Emissions at Pier 70

Ships have the potential to create emissions while at berth or in dry dock at Pier 70 for maintenance. Ships that arrive at Pier 70 keep their power systems running and many of the crew continue to live aboard while the ship was in for maintenance, so auxiliary engines have historically been used to supply power. Due to the way shipyard emissions were evaluated in 2005, and in order to keep the 2013 inventory consistent with that older methodology, the emissions at the shipyard were not reflected in the summary 2013 inventory in Tables 2-9 and 2-12.

Shoreside power was installed at the Pier 70 shipyard and brought online in late 2012. An estimate of the emission reductions achieved by shoreside power while at the ship yard is also presented here.

The emissions during 2013 and the emissions reductions are presented here so that future inventories will be able to capture the emissions at Pier 70 and as well as the emission reductions realized from use of shoreside power.

Two cruise ships called for maintenance in 2013 at Pier 70 for about 12 days each. These emissions are presented here as a separate estimate because the 2005 Port emissions inventory did not present the emissions from ships at Pier 70. Table 2-13 presents the two cruise ship calls to Pier 70 along with the auxiliary power and elapsed time at berth or in dry dock. The estimated load was assumed to be 8% of the auxiliary power available or half the normal load for a cruise ship during a normal cruise terminal call when carrying passengers. The auxiliary engines on these ships were older 4-stroke medium speed diesel engines, so those emission factors shown in Table 2-5 were used to estimate emissions for these vessels.

Table 2-13. Cruise ship calls to the Pier 70 shipyard in 2013.

Ship	Total Power (kW)	Arrival Date	Departure Date	Elapsed (hours)	Estimated Load (kW)
Carnival Inspiration	42,240	November 5	November 17	270.0	3,379
Amsterdam	56,416	December 5	December 17	290.3	4,513

In addition, the Moku Pahu container ship laid up at Pier 70 twice during 2013, but there was no crew or cargo aboard, so power was shut down during this period. The Moku Pahu was assumed to not run their auxiliary engines while at berth, and so was assumed not to generate

emissions while at Pier 70. As described above, the emissions when the Moku Pahu shifted to and from Pier 70 to the south Bay anchorage were included.

Separately, five Navy ships were in for maintenance at Pier 70, but used Port-supplied shore power connections instead of their auxiliary engines for most of their time at ship yard. The use of shore power has reduced emissions from those vessels, and the energy (kW-hr) consumed by shore power was used to estimate the emissions reduced as a result. However there were periods when these ships were at ship yard but not connected to shoreside power.

Table 2-14 shows the ship emissions and, separately, the emission reductions from shore power use. Appendix C provides a detailed description of how these estimates were prepared.

Table 2-14. 2013 emissions and emission reductions at berth or in dry dock at Pier 70. (tons)

Estimate	Energy (kW-hr)	ROG	CO	NOx	PM	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O
Cruise Ship Emissions	2,222,345	1.59	2.69	32.34	0.77	0.70	3.04	1,580	0.20	0.04
Navy Ship Emissions (before and after shore power connection)	283,734	0.16	0.34	3.63	0.10	0.09	0.39	216	0.03	0.01
Ship Emissions	**2,506,079**	**1.75**	**3.04**	**35.97**	**0.86**	**0.79**	**3.43**	**1,796**	**0.22**	**0.05**
Navy Ship Shoreside Power Emission Reductions	4,643,600	2.66	5.63	62.77	1.60	1.47	6.40	3,532	0.41	0.09

2.5 Shoreside Power and Emissions Reductions at Pier 27

Shoreside power for cruise ships was first brought online at the Port's Pier 27 in late 2010, becoming the first such operable system in California. Unfortunately, the system had to be temporarily mothballed in early 2012 for the construction of the new James C. Herman Cruise Terminal at Pier 27. Shoreside power was brought back online in mid-2014. Therefore, the inventory year 2013 does not include any reduction of cruise ship emissions through the use of shoreside power. A separate estimate of the emission reductions expected from the system in 2014 is included, as an example of the additional emission reductions likely to be achieved by the system now that it is in regular operation. Appendix D provides a detailed analysis of the shoreside power generated by cruise ships during 2013 and estimated for 2014. In 2014, the estimated power demanded by non-exempt cruise ships was 7,812 MW-hr. The ARB shoreside power requirement for 2014 was that 50% non-exempt cruise ship power should be derived from the shore grid. All cruise ships calling to the Port in 2014 were 2010 or earlier model years, so all use the main medium speed engine emission factors. Table 2-15 shows the expected emission reduction from 50% of the 7,812 MW-hr from the shore grid.

Table 2-15. 2014 potential emission reductions from shoreside power at Pier 27. (tons)

ROG	CO	NOx	PM	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O
2.57	4.35	52.25	1.24	1.14	4.91	2,553	0.32	0.07

3.0 HARBOR CRAFT

3.1 Introduction

Harbor craft consist of a variety of vessel types including assist tugs, tug and barge movements, excursion, and pilot boats either based at the Port or serving the vessels headed to and from the Port. In keeping with the approach for the previous 2005 Port inventory, harbor craft at private berths as well as general ferries, fishing boats, pleasure craft, and dredging activities are not included in this report.

3.2 Emissions Calculation Methodology

The emissions estimation methodology for this inventory followed the ARB's Commercial Harbor Craft Emission Inventory Database calculation methods. (ARB, 2011e) The ARB methodology provides emission factors that are specific to main propulsion and auxiliary engine model year, and applies both an engine emissions deterioration rate and a fuel correction factor.

The basic equation used to calculate emissions from each type of vessel is the following:

$$Emissions = \frac{EF_{zh} \times FC \times \left(1 + DE \times \frac{A}{UL}\right) \times HP \times LF_{wt} \times Hrs}{(453.6 \times 2000)} \quad (3\text{-}1)$$

Where:

Emissions – Emissions in tons
EF_{zh} – Horsepower and model year specific zero-hour emission factor [g/hp-hr]
FC – Fuel correction factors for using low sulfur content diesel fuels
DE – Deterioration rate of the engine
A – Age of the engine as provided by the operators
UL – Useful life of the engine
HP – Weighted average main propulsion and/or auxiliary engine brake horsepower rating of the engines in each tug group
LF_{wt} – Time weighted load factor for the maneuvering phase for the main engine and/or auxiliary engine, taken from the literature or the ARB methodology, stated as a fraction of full load
Hrs – Annual operating hours within 24nm of the Port; provided by the operators

Input data estimates were found in the Commercial Harbor Craft Emission Inventory Database except where specific data collected in this work was used as noted below for each vessel type.

3.3 Input Data and Emissions

A survey was conducted to collect the following vessel engine characteristics (type of vessel, model year, retrofit records, and horsepower) and activity level (hours of operation, number of

calls) from harbor craft operating at the Port in 2013. This information was used as input for the emissions calculations.

1. Vessel Name
2. Vessel Type
3. Number of Propulsion (Main) Engines
4. Propulsion (Main) Engine Make and Model
5. Propulsion (Main) Engine Model Year
6. Propulsion (Main) Engine Rated Horsepower
7. Propulsion (Main) Engine Retrofit Type / Repower
8. Propulsion (Main) Engine Annual Usage
9. Number of Auxiliary Engines
10. Auxiliary Engine Rated Horsepower
11. Auxiliary Engine Annual Usage

The survey covered the excursion and pilot vessels. OGV assist tugs activity was estimated from the number of assists performed multiplied by the typical operating time and transiting, and tug characteristics collected from company web sites. For each category we describe the data collect and emission estimates.

3.4 Assist Tugs

Assist tugs are used to assist OGV inbound and outbound from the Port's piers. The assist tugs assigned to these operations come from the fleets based in the Bay Area. The assist tug fleets that served the Port were the tug operators AMNAV, Baydelta, Crowley, Foss, and Starlight. These fleets are based around the Bay as described in Table 3-1 and all assists were assumed to originate from and return to these bases for each event.

Table 3-1. Tug fleet base to pier transit distances (estimated using Google Earth).

Fleet	Base	Distance from Base to Port Piers (nm)				
		Pier 35	Pier 70	Pier 80	Pier 92	Pier 94
AMNAV	Oakland	5.05	5.15	5.9	6.3	6.2
BayDelta	Oakland	5.05	5.15	5.9	6.3	6.2
Crowley	SF Pier 18	0.85	2.80	3.5	4.0	4.0
Foss	Richmond	7.30	10.25	11.0	11.6	11.6
Starlight	Alameda	5.90	5.45	6.0	6.4	6.3

For each vessel that called to the Port, the Marine Exchange provided the number of tugs from each tug fleet for each of the OGV calls to the Port. There were 106 calls where tug assists occurred including the 103 when freight or passengers moved through the Port, two container ship calls to the Pier 70 ship repair, and one container ship to Pier 35.

3.4.1 Fleets

The tug fleets and engine characteristics were gleaned from the public websites. All tugs have two main propulsion and two auxiliary engines totaling the power shown in Table 3-2. The main engine power was found for every tug, but only a few had published auxiliary powers so the most common auxiliary power level was assumed for other tugs.

Table 3-2. Tug fleet characteristics (at the end of 2013).

Fleet	Name	Model Year	Propulsion Power (Hp)	Auxiliary Power (Hp)
AMNAV	Delta Lindsay	2010	6850	282
AMNAV	Independence	2007	5080	282
AMNAV	Revolution	2006	5080	282
AMNAV	Sandra Hughes	2007	5080	282
AMNAV	Liberty	2008	3400	282
AMNAV[1]	Patriot	1981	4800	282
AMNAV	Pacific Combi	1994	3600	282
AMNAV	Patricia Ann	2008	5080	282
Starlight	Z-3	1999	4000	274
Starlight	Z-4	1999	4000	274
Starlight	Z-5	1999	4000	274
Bay Delta	Delta Billie	2009	6800	282
Bay Delta	Delta Cathryn	2009	6800	282
Bay Delta	Delta Linda	1999	4400	282
Bay Delta	Delta Deanna	1999	4400	282
Bay Delta	Resolute	1995	6700	282
Crowley	Guard	1997	5500	282
Crowley	Valor	2007	6800	282
Foss	Marshall Foss	2001	6250	282
Foss	Keegan Foss	1998	3900	282

1 – Assumed too old to be in regular service

3.4.2 Activity

The number of hours for assist tug activity at the Port was estimated from the hours of transit to and from each pier with time added for each assist. The transit time was determined as the round trip distance from and return to the fleet base dock divided by an assumed 11 knots transit speed. For each assist, 55 minutes were added for the period when the tug is assisting the vessel in and out of Port.

SF Marine Exchange identified the tug fleet but not the individual tugs assigned to the Port ships. The time for each fleet determined as the total of the assist and transit was distributed evenly across each vessel in the fleet. Table 3-3 shows the tug assists (either assisting inbound or outbound from the Port) for 2013 for the 106 calls to the Port.

Table 3-3. Tug assists by fleet.

Tug Fleet	Assists
AMNAV	121
Bay Delta	31
Crowley	22
Foss	60
Starlight	29
Total	263

3.4.3 Load Factors

However, the main engine load factor was estimated to be 0.31, and the auxiliary engines load factor was estimated to be 0.43. These load factors corresponding to values used in both the Port of Oakland 2005/2012 Seaport Air Emissions Inventory (ENVIRON 2008) and the latest Port of Los Angeles Inventory of Air Emissions (POLA 2012).

3.4.4 Emissions

ENVIRON used zero hour emission factors, engine emissions deterioration factors and fuel correction factors for both main propulsion and auxiliary engines from ARB's database emission inventory tool. (ARB, 2011b) The model year and engine power determine the appropriate emission factor which is multiplied by the time and load factors for the tug engines to estimate emissions during 2013 as shown in Table 3-4.

Table 3-4. Tug assist emissions in 2013 (tons).

Company	ROG	CO	NOx	SOx	PM_{10}/DPM	$PM_{2.5}$	CO_2
Main Engine	1.02	3.11	8.29	0.01	0.34	0.33	567
Aux Engine	0.09	0.28	0.59	0.00	0.02	0.02	44
Assist Tug Total	**1.10**	**3.39**	**8.88**	**0.01**	**0.37**	**0.36**	**611**

3.5 Tug and Barge

Terminals also receive barges that are moved in and out of the Port using tugs designed for the task. These tugs were not the same types as those used to assist larger OGV. In most cases the barges are used to transport material (usually bulk sand and gravel) within the Bay. The tug activity included in this inventory was the time for inbound and outbound trip from the previous dock and to the next dock within the Bay.

3.5.1 Fleets

Tugs used to move barges were not identified for all movements. We assumed similar tug characteristics as the San Joaquin River (2120 hp) or Fatcat (1550 hp) pusher tugs and used a 2001 model year engine.

3.5.2 Activity

The fleets also provided the vessel activity in terms of hours per year, and the results are summarized in Table 3-5. The number of hours of operation was estimated using the 2005 inventory estimate of 26 round trip nautical miles within San Francisco County at 7 knots for each inbound or outbound barge move or 3.71 hours per move.

Table 3-5. Barge tug average power and activity in 2013.

Terminal	Barge Calls	Hours	Tug	Main Engine Power (hp)	Auxiliary Engine Power (hp)
Hanson	56	416	San Joaquin River	2120	64
CEMEX	14	104	Fatcat	1550	64
Central	68	505	Fatcat	1550	64

3.5.3 Load Factors

The estimated load factor for the different vessel types come from ARB (2011d) and are 0.68 for main engines and 0.43 for auxiliary engines.

3.5.4 Emissions

Tug and barge movement emissions are shown in Table 3-6.

Table 3-6. Tug and barge emissions in 2013 (tons).

Company	ROG	CO	NOx	SOx	PM_{10}/DPM	$PM_{2.5}$	CO_2
Main Engine	1.40	3.11	10.74	0.01	0.53	0.52	830
Aux. Engine	0.06	0.16	0.37	0.00	0.02	0.02	29
Tug Total	**1.46**	**3.27**	**11.11**	**0.01**	**0.55**	**0.54**	**859**

3.6 Excursion and Pilot Vessels

Four fleets of Port-based harbor craft vessels were found to be operated in 2013: Hornblower, Blue and Gold, Red and White, and San Francisco Bay Pilots (SF Bay Pilots). Hornblower, Blue and Gold, and Red and White primarily operate excursion and ferries (for example the Alcatraz or Angel Island routes) but are based at the Port. The SF Bay Pilots are based at the Port but serve all ships that enter the Bay.

3.6.1 Fleets

Vessels used at the port were determined to be used as ferry or excursion (both types use the same input factors for emission estimates), one crew and supply vessel, and pilot vessels. The fleets provided the vessels types, engine characteristics of model year and power for both main and auxiliary engines. The number and power of each engine provides the cross reference to the appropriate zero-hour emission factor and deterioration rate.

3.6.2 Activity

The fleets also provided the vessel activity in terms of hours per year, and the results are summarized in Table 3-7.

Table 3-7. Other vessels average power and activity in 2013.

Vessel Type	Number	Main Engines		Auxiliary Engines	
		Power (hp)	Hours	Power (hp)	Hours
Crew and Supply	1	1,000	601	80	279
Ferry/Excursion	24	1,492	1,727	126	1,743
Pilot	4	1,038	2,875	148	1,438

3.6.3 Load Factors

The estimated load factor for the different vessel types come from ARB (2011d) and are shown in Table 3-8.

Table 3-8. Load factors for various vessel types (ARB[4]).

Vessel Type	Type ID	Main Load Factor	Auxiliary Load Factor
Crew and Supply	CNS	0.38	0.32
Ferries and Excursion	FRY	0.42	0.43
Pilot Vessels	POV	0.51	0.43

3.6.4 Emissions

Emissions calculations followed the ARB (2011d) methods incorporating zero-hour and deterioration. The summary emission totals for these vessels are shown in Table 3-9 for criteria pollutants and Table 3-10 for greenhouse gas emissions.

Table 3-9. Other vessel emissions in 2013 (tons).

Vessel Type	ROG	CO	NOx	SOx	PM_{10}/DPM	$PM_{2.5}$
Crew/Supply	0.430	0.985	4.086	0.001	0.159	0.154
Ferry/Excursion	24.282	108.332	191.076	0.178	7.141	6.926
Pilot Vessels	5.989	20.082	56.476	0.037	2.558	2.481
Total	**30.70**	**129.40**	**251.64**	**0.22**	**9.857**	**9.561**

Table 3-10. Other vessel GHG emissions in 2013 (tons).

Vessel Type	CO_2	CH_4	N_2O	CO_2e
Crew/Supply	148	0.039	0.005	150
Ferry/Excursion	18,933	2.185	0.645	19,178
Pilot Vessels	3,969	0.539	0.135	4,023
Total	**23,050**	**2.763**	**0.785**	**23,351**

[4] Revised 2007 Documentation (Appendix B); http://www.arb.ca.gov/msei/chc-appendix-b-emission-estimates-ver02-27-2012.pdf

3.7 Results

The emissions by vessel type and for all harbor craft are shown in Table 3-11 and Figure 3-1.

Table 3-11. Harbor Craft emissions in 2013 (tons).

Vessel Type	ROG	CO	NOx	SOx	PM_{10}/DPM	$PM_{2.5}$
Assist Tug	1.10	3.39	8.88	0.01	0.37	0.36
Tug and Barge	1.46	3.27	11.11	0.01	0.55	0.54
Excursion	27.98	119.53	207.27	0.19	7.97	7.73
Pilot	6.59	21.78	59.21	0.04	2.74	2.66
Crew and Supply	0.46	1.04	4.14	0.00	0.16	0.16
Total	**37.59**	**149.02**	**290.61**	**0.25**	**11.80**	**11.44**

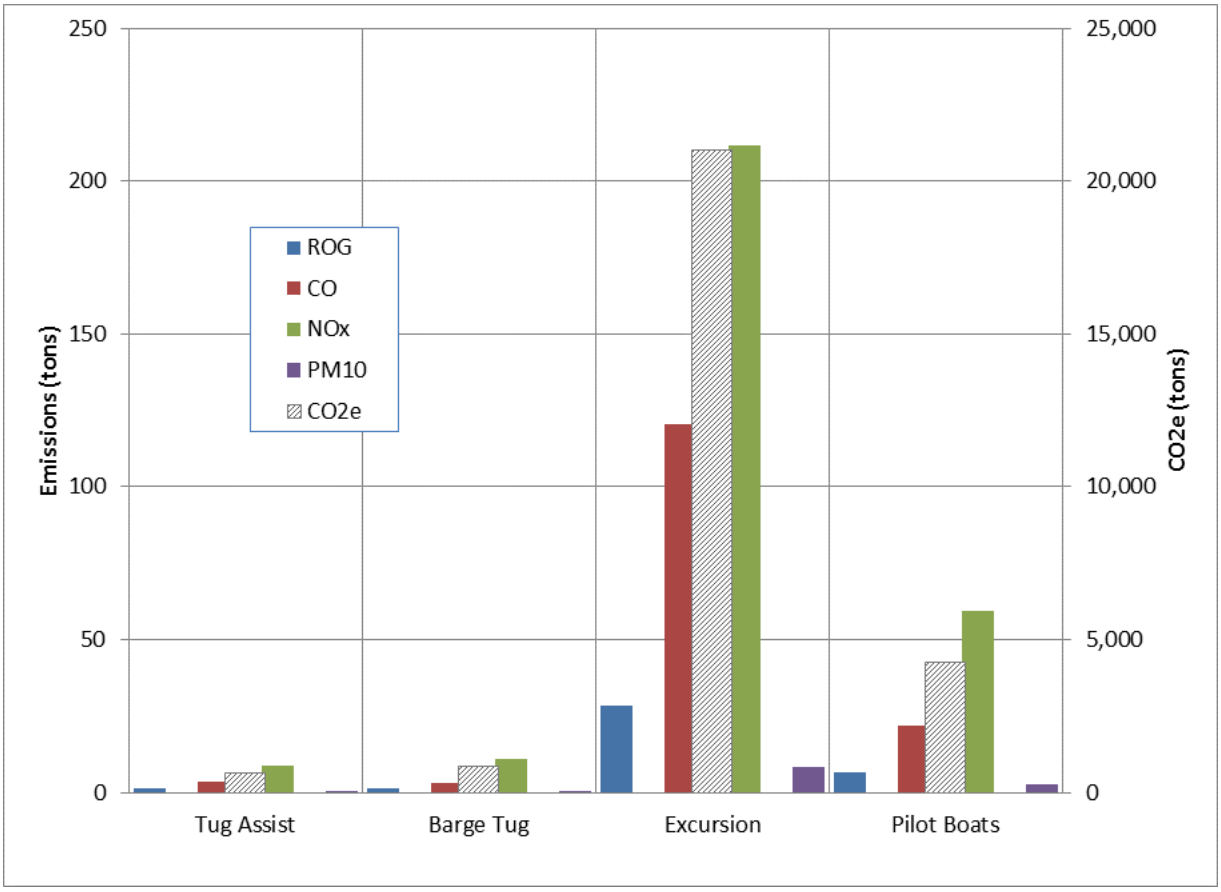

Figure 3-1. Harbor Craft emissions in 2013.

4.0 CARGO HANDLING EQUIPMENT AND OTHER OFF-ROAD EQUIPMENT

4.1 Introduction

Of the Port's tenants, only a few have maritime activity and are considered maritime businesses. Ten Port tenants were identified to transfer marine freight using off-road equipment. Most of the tenants omitted from consideration for their off-road equipment activity estimates included the fish processors, located in the Fisherman's Wharf area, who were also excluded from the 2005 emission inventory. Other omitted tenants included those not conducting marine transport or have negligible marine or shore-based off-road activity. This section describes the equipment used and general shore activity at the Port.

Transportation refrigeration units use off-road engines and comprised an insignificantly small portion of the 2005 inventory and none were reported shipped through the Port in 2013.

4.2 CHE and OFFROAD Emission Estimates

To estimate emissions from shore equipment, a combination of the ARB (2011e and 2012b) CHE Emission Inventory Model, OFFROAD2011, and OFFROAD2007 emission estimation methods and input data were used. Emissions were calculated using the following equation:

$$Equip_{emiss} = \frac{(EF_{zh} + dr \times CHrs) \times HP \times FCF \times LF_{wt} \times CF \times Hrs \times Pop}{(453.6 \times 2000)} \quad (4\text{-}1)$$

Where:

Equip $_{emiss}$ is the annual emissions in tons,
EF $_{zh}$ is the zero-hour emission factor in grams per brake horsepower-hour,
dr is the deterioration rate or the increase in zero-hour emissions as the equipment is used (grams/bhp-hr^2),
CHrs is the cumulative hours or total number of hours accumulated on the equipment [capped at 12,000] [Determined from the Annual Hours x (Calendar Year – Model Year + 1)]
HP is the engine rated brake horsepower
FCF is the fuel control factor (% reduction) used to correct for emission reductions due to California diesel fuel,
LF $_{wt}$ is the weighted load factor (average load expressed as a % of rated power),
CF is the control factor (% reduction) associated with use of emission control technologies where applicable,
Hrs is the annual operating hours of the equipment,
Pop is the population number of the equipment, and 453.6 *x 2000)* is a conversion from grams to tons.

This combination of models was used so that all equipment types are included and all emissions estimated. The CHE model only provides HC (with conversion to ROG), CO, NOx, and PM for equipment specifically designed as CHE including, construction equipment (loaders and

excavators for bulk), container handling equipment (top and side handler and other lift equipment not forklifts or cranes), forklifts, other general industrial equipment (such as mobile conveyers) RTG cranes, and yard tractors. The OFFROAD2011 model provides only HC, NOx, and PM emission factors for many types of off-road equipment. Finally, OFFROAD2007 provides estimates for any equipment not included in the first two models and fuel consumption (for SOx estimates), CO_2, CH_4, and N_2O for greenhouse gases.

4.3 Input Data

Surveys sent out to the Port's terminal operators and follow up phone calls or visits to complete the following detailed information for each piece of CHE. This information was used as input for the emissions estimation.

- Equipment Type Description
- Equipment Model Number
- Equipment Model Year
- Fuel Type
- Engine Model Year
- Engine Retrofit Type/Repower
- Rated horsepower
- Annual hours of operation
- Cumulative hours of operation

The list of equipment types and their average power and annual hours of operation is shown in Table 4-1. The engine model year was identified from survey results and equipment model numbers for each piece of equipment. The equipment cataloged operated at freight terminals and transload facilities at or between Piers 80 – 96, the cruise terminal, and vessel repair yards.

Table 4-1. Shore off-road equipment input data.

Equipment Type	Number	Power (hp)	Annual Hours
Aerial Lifts	1	80	520
Air Compressors	2	50	120
Cranes	3	263	185
Excavators	1	60	35
Forklifts	37	1990	299
Generator	2	192	94
Other General Industrial Equipment	1	150	175
RTG Crane	3	640	362
Rubber Tired Loaders	7	1413	1330
Skid Steer Loaders	2	140	799
Sweepers/Scrubbers	1	200	260
Tractors/Loaders/Backhoes	1	35	175
Welders	1	40	350
Yard Tractor	2	280	305

4.4 Results

The final emission estimates for off-road equipment are shown in Table 4-2.

Table 4-2. Shore off-road equipment emission estimates for 2013. (tons)

Equipment Type	ROG	CO	NOx	SOx	PM_{10}	$PM_{2.5}$	DPM	CO_2	CH_4	N_2O	CO_2e
CHE											
Cranes	0.02	0.08	0.11	0.00	0.01	0.01	0.01	1	0.00	0.00	1
Forklifts	0.34	93.37	1.74	0.00	0.05	0.04	0.04	180	0.29	0.00	187
RTG Crane	0.01	4.18	0.15	0.00	0.01	0.01	0.01	11	0.00	0.00	11
Yard Tractor	0.07	5.68	0.54	0.00	0.02	0.02	0.02	36	0.01	0.00	36
OFFROAD											
Aerial Lifts	0.10	1.01	0.20	0.00	0.00	0.00	0.00	11	0.00	0.00	12
Air Compressors	0.01	0.04	0.03	0.00	0.00	0.00	0.00	2	0.00	0.00	2
Excavators	0.00	0.01	0.04	0.00	0.00	0.00	0.00	2	0.00	0.00	2
Generator	0.02	0.04	0.06	0.00	0.01	0.01	0.01	5	0.00	0.00	6
Other General Industrial Equipment	0.00	0.02	0.02	0.00	0.00	0.00	0.00	3	0.00	0.00	3
Rubber Tired Loaders	0.38	1.58	4.13	0.00	0.20	0.18	0.20	411	0.05	0.00	412
Skid Steer Loaders	0.01	0.18	0.14	0.00	0.01	0.01	0.01	29	0.00	0.00	29
Sweepers/Scrubbers	0.01	0.03	0.19	0.00	0.00	0.00	0.00	15	0.00	0.00	15
Tractors/Loaders/Backhoes	0.01	0.03	0.02	0.00	0.00	0.00	0.00	2	0.00	0.00	2
Welders	0.01	0.03	0.07	0.00	0.00	0.00	0.00	14	0.00	0.00	1
Total	**0.99**	**106.27**	**7.42**	**0.01**	**0.31**	**0.28**	**0.30**	**722**	**0.36**	**0.01**	**732**

Table 4-3. Shore off-road equipment emission estimates by fuel type for 2013. (tons)

Equipment Type	ROG	CO	NOx	SOx	PM_{10}	$PM_{2.5}$	DPM	CO_2	CH_4	N_2O	CO_2e
Diesel	0.65	21.69	6.35	0.01	0.30	0.28	0.30	603	0.08	0.00	605
Gasoline	0.11	5.02	0.24	0.00	0.00	0.00	0.00	14	0.01	0.01	16
Propane	0.22	79.56	0.83	0.00	0.01	0.01	0.00	105	0.28	0.00	111
Total	**0.99**	**106.27**	**7.42**	**0.01**	**0.31**	**0.29**	**0.30**	**722**	**0.36**	**0.01**	**732**

5.0 TRUCK AND BUS TRIPS

5.1 Introduction

The truck and bus trip emission estimation method followed the approach used for 2005 emission inventory where in terminal and the offsite (to and from the terminal to the nearest freeway entrance/exit) activity was estimated along with the number of round trips through the terminal.

Emission rates for driving and idling were estimated using EMFAC2014[5] with the county average fleets for heavy-duty trucks and passenger buses.

5.2 Emissions Calculations

It was important to account for the vehicle traffic to and from terminals by the number of trips, and descriptions of those trips in terms of the speed and distance. Using the number of visits by vehicle type (truck or bus) and county average age distribution, and an estimate of the average trip mileage and speed, on-road vehicle exhaust and evaporative emissions were estimated as follows:

$$Emissions = \frac{EF \times Miles \times Trips}{(453.6 \times 2000)} \quad (5\text{-}1)$$

Where:

Emissions is the annual emissions in tons,
EF is the vehicle type-, regional-, model year-, and speed-specific emission factor in grams per miles traveled; generated using ARB's EMFAC 2011 model
Miles is the miles traveled in one trip,
Trips is the number of trips
(453.6 x 2000) is a conversion from grams to tons.

For idling activities, the "miles traveled" were substituted for "idling hours."

5.3 Input Data

The numbers of truck visits by terminal were collected from surveys of the terminal operators, and the driving distances estimated from trip routes. The number of trips and by terminal and the emission estimation method are described below.

5.3.1 Truck and Bus Estimates

The truck and bus trip estimates along with the idle time and driving distances and average speed are provided in Tables 5-1 and 5-2.

[5] http://www.arb.ca.gov/msei/categories.htm#emfac2014

Table 5-1. Heavy truck trips and activity for 2013.

Operator	Berth	No. of Visits	Within Terminal Activity (Per In/Out Trip)			Outside Terminal	Off-site		
			Idle (min)	Speed (mph)	Onsite Distance (miles)	Idle Time Per Visit (min)	Route	Distance (mi)	Speed (mph)
Hanson Aggregates	Pier 94	7,713	10	10	1	0	Terminal to Hwy 101	1.81	25.2
Metro	Pier 80	70	0	10	0.5	4	Hwy 101 Ceasar Chavez to Terminal	1.23	24
CEMEX	Pier 92	46,975	6	5	0.12	0	Terminal to Hwy 101	1.63	12.4
Central Concrete	Pier 92	31,200	3	5	0.2	3	Terminal to Hwy 101	1.76	15
Metro Cruise	Pier 35	320	2	3	0.2	0	Hwy 101 via the Embarcadero to Pier 35	3.14	21

Table 5-2. Bus trips and activity for 2013.

Facility	Berth	No. of Visits	Idle Time at Drop-off Location (mins)	Off-Site		
				Route	Distance (mi)	Speed (mph)
Hornblower	Pier 30-32	240	4.25	From Parking Lot to Bay Bridge	0.6	36
Blue and Gold Fleet	Pier 39	480	4.25	Pier 39 to Highway 101	2.7	21
Metro Cruise	Pier 35	960	1	Pier 35 to Highway 101	3.14	21
Red and White Fleet	Pier 43½	763	7.5	Terminal drop-off location to Highway 101 North	2.61	21.75

5.3.2 Emission Estimates

EMFAC2014 was used to estimate the emissions at idle and driving on and off-site. Lookup tables of emission rates for the county average heavy-duty truck and bus emission rates at idle and as a function of speed were used to estimate emissions from individual truck visits. For this source category, EMFAC estimates exhaust emissions and additional PM generated from tire and break wear and road dust. Annual emissions were determined by multiplying the annual visits by the emissions per trip (departing to the nearest interstate and returning from the interstate). The emission estimates for 2013 are shown in Table 5-3.

Table 5-3. Heavy truck and bus emissions for 2013. (tons)

Mode	ROG	CO	NOx	SO_2	Exhaust PM_{10}/DPM	$PM_{2.5}$	PM_{10} Total	CO_2	CH_4
On-Terminal Travel	0.09	0.15	0.61	0.00	0.02	0.02	0.02	91	0.00
On-Terminal Idle	0.03	0.09	0.69	0.00	0.00	0.00	0.00	61	0.00
Off-Terminal Idle	0.01	0.02	0.14	0.00	0.00	0.00	0.00	13	0.00
Off-Site Travel	0.74	1.54	6.25	0.01	0.16	0.16	0.20	1,084	0.03
Truck (HHDT) Emissions	**0.87**	**1.80**	**7.70**	**0.01**	**0.19**	**0.18**	**0.22**	**1,249**	**0.04**
Drop-off Location Idle	0.00	0.00	0.02	0.00	0.00	0.00	0.00	1	0.00
Off-Site Travel	0.01	0.02	0.13	0.00	0.00	0.00	0.00	24	0.00
Bus Emissions	**0.01**	**0.03**	**0.14**	**0.00**	**0.00**	**0.00**	**0.00**	**26**	**0.00**
Total	**0.87**	**1.83**	**7.84**	**0.01**	**0.19**	**0.18**	**0.22**	**1,275**	**0.04**

6.0 LOCOMOTIVE

6.1 Introduction and Emissions Calculations

San Francisco Bay Railroad (SF Bay Rail) is the only railroad working at the Port providing connection to Union Pacific mainline off-site as well as trans-loading capability. The rail yard is located between Piers 94 and 92.

Following the emission estimation approach for the 2005 inventory, the fuel consumption for the SF Bay Rail locomotives was multiplied by emission factors per gallon of fuel consumed.

6.2 Locomotive Fleet

SF Bay Rail operates the one rail yard at the Port and builds trains for cargo moving through Pier 80 through Pier 96 using two switch locomotives. The locomotives have remained the same as in 2005, and the estimated activity is provided in Table 6-1.

Table 6-1. Locomotives engine characteristics and activity.

Equipment Type	Make	Model Year	Engine Model	Rated Power (hp)	Activity (Hrs/year)
Locomotive # 23	Alco S-2	1944	Alco 539T	1000	525
Locomotive #25	Alco S-2	1945	Alco 539T	1000	525

To estimate emissions we use the same rated power, activity, and an average load factor of 0.1 (EPA, 2009) for a typical switch duty cycle to estimate the work performed by these engines. EPA (2009) estimated that the fuel consumption for switch engines is 15.2 hp-hr/gallon was applied to the work to estimate that 6908 gallons of fuel were consumed by SF Bay Rail locomotives during 2013 that was comparatively higher than the 1800 gallons that was provided as the activity for 2005.

Table 6-2 provides the emission factors for these locomotives, which are the same as reported for 2005 based on ARB testing of the unique SF Bay Rail locomotives, however with lower 15 ppm sulfur fuel reducing the SOx emission factor. The methane (CH_4) and nitrous oxide (N_2O) fractions (as a function of HC and fuel consumption respectively) were taken from the Port of Oakland (ENVIRON, 2013) estimates for locomotives.

Table 6-2. ALCO locomotives emission factors (lb/1000 gallons).

HC	CO	NOx	SOx	PM_{10}
54	80.6	172	0.21	23.3

6.3 Results

The locomotive emissions in 2012 shown in Table 6-3 are higher than 2005 by reason of higher estimated fuel consumption and using the same engines. But overall the emissions from locomotives were a minor fraction of the Port's emissions.

Table 6-3. Locomotives emissions. (tons)

ROG	HC	CO	NOx	SOx	PM_{10}/DPM	$PM_{2.5}$	CO_2	CH_4	N_2O	CO_2e
0.20	0.19	0.28	0.59	0.00	0.08	0.08	78	0.01	77.6	78.5

7.0 RESULTS

7.1 2005 Summary

For reference Table 7-1 provides the summary emission estimates for the Port of San Francisco estimated for the 2005 calendar year. (Moffat and Nichol and ENVIRON 2010)

Table 7-1. Port of San Francisco 2005 Emission Inventory. (tons)

Source Category	ROG	CO	NOx	PM_{10}	SO_2
Ocean-Going Vessels (OGV)	7.6	19.9	246.1	25.5	195.5
Harbor Craft (HC)	31.1	96.4	361.8	14.8	4.1
Cargo Handling Equipment (CHE)	3.1	13.0	40.3	1.5[a]	0.3[a]
Heavy Duty On-Road Vehicles (HDV)	2.1	6.5	13.6	0.8	0.1
Transportation Refrigeration Units (TRU)	0	0.1	0	0	0
Rail Locomotives (RL)	0	0.1	0.2	0	0
Total	**43.9**	**135.9**	**662.0**	**42.6**	**200.0**

[a] – Two numbers transposed in the 2005 emission inventory.

7.2 2013 Summary

The Port's air emissions inventory for 2013 is summarized in Table 7-2 for criteria pollutants and for greenhouse gases (GHG) in Table 7-3. In most cases, the criteria pollutant emissions were lower due to use of both low sulfur fuel and cleaner engines for all source categories, and due to reduced activity for some source categories. Increases in ROG and CO can be attributed to changes in ARB emission factors for Harbor Craft and greater use of high CO emitting propane shore-based off-road equipment.

Table 7-2. Port of San Francisco 2013 Emission Inventory. (tons)

Source Category	ROG	CO	NOx	PM_{10}	SO_2
Ocean-Going Vessels (OGV)	12.02	21.11	246.79	6.30	27.69
Harbor Craft (HC)	37.59	149.02	290.61	11.80	0.25
Cargo Handling Equipment (CHE)	0.99	106.27	7.42	0.31	0.01
Heavy Duty On-Road Vehicles (HDV)	0.87	1.83	7.84	0.19	0.01
Rail Locomotives (RL)	0.20	0.28	0.59	0.08	0.00
Total	**51.67**	**278.50**	**553.25**	**18.68**	**27.96**
Relative to 2005	18%	105%	-16%	-56%	-86%

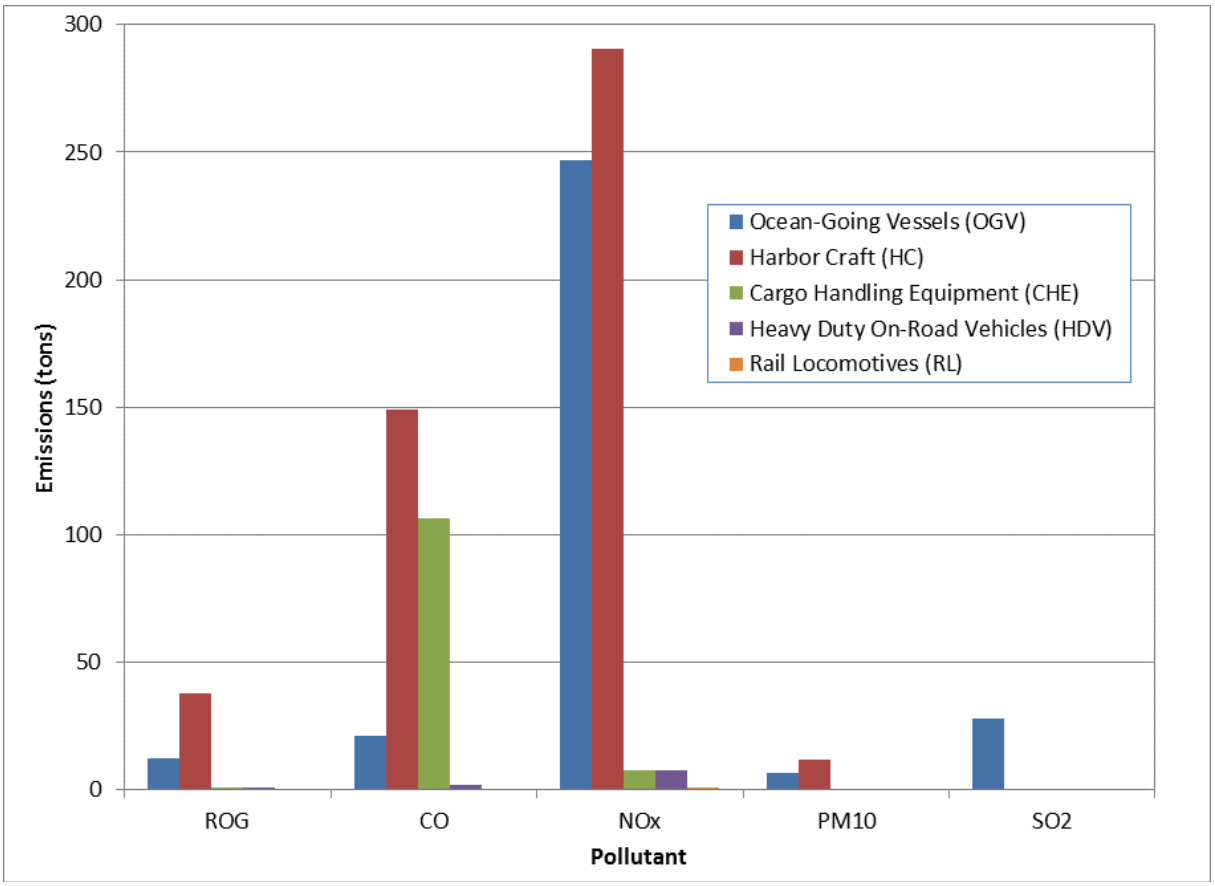

Figure 7-1. Port of San Francisco 2013 Emission Inventory.

Table 7-3. Port of San Francisco 2013 GHG Emission Inventory. (tons)

Source Category	CH_4	N_2O	CO_2	CO_2e
Ocean-Going Vessels (OGV)	1.66	0.36	14,052	14,198
Harbor Craft (HC)	3.38	0.90	26,437	26,787
Cargo Handling Equipment (CHE)	0.36	0.01	722	732
Heavy Duty On-Road Vehicles (HDV)	0.04	0.00	1,275	1,276
Rail Locomotives (RL)	0.01	0.00	78	79
Total	**5.45**	**1.27**	**42,563**	**43,071**

7.3 Source Category 2013 and 2005 Emission Inventory Comparison

7.3.1 Summary

The summary of the emission effects by source category are shown in Table 7-4. The comparison shows the relative change in emissions from 2005 to 2013, so negative figures mean a reduction in emissions. For NOx, PM_{10}, and SO_2, the emissions were generally lower for all source categories due to the use of both lower sulfur fuel and cleaner engines. An exception is for locomotives where a change in estimated activity levels was noted as the source of the

increase. The ROG and CO increases were due to new high CO emitting propane CHE equipment, higher OGV ROG emission rates when using lower sulfur fuel, and higher Harbor Craft activity.

Table 7-4. Port of San Francisco 2013/2005 Emission Inventory comparison.

Source Category	ROG	CO	NOx	PM_{10}	SO_2
Ocean-Going Vessels (OGV)	58%	6%	0%	-75%	-86%
Harbor Craft (HC)	21%	55%	-20%	-20%	-94%
Cargo Handling Equipment (CHE)	-68%	716%	-81%	-80%	-98%
Heavy Duty On-Road Vehicles (HDV)	-58%	-72%	-42%	-77%	-88%
Rail Locomotives (RL)	392%	286%	281%	281%	-74%
Overall	**18%**	**105%**	**-16%**	**-56%**	**-86%**

7.3.2 OGV

The OGV emission effects are primarily due to the use of lower sulfur fuel (0.3% compared with 2.7% for most vessels) reducing PM and SO_2 emission factors by 79% and 90% respectively, but increasing ROG emission factors by about 55%. While the number of vessel calls to the Port was lower in 2013, the ships that did call were larger and carried more passengers or freight per call, and cruise ships remained at berth longer than was estimated in 2005.

7.3.3 Harbor Craft

While it is difficult to compare overall harbor craft activity levels in 2013 with 2005, excursion vessels had higher activity due to higher powered engines (about twice as powerful as 2005) and about the same number of hours, while assist and barge tugs performed fewer moves in 2013. ARB's regulation of Commercial Harbor Craft has encouraged lower emitting engines to be installed and lower sulfur fuel is now used, which reduced NOx, PM, and SO_2 emissions. Table 7-5 shows that, despite higher activity for excursion vessels and pilot boats, the NOx and PM_{10} emissions were lower because of the engine turnover.

Table 7-5. Port of San Francisco 2013/2005 Harbor Craft comparison by vessel type. (tons)

2005 By Vessel Type	ROG	CO	NOx	PM_{10}	SO_2
Tug Assist	0.86	3.47	13.97	0.57	0.11
Barge Tug	2.59	7.74	28.88	1.21	0.17
Excursion	19.99	62.69	236.18	9.58	2.80
Pilot Boats	7.61	22.52	82.75	3.45	1.05
2005 Total	**31.05**	**96.42**	**361.78**	**14.81**	**4.13**
2013 By Vessel Type	**ROG**	**CO**	**NOx**	**PM_{10}**	**SO_2**
Tug Assist	1.10	3.39	8.88	0.37	0.01
Barge Tug	1.46	3.27	11.11	0.55	0.01
Excursion	28.44	120.58	211.41	8.14	0.19
Pilot Boats	6.59	21.78	59.21	2.74	0.04
2013 Total	**37.59**	**149.02**	**290.61**	**11.80**	**0.25**

7.3.4 Shore Equipment

The shore equipment activity was significantly lower and fleet turnover combined to lower emissions from this equipment. The shore based equipment, however, showed higher CO emissions due to greater use of propane engines that have higher CO but lower NOx and PM emission rates.

7.3.5 On-road Vehicles

There were about 15% fewer truck and bus moves in 2013, and the fleet turnover to newer models for the county average vehicles both reduce the on-road vehicle emissions. Vehicle emissions were not a significant part of either the 2005 or 2013 Port inventory.

7.3.6 Locomotives

As noted, the number of hours and fuel consumption estimated for SF Bay Rail was considerably higher in 2013 than was estimated for 2005. The two locomotives used were the same as used in 2013. However, despite the increase in emissions and emission reduction from other source categories, locomotives do not comprise a significant portion of the Port inventory.

7.4 Pier 70 At Berth Emissions and Shoreside Power

Two cruise ships called for maintenance in 2013 at Pier 70 for about 12 days each as did five Navy ships. These emissions are presented here as a separate estimate because the 2005 Port emissions inventory did not present the emissions from ships while at Pier 70.

Separately, the five Navy ships used Port-supplied shore power connections instead of their auxiliary engines for much of their time at Pier 70. The use of shore power has reduced emissions from those vessels, and the energy (kW-hr) consumed by shore power was used to estimate the emissions reduced as a result.

Table 7-6 shows the ship emissions when auxiliary engines were running and, separately, the emission reductions from shoreside power use. Appendix C provides a detailed description of how these estimates were prepared.

Table 7-6. 2013 emissions and emission reductions at berth or in dry dock at Pier 70. (tons)

Estimate	Energy (kW-hr)	ROG	CO	NOx	PM	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O
Cruise Ship Emissions	2,222,345	1.59	2.69	32.34	0.77	0.70	3.04	1,580	0.20	0.04
Navy Ship Emissions	283,734	0.16	0.34	3.63	0.10	0.09	0.39	216	0.03	0.01
2013 Pier 70 At Berth Emissions	**2,506,079**	**1.75**	**3.04**	**35.97**	**0.86**	**0.79**	**3.43**	**1,796**	**0.22**	**0.05**
Navy Ship Shoreside Power Emission Reductions	4,643,600	2.66	5.63	62.77	1.60	1.47	6.40	3,532	0.41	0.09

8.0 REFERENCES

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APPENDIX A

Ship Calls

Appendix A. Ship Calls

IMO No.	Vessel Name	Arrival Date	Departure Date	Berthing Time (hrs.)	Berth
7932202	MOKU PAHU	15-Oct-13	18-Oct-13	67.8	P80C
8309531	STOLT SAPPHIRE	14-Feb-13	19-Feb-13	82.7	P92
8913162	AMADEA	21-Feb-13	21-Feb-13	8.7	P35
8913162	AMADEA	03-Mar-13	04-Mar-13	29.1	P35S
9064126	SEVEN SEAS NAVIGATOR	10-May-13	10-May-13	11.6	P35N
9064126	SEVEN SEAS NAVIGATOR	02-Sep-13	02-Sep-13	10.7	P35S
9066667	CRYSTAL SYMPHONY	04-May-13	04-May-13	9.5	P35S
9072446	CELEBRITY CENTURY	24-Apr-13	24-Apr-13	12.3	P35S
9072446	CELEBRITY CENTURY	30-Apr-13	01-May-13	36.3	P35S
9072446	CELEBRITY CENTURY	03-Oct-13	03-Oct-13	14.9	P35N
9087489	CARNIVAL INSPIRATION	05-Nov-13	17-Nov-13	0.0	P70
9104005	GRAND PRINCESS	16-Mar-13	16-Mar-13	15.9	P35S
9104005	GRAND PRINCESS	31-Mar-13	31-Mar-13	12.3	P35S
9104005	GRAND PRINCESS	10-Apr-13	10-Apr-13	10.0	P35S
9104005	GRAND PRINCESS	25-Apr-13	25-Apr-13	12.0	P35S
9104005	GRAND PRINCESS	10-May-13	10-May-13	11.4	P35S
9104005	GRAND PRINCESS	20-May-13	20-May-13	9.7	P35S
9104005	GRAND PRINCESS	30-May-13	30-May-13	10.5	P35S
9104005	GRAND PRINCESS	09-Jun-13	09-Jun-13	10.0	P35S
9104005	GRAND PRINCESS	19-Jun-13	19-Jun-13	10.2	P35S
9104005	GRAND PRINCESS	29-Jun-13	29-Jun-13	10.2	P35S
9104005	GRAND PRINCESS	09-Jul-13	09-Jul-13	10.6	P35S
9104005	GRAND PRINCESS	19-Jul-13	19-Jul-13	10.2	P35S
9104005	GRAND PRINCESS	29-Jul-13	29-Jul-13	10.9	P35S
9104005	GRAND PRINCESS	08-Aug-13	08-Aug-13	11.1	P35S
9104005	GRAND PRINCESS	18-Aug-13	18-Aug-13	10.5	P35S
9104005	GRAND PRINCESS	28-Aug-13	28-Aug-13	10.7	P35S
9104005	GRAND PRINCESS	07-Sep-13	07-Sep-13	10.1	P35S
9104005	GRAND PRINCESS	17-Sep-13	17-Sep-13	11.0	P35S
9104005	GRAND PRINCESS	27-Sep-13	27-Sep-13	10.5	P35S
9104005	GRAND PRINCESS	04-Oct-13	04-Oct-13	10.5	P35S
9104005	GRAND PRINCESS	19-Oct-13	19-Oct-13	10.3	P35S
9104005	GRAND PRINCESS	26-Oct-13	26-Oct-13	10.6	P35S
9104005	GRAND PRINCESS	10-Nov-13	10-Nov-13	10.7	P35S
9104005	GRAND PRINCESS	25-Nov-13	25-Nov-13	11.6	P35S
9104005	GRAND PRINCESS	10-Dec-13	10-Dec-13	9.9	P35S
9104005	GRAND PRINCESS	20-Dec-13	21-Dec-13	38.3	P35S
9126819	DISNEY WONDER	22-May-13	23-May-13	34.3	P35S
9126819	DISNEY WONDER	12-Sep-13	13-Sep-13	19.2	P35S
9156474	REGATTA	09-May-13	09-May-13	10.8	P35N
9156474	REGATTA	22-Aug-13	22-Aug-13	12.3	P35S
9169524	AURORA	29-Jan-13	30-Jan-13	39.7	P35S
9188037	AMSTERDAM	05-Dec-13	17-Dec-13	0.0	P70
9188037	AMSTERDAM	18-Dec-13	18-Dec-13	9.8	P35S
9192363	STAR PRINCESS	27-Sep-13	27-Sep-13	9.3	P35N

IMO No.	Vessel Name	Arrival Date	Departure Date	Berthing Time (hrs.)	Berth
9192363	STAR PRINCESS	01-Oct-13	01-Oct-13	17.7	P35N
9197002	SAGA ANDORINHA	03-Oct-13	04-Oct-13	26.3	P80C
9218131	NORWEGIAN SUN	08-May-13	08-May-13	10.0	P35S
9218131	NORWEGIAN SUN	21-Sep-13	21-Sep-13	9.9	P35S
9221279	ZUIDERDAM	01-Oct-13	01-Oct-13	11.1	P35S
9226906	ARCADIA	22-Mar-13	23-Mar-13	34.2	P35S
9228186	SAPPHIRE PRINCESS	31-Mar-13	01-Apr-13	24.2	P35S
9228186	SAPPHIRE PRINCESS	07-Apr-13	08-Apr-13	24.5	P35S
9228186	SAPPHIRE PRINCESS	14-Apr-13	15-Apr-13	22.8	P35S
9228186	SAPPHIRE PRINCESS	28-Apr-13	29-Apr-13	25.5	P35S
9228186	SAPPHIRE PRINCESS	05-May-13	06-May-13	23.8	P35S
9228186	SAPPHIRE PRINCESS	13-May-13	13-May-13	12.2	P35S
9228186	SAPPHIRE PRINCESS	03-Oct-13	03-Oct-13	9.4	P35S
9228186	SAPPHIRE PRINCESS	07-Oct-13	07-Oct-13	16.3	P35S
9228186	SAPPHIRE PRINCESS	14-Oct-13	14-Oct-13	16.6	P35S
9230402	ISLAND PRINCESS	25-Sep-13	25-Sep-13	6.8	P35S
9304045	NORWEGIAN JEWEL	09-May-13	09-May-13	9.2	P35S
9304045	NORWEGIAN JEWEL	25-Sep-13	25-Sep-13	11.5	P35N
9320556	QUEEN VICTORIA	03-Feb-13	03-Feb-13	15.9	P35S
9342281	NORWEGIAN PEARL	07-May-13	07-May-13	9.7	P35S
9342281	NORWEGIAN PEARL	02-Oct-13	02-Oct-13	12.1	P35S
9362530	CELEBRITY SOLSTICE	11-May-13	11-May-13	13.8	P35S
9362530	CELEBRITY SOLSTICE	15-Sep-13	16-Sep-13	31.8	P35S
9363637	SAGA JOURNEY	27-Feb-13	28-Feb-13	29.6	P80C
9368338	BBC RHINE	08-Jul-13	10-Jul-13	41.1	P80C
9398917	COSTA DELIZIOSA	05-Feb-13	06-Feb-13	29.6	P35N
9593854	STAR LAGUNA	30-Sep-13	02-Oct-13	47.3	P80C
9600970	RT.HON.PAUL E.MARTIN	22-Jan-13	23-Jan-13	39.9	P94
9600970	RT.HON.PAUL E.MARTIN	09-Feb-13	11-Feb-13	10.1	P94
9600970	RT.HON.PAUL E.MARTIN	18-Feb-13	20-Feb-13	13.0	P94
9600970	RT.HON.PAUL E.MARTIN	28-Feb-13	02-Mar-13	13.9	P94
9600970	RT.HON.PAUL E.MARTIN	09-Mar-13	11-Mar-13	17.4	P94
9600970	RT.HON.PAUL E.MARTIN	18-Mar-13	21-Mar-13	25.3	P94
9600970	RT.HON.PAUL E.MARTIN	08-Apr-13	11-Apr-13	23.5	P94
9600970	RT.HON.PAUL E.MARTIN	18-Apr-13	21-Apr-13	22.7	P94
9600970	RT.HON.PAUL E.MARTIN	28-Apr-13	30-Apr-13	22.1	P94
9600982	BALTO	14-May-13	16-May-13	23.8	P94
9600982	BALTO	24-May-13	26-May-13	19.7	P94
9600982	BALTO	20-Jun-13	23-Jun-13	10.5	P94
9600982	BALTO	05-Sep-13	07-Sep-13	13.8	P94
9600982	BALTO	25-Sep-13	27-Sep-13	14.0	P94
9600982	BALTO	22-Oct-13	25-Oct-13	21.2	P94
9600982	BALTO	02-Nov-13	05-Nov-13	20.6	P94
9600982	BALTO	13-Nov-13	16-Nov-13	22.0	P94
9600982	BALTO	21-Dec-13	23-Dec-13	23.9	P94
9600982	BALTO	31-Dec-13	05-Jan-14	24.6	P94
9600994	CSL TECUMSEH	07-Jun-13	09-Jun-13	22.1	P94

IMO No.	Vessel Name	Arrival Date	Departure Date	Berthing Time (hrs.)	Berth
9600994	CSL TECUMSEH	26-Jun-13	29-Jun-13	14.3	P94
9600994	CSL TECUMSEH	02-Aug-13	05-Aug-13	15.5	P94
9600994	CSL TECUMSEH	12-Aug-13	15-Aug-13	14.0	P94
9600994	CSL TECUMSEH	22-Aug-13	30-Aug-13	10.4	P94
9600994	CSL TECUMSEH	01-Oct-13	05-Oct-13	29.6	P94
9600994	CSL TECUMSEH	12-Oct-13	14-Oct-13	10.3	P94
9600994	CSL TECUMSEH	04-Dec-13	07-Dec-13	22.3	P94
9613874	SAGA FRAM	28-May-13	28-May-13	14.0	P80
9640944	BALCHEN	20-Oct-13	23-Oct-13	15.7	P94
9640956	CSL TACOMA	04-Nov-13	07-Nov-13	33.5	P94
9646455	AGGERSBORG	22-Apr-13	23-Apr-13	35.7	P80C

APPENDIX B

Vessel Characteristics

Appendix B. Vessel Characteristics

Calls	IMO Number	Vessel Name	Flag	Engine	Engine Speed	Speed (knots)	Keel Laid Date	Engine Make	Engine Model	Engine (kW)	Vessel Type	DWT
9	9600970	Rt Hon Paul E Martin	BAH	2-Stroke	Slow	14.5	1/1/2012	B&W	5S65ME-C	14350	Bulk Cargo	71406
10	9600982	Balto	MAI	2-Stroke	Slow	14.5	1/1/2013	B&W	5S65ME-C	14350	Bulk Cargo	71500
8	9600994	Csl Tecumseh	BAH	2-Stroke	Slow	14.5	1/1/2013	B&W	5S65ME-C8	14350	Bulk Cargo	71319
1	9640944	Balchen	MAI	2-Stroke	Slow	14.5	1/1/2013	B&W	5S65ME-C	14350	Bulk Cargo	71348
1	9640956	Csl Tacoma	BAH	2-Stroke	Slow	14.5	1/1/2013	B&W	5S65ME-C	14350	Bulk Cargo	71552
1	9646455	Aggersborg	PAN	2-Stroke	Medium	15	1/1/2012	MaK	6M43C	5400	Bulk Cargo	12645
1	9613874	Saga Fram	HKG	2-Stroke	Slow	15	1/1/2013	B&W	5S60ME-C8	11900	Bulk Cargo	54930
1	9593854	Star Laguna	NIS	2-Stroke	Slow	15.5	1/1/2012	B&W	5S60ME-C8	10780	Bulk Cargo	50827
Shift	9670822	Cap Corrientes	LIB	2-Stroke	Slow	20.3	1/1/2013	B&W	7S70ME-C8	22890	Bulk Cargo	51759
1	9169524	Aurora	Ber.	4-Stroke	Medium	24	5/11/1998	MAN	14V48/60	56000	Cruise	8486
1	8309531	Stolt Sapphire	Lib.	2-Stroke	Slow	15		B&W	6L60MC	9179	Tanker	38746
1	9320556	Queen Victoria	UK	4-Stroke	Medium	21.7	5/19/2006	Sulzer	16ZAV40S	63360	Cruise	7685
2	8913162	Amadea	Bah.	4-Stroke	Medium	21	4/16/1990	MAN	7L58/64	15560	Cruise	2248
1	9363637	Saga Journey	HK	2-Stroke	Slow	14.9		Sulzer	7RTA52U	9282	Bulk Cargo	46652
26	9104005	Grand Princess	Ber.	4-Stroke	Medium	22.5	7/18/1996	Sulzer	16ZAV40S	69120	Cruise	6750
1	9226906	Arcadia	Ber.	4-Stroke	Medium	22	7/12/2003	Sulzer	16ZAV40S	63360	Cruise	10939
2	9342281	Norwegian Pearl	Bah.	4-Stroke	Medium	25	1/31/2005	MAN B&W	12V48/60B	72080	Cruise	10000
2	9218131	Norwegian Sun	Bah.	4-Stroke	Medium	20	11/2/1999	MAN	7L58/64	49212	Cruise	7100
2	9156474	Regatta	Mar.	4-Stroke	Medium	18	1/7/1998	Wartsila	12V32	18600	Cruise	2700
2	9304045	Norwegian Jewel	Bah.	4-Stroke	Medium	24.6	6/4/2004	MAN B&W	12V48/60B	72080	Cruise	7500
2	9362530	Celebrity Solstice	Malta	4-Stroke	Medium	21	3/17/2007	Wartsila	16V46	57120	Cruise	9500
1	9368338	BBC Rhine	Lib.	4-Stroke	Medium	14.2	5/28/2008	Wartsila	8L46B	7800	General Cargo	17110
1	9230402	Island Princess	Ber.	4-Stroke	& Turbine	24	12/12/2000	GE	LM2500	62683	Cruise	8015
1	9197002	Saga Andorinha	UK	2-Stroke	Slow	15		Sulzer	7RTA52	7609	General Cargo	47027
1	9087489	Carnival Inspiration	Bah.	4-Stroke	Medium	18	6/30/1993	Sulzer	12ZAV40S	42240	Cruise	7180
1	7932202	Moku Pahu	US	4-Stroke	Medium	15	9/4/1980	Semt-Pielstick	14PC2V-400	10298	Bulk Cargo	1455
2	9064126	Seven Seas Navigator	Bah.	4-Stroke	Medium	17.5	4/12/1988	Wartsila	8L38	15536	Cruise	2581
1	9066667	Crystal Symphony	Bah.	4-Stroke	Medium	21	1/10/1994	Sulzer	9ZAL40S	36330	Cruise	4500
3	9072446	Celebrity Century	Malta	4-Stroke	Medium	21.5	1/30/1994	MAN	9L48/60	29250	Cruise	7260
2	9126819	Disney Wonder	Bah.	4-Stroke	Medium	21.5	5/15/1997	Sulzer	16ZAV40S	57670	Cruise	8604

Calls	IMO Number	Vessel Name	Flag	Engine	Engine Speed	Speed (knots)	Keel Laid Date	Engine Make	Engine Model	Engine (kW)	Vessel Type	DWT
2	9188037	Amsterdam	Neth.	4-Stroke	Medium	21	3/10/1999	Sulzer	16ZAV40S	55216	Cruise	7327
2	9192363	Star Princess	Ber.	4-Stroke	Medium	22	6/10/1999	Sulzer	16ZAV40S	63360	Cruise	6750
1	9221279	Zuiderdam	Neth.	4-Stroke	& Turbine	22	2/17/2001	GE	LM2500	75140	Cruise	10965
9	9228186	Sapphire Princess	Ber.	4-Stroke	& Turbine	23	7/29/2001	GE	LM2500+	60700	Cruise	7921
1	9398917	Costa Deliziosa	Italy	4-Stroke	Medium	23.6	12/20/2007	MaK	12M43C	54400	Cruise	8000

APPENDIX C

At Berth and Dry Dock Emissions and Shoreside Power Benefits at Pier 70

Appendix C: At Berth and Dry Dock Emissions and Shoreside Power Benefits at Pier 70

Ship auxiliary engine activity and emissions at berth or while in dry dock at Pier 70 were not estimated for 2005, and so this activity is included in this inventory as a separate line item. Future inventories will be able to use and compare the 2013 emissions as well as the emission reductions realized from the use of shoreside power at Pier 70.

Two cruise ships (Carnival Inspiration and Amsterdam) and five Navy ships were in for maintenance at Pier 70 during 2013. The two cruise ships were in for 12 days. The Navy ships primarily used shore power in 2013, but there were trial days, shifts, and time before each connection and after each disconnection when these ships were not on shore power and still at berth. This section describes the emission estimates for cruise ships and Navy ships, and the emissions reduced with the use of shore power for Navy ships.

The two cruise ships' emission factors were based on older estimates because the Carnival Inspiration and Amsterdam were constructed prior to 2000, and are diesel-electric ships driven by larger 4-stroke main engines. The Navy ships emission factors were the smaller auxiliary diesel engine emission and so used the ARB factors for newer Tier 1 and older based on the model year of each vessel. The emission factors shown in Table C-1 were collected from Table 2-5.

Table C-1. Emission factors (g/kW-hr) used for Pier 70 emission estimates

	Emission Factors (Older main 4-stroke diesel-electric; and auxiliary diesel engines)								
Engine Type	**ROG**	**CO**	**NOx**	**PM**	**$PM_{2.5}$**	**SO_2**	**CO_2**	**CH_4**	**N_2O**
4-Stroke Main	0.65	1.1	13.2	0.3125	0.2875	1.24	645	0.08	0.018
<2000 Auxiliary	0.52	1.1	13.9	0.3125	0.2875	1.25	690	0.08	0.018
<2011 Auxiliary	0.52	1.1	11.54	0.3125	0.2875	1.25	690	0.08	0.018

The cruise ship arrival and departure dates and times were provided by the Marine Exchange to provide a specific estimate of the elapsed time at berth. For the Navy ships, there were days when the power was disconnected for trials or other reasons, and, for each move or shift, four hours of auxiliary engine power was assumed before each connection and after each disconnection.

The at-berth or in dry dock power was estimated for cruise ships at 0.08 load factor (or half the 0.16 load factor estimated by ARB for a normal vessel call when taking on passengers) and multiplied by the total power and hours while at Pier 70. BAE recorded and reported the Navy ship shoreside power usage (kW-hr) and hours when on the shoreside power. The average load demanded by the Navy vessel while at berth was then determined for each auxiliary engine bank (either port and starboard or forward and aft) from the shoreside power demands.

The summary time and estimated auxiliary engine load for ships off shoreside power at Pier 70 are shown in Table C-2.

Table C-2. 2013 at berth or in dry dock time and average load at Pier 70.

Cruise Ship	Total Power (kW)	Arrival Date	Departure Date	Elapsed Time (hrs)	Estimated Load (kW)
Carnival Inspiration	42,240	November 5, 2013	November 17, 2013	270	3,379
Amsterdam	56,416	December 5, 2013	December 17, 2013	290	4,513
Navy Ship	**Moves/Shifts**	**Days Off Power**		**Estimated Hours Off Power**	**Average Load (kW)**
Ship 1 SE	4	0		16	497
Ship 1 NW	4	0		16	581
Ship 2	2	0		8	434
Ship 3 N/FWD	6	7		192	591
Ship 3 S/Aft	6	7		192	541
Ship 4 Port/W	2	1		32	698
Ship 4 Stbd/E	2	1		32	529
Ship 5	2	0		8	790

The emission factors in Table C-1 were applied to the energy demanded from that shown in Table C-2 by multiplying the hours by the load. Table C-3 shows the at-berth emissions at Pier 70, and the emission reductions from the use of shoreside power as recorded by BAE.

Table C-3. 2013 emissions and emission reductions (tons) at berth or in dry dock at Pier 70.

Ship	Model Year	Energy (kW-hr)	ROG	CO	NOx	PM	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O
Carnival Inspiration	1993	912,215	0.65	1.11	13.27	0.31	0.29	1.25	649	0.08	0.02
Amsterdam	1999	1,310,130	0.94	1.59	19.06	0.45	0.42	1.79	931	0.12	0.03
Cruise Ship Emissions		**2,222,345**	**1.59**	**2.69**	**32.34**	**0.77**	**0.70**	**3.04**	**1,580**	**0.20**	**0.04**
Ship 1 SE	2007	7,955	0.00	0.01	0.10	0.00	0.00	0.01	6.05	0.00	0.00
Ship 1 NW	2007	9,295	0.01	0.01	0.12	0.00	0.00	0.01	7.07	0.00	0.00
Ship 2	1987	3,469	0.00	0.00	0.05	0.00	0.00	0.00	2.64	0.00	0.00
Ship 3 N/FWD	2008	113,567	0.07	0.14	1.44	0.04	0.04	0.16	86.38	0.01	0.00
Ship 3 S/Aft	2008	103,857	0.06	0.13	1.32	0.04	0.03	0.14	78.99	0.01	0.00
Ship 4 Port/W	2009	22,350	0.01	0.03	0.28	0.01	0.01	0.03	17.00	0.00	0.00
Ship 4 Stbd/E	2009	16,924	0.01	0.02	0.22	0.01	0.01	0.02	12.87	0.00	0.00
Ship 5	1976	6,316	0.00	0.01	0.10	0.00	0.00	0.01	4.80	0.00	0.00
Navy Ship Emissions		**283,734**	**0.16**	**0.34**	**3.63**	**0.10**	**0.09**	**0.39**	**216**	**0.03**	**0.01**
2013 Pier 70 At Berth Emissions		**2,506,079**	**1.75**	**3.04**	**35.97**	**0.86**	**0.79**	**3.43**	**1,796**	**0.22**	**0.05**
Shoreside Power Emission Reductions											
Ship	**Model Year**	**Energy (kW-hr)**	**ROG**	**CO**	**NOx**	**PM**	**$PM_{2.5}$**	**SO_2**	**CO_2**	**CH_4**	**N_2O**
Ship 1 SE	2007	137,701	0.08	0.17	1.75	0.05	0.04	0.19	105	0.01	0.00
Ship 1 NW	2007	160,902	0.09	0.20	2.05	0.06	0.05	0.22	122	0.01	0.00
Ship 2	1987	402,233	0.23	0.49	6.16	0.14	0.13	0.55	306	0.04	0.01

Ship	Model Year	Energy (kW-hr)	ROG	CO	NOx	PM	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O
Ship 3 N/FWD	2008	1,022,526	0.59	1.24	13.01	0.35	0.32	1.41	778	0.09	0.02
Ship 3 S/Aft	2008	910,049	0.52	1.10	11.58	0.31	0.29	1.25	692	0.08	0.02
Ship 4 Port/W	2009	569,263	0.33	0.69	7.24	0.20	0.18	0.78	433	0.05	0.01
Ship 4 Stbd/E	2009	422,031	0.24	0.51	5.37	0.15	0.13	0.58	321	0.04	0.01
Ship 5	1976	1,018,895	0.58	1.24	15.61	0.35	0.32	1.40	775	0.09	0.02
Shoreside Power Reductions		**4,643,600**	**2.66**	**5.63**	**62.77**	**1.60**	**1.47**	**6.40**	**3,532**	**0.41**	**0.09**

APPENDIX D

Cruise Ship at Berth Power Generation and Pier 70 Shore Power Use

July 29, 2014

MEMORANDUM

To: Jay Ach, Port of San Francisco
From: Chris Lindhjem, Lit Chan and Doug Daugherty
Subject: Cruise Ship at Berth Power Generation and Pier 70 Shore Power Use

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This memorandum addresses the power generation of cruise ships and the use of shore power at the Port of San Francisco (Port). The 'at-berth' auxiliary engine power generation of cruise ships at Pier 35 of the Port was quantified for 2013, and was estimated for 2014. In addition, the shore power use at the Pier 70 BAE Systems Ship Repair facility (BAE) was quantified for 2012 and 2013. The actual shore power used at BAE was compared with the calculated 2013 and estimated 2014 cruise ship auxiliary power generation while at berth. The BAE power usage for 2013 exceeded the 50% power reduction requirement for cruise ships berthed at Pier 35.

Regulatory Background

Cruise ships from fleets that visit the same California port five or more times total in a calendar year are required to comply with the State regulations that limit their use of auxiliary engines. The first requirement is that the fleet's onboard auxiliary, diesel-engine power generation while docked at the berth shall be reduced by at least 50 percent from the fleet's baseline power generation for the years 2014, 2015, and 2016.[6]

Analysis of Cruise Ships

Cruise ship calls to the Port were analyzed using the standard ARB methods to estimate the power consumed while at berth. The actual time at berth for all calls in 2013 was determined from the complete 2013 data, whereas for 2014, the cruise ship schedule was used to estimate the at-berth cruise ship activity.

For ships with 'diesel-electric' or 'combined' gas turbine and diesel-electric propulsion designs, the total installed power of all engines was used as the available auxiliary power at berth, while only the auxiliary engine power was used for ships with geared-drive 'motor diesel' propulsion power designs that have separate propulsion and auxiliary engines. This was the approach

[6] State of California, "AIRBORNE TOXIC CONTROL MEASURE FOR AUXILIARY DIESEL ENGINES OPERATED ON OCEAN-GOING VESSELS AT- BERTH IN A CALIFORNIA PORT," Adopt new section 93118.3, title 17, chapter 1, subchapter 7.5, California Code of Regulations (CCR)

used by ARB[7] in preparing statewide emission inventories for ocean-going vessels (OGV). The cruise ship time at berth by the engine capacity for each ship was used to multiply by the ARB[8] cruise ship load factor of 0.16 to estimate total power generated while at berth.

2013 Ship Calls

ENVIRON obtained the records of ship calls to the Port in 2013 from the San Francisco Marine Exchange (MarEx), and these data included 64 cruise ship calls to Pier 35. MarEx provided a list of ship movements with date and time stamps for six positions: Pilot On, Arrival at the Golden Gate, First Line, Last Line, Departure through the Golden Gate, and Pilot Off. The date and time of shifts to and from anchorage, other docks, or other ports were also provided for other ships calling to the Port, but no cruise ships shifted to anchorage, other docks or other ports in the Bay.

The 'at-berth' time was estimated from the difference between the Last Line (last mooring line removed from the pier) and the First Line (first mooring line tied to the pier). MarEx only began providing nearly all First Line and Last Line times starting in May of 2013, but provided the Arrival and Departure times for all calls. The average time between Arrival and First Line was 0.661 hours for the 38 calls where both time stamps were available, and this average time was added to the Arrival time to estimate the First Line time for those calls when the First Line time was not provided. Likewise, the average time between the Last Line and Departure time was 0.51 hours for 59 calls, and this average time was subtracted from the Departure time to estimate the Last Line time. The final 2013 ship call data and estimates are provided in the appendix.

The Port[9] also published the 2013 cruise ship schedule, which included a record of the Cruise Line operating each vessel, and the expected 'at berth' time. The actual 'at berth' time was on average 13% longer than the expected scheduled time. The cruise ship schedule is also provided in the appendix.

2014 Ship Call Schedule

The 2014 Ship Call Schedule was used to estimate the at-berth power generation, and is provided in the appendix. Since in 2013 the total time at berth exceeded the expected time at berth by 13%, for 2014 an additional 13% was added to the schedule to reflect the likely actual 'at-berth' time for calls in 2014.

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[7] ARB, Mobile Source Emission Inventory -- Current Methods and Data, http://www.arb.ca.gov/msei/categories.htm#ogv_category

[8] ARB, Mobile Source Emission Inventory -- Current Methods and Data, http://www.arb.ca.gov/msei/categories.htm#ogv_category

[9] http://www.sfport.com/index.aspx?page=2029

Cruise Ship Call Summary Results

The total 'at berth' power generation is summarized below. The results were presented based on the following approach:

1. 2013 ship calls with actual 'at-berth' time by ship call
    a. Comparison to the schedule ship call berth time
    b. Just the qualifying ship calls without exempt calls by cruise lines that called four or fewer times in 2013
    c. 2013 vessel auxiliary load and total power (MW-hr) used.
2. 2014 ship calls
    a. Schedule time at berth
    b. Adjusted to expected actual time at berth
    c. 2014 vessel auxiliary power expected.

The statistics for 2013 for the actual (from the MarEx) and scheduled calls, and the 2014 scheduled ship calls are provided in the appendix. Table 1 summarizes the statistics for the expected auxiliary power demand at berth for each calendar year for all cruise ships and those required to comply with the shore power requirements.

Table 1. Cruise Ship Calls at Berth Power Generated

Year and Ship Call Source	Total Power (MW-hrs)	Qualifying, i.e., Total – Exempt (MW-hr)	CARB Goal 2014-2016* (MW-hr)
2013 Scheduled	7,612	5,704	2,852[1]
2013 Actual Marine Exchange	8,755	6,720	3,360[1]
2014 Scheduled	8,434	6,342	3,137
2014 Actual Estimated	9,551	7,182	3,591

*50% of qualifying fleets' generation
[1] Goal was NOT in effect in 2013

Analysis of BAE Systems Ship Repair Shore Power Use

BAE Systems performs maintenance on a number of ships at Pier 70, and the facility is shown in Figure 1. Many ships stay within the maintenance facility for several days at a time and often maintain their on-board systems by running auxiliary generators while undergoing maintenance. The Port has provided Pier 70 with the ability to shore power those ships to reduce emissions from on-board diesel engines. This section summarizes the shore power used at the Pier 70 facility during 2012 and 2013.

Figure 1. BAE Systems Ship Repair Facility[10]

The BAE Systems Facility has scheduled maintenance for several T-AKE military support vessels. These vessels were laid-up for multiple days within the dry dock or at nearby piers. Several of these ships were laid-up with shore power used instead of on-board generators powered by diesel engines. The Port provided confidential data of the weekly electric shore power usage of the military vessels while at dock at BAE.

In 2012, one ship used shore power while it was in for maintenance, and consumed 642 MW-hrs of shore power during October of that year. In 2013, five ships together used a total of 4,644 MW-hrs of shore power, and shore power continues to be used in 2014. We assume that the 2014 shore power usage will be similar to that for 2013.

Comparison of BAE Power Usage to Cruise Ship Power Generation at Pier 35

In 2013, the shore power used at the BAE Systems facility at Pier 70 represented 69% of the 6,720 MW-hr estimated power generated by qualifying cruise ship fleets at Pier 35 that would have needed to meet the California control measure for auxiliary diesel engines operating at berth in a California port had the control measure been applicable for 2013. The use of shore power in 2013 at Pier 70 was 65% of the estimated power generated by qualifying cruise ship calls expected for 2014. For both 2013 and 2014, the BAE shoreside power usage exceeded the requirement for 50% at-berth generation reduction by cruise ships at Pier 35. The comparison is summarized in Table 2 below.

[10] http://www.baesystems.com/product/BAES_021148/bae-systems-ship-repair---san-francisco?_afrLoop=510927112889000

Table 2. BAE Shoreside Power Consumed Compared to Cruise Ship At-Berth Power Generation

Year	Total Power Used at BAE (MW-hrs)	Percent of Pier 35 Qualifying Cruise Generation	Percent of CARB Annual Goal* for Pier 35, 2014-2016
2013	4,644	69%	138%[1]
2014	assumed 4,644	65%	129%

*50% of qualifying fleets' generation; note that goal was NOT in effect for 2013

[1] Goal was NOT in effect in 2013

Appendix

Table A-1. 2013 Cruise Ship Calls (Time in yellow was estimated from arrival and departure time through the Golden Gate)

IMO No	VESSEL NAME	Arrival Date	Golden Gate Arrival Time	Arrival Time	Departure Date	Departure Time	Golden Gate Departure Time	Elapsed Time (hr)	Berth Code	Drive Type	Power (kW)	Estimated (kW-hr)	Qualifying
9169524	AURORA	1/29/13	5:35:00 AM	6:14:39 AM	1/30/2013	9:55:00 PM	10:30:00 PM	39.67	P35S	Diesel-Electric	56,000	355,464	0
9320556	QUEEN VICTORIA	2/3/13	4:26:00 AM	5:05:39 AM	2/3/2013	9:00:00 PM	9:31:00 PM	15.91	P35S	Diesel-Electric	63,360	161,246	0
9398917	COSTA DELIZIOSA	2/5/13	7:29:00 AM	8:08:39 AM	2/6/2013	1:46:27 PM	2:17:00 PM	29.63	P35N	Diesel-Electric	54,400	257,899	0
8913162	AMADEA	2/21/13	11:45:00 AM	12:24:39 PM	2/21/2013	9:05:27 PM	9:36:00 PM	8.68	P35	Motor Diesel	8,500	11,805	0
8913162	AMADEA	3/3/13	7:16:00 AM	7:55:39 AM	3/4/2013	1:00:00 PM	1:35:00 PM	29.07	P35S	Motor Diesel	8,500	39,538	0
9104005	GRAND PRINCESS	3/16/13	5:24:00 AM	6:03:39 AM	3/16/2013	9:56:00 PM	10:18:00 PM	15.87	P35S	Diesel-Electric	69,120	175,536	175,536
9226906	ARCADIA	3/22/13	7:07:00 AM	7:46:39 AM	3/23/2013	5:58:27 PM	6:29:00 PM	34.20	P35S	Diesel-Electric	63,360	346,672	0
9104005	GRAND PRINCESS	3/31/13	3:20:00 AM	3:59:39 AM	3/31/2013	4:19:00 PM	6:33:00 PM	12.32	P35S	Diesel-Electric	69,120	136,276	136,276
9228186	SAPPHIRE PRINCESS	3/31/13	3:50:00 PM	4:29:39 PM	4/1/2013	4:39:00 PM	5:13:00 PM	24.16	P35S	Combined	60,700	234,600	234,600
9228186	SAPPHIRE PRINCESS	4/7/13	3:16:00 PM	3:55:39 PM	4/8/2013	4:27:00 PM	4:59:00 PM	24.52	P35S	Combined	60,700	238,161	238,161
9104005	GRAND PRINCESS	4/10/13	5:37:00 AM	6:16:39 AM	4/10/2013	4:16:00 PM	4:43:00 PM	9.99	P35S	Diesel-Electric	69,120	110,471	110,471
9228186	SAPPHIRE PRINCESS	4/14/13	5:50:00 PM	6:29:39 PM	4/15/2013	5:16:00 PM	5:49:00 PM	22.77	P35S	Combined	60,700	221,165	221,165
9072446	CELEBRITY CENTURY	4/24/13	10:11:00 AM	10:50:39 AM	4/24/2013	11:08:27 PM	11:39:00 PM	12.30	P35S	Motor Diesel	18,687	36,766	36,766
9104005	GRAND PRINCESS	4/25/13	5:36:00 AM	6:15:39 AM	4/25/2013	6:14:00 PM	6:33:00 PM	11.97	P35S	Diesel-Electric	69,120	132,405	132,405
9228186	SAPPHIRE PRINCESS	4/28/13	1:33:00 PM	2:12:39 PM	4/29/2013	3:44:00 PM	4:15:00 PM	25.52	P35S	Combined	60,700	247,873	247,873
9072446	CELEBRITY CENTURY	4/30/13	5:06:00 AM	5:45:39 AM	5/1/2013	6:03:00 PM	6:30:00 PM	36.29	P35S	Motor Diesel	18,687	108,501	108,501
9066667	CRYSTAL SYMPHONY	5/4/13	6:45:00 AM	7:24:39 AM	5/4/2013	4:53:00 PM	5:23:00 PM	9.47	P35S	Diesel-Electric	36,330	55,061	0
9228186	SAPPHIRE PRINCESS	5/5/13	12:34:00 PM	1:13:39 PM	5/6/2013	1:04:00 PM	1:31:00 PM	23.84	P35S	Combined	60,700	231,525	231,525
9342281	NORWEGIAN PEARL	5/7/13	6:48:00 AM	7:27:39 AM	5/7/2013	5:08:00 PM	5:50:00 PM	9.67	P35S	Diesel-Electric	72,080	111549	111,549
9218131	NORWEGIAN SUN	5/8/13	6:33:00 AM	7:12:39 AM	5/8/2013	5:10:00 PM	5:38:00 PM	9.96	P35S	Diesel-Electric	49,212	78,,390	78,390
9156474	REGATTA	5/9/13	6:35:00 AM	7:14:39 AM	5/9/2013	6:00:00 PM	6:29:00 PM	10.76	P35N	Diesel-Electric	18,600	32,009	0
9304045	NORWEGIAN JEWEL	5/9/13	12:18:00 PM	12:57:39 PM	5/9/2013	10:09:00 PM	10:39:00 PM	9.19	P35S	Diesel-Electric	72,080	105,975	105,975
9064126	SEVEN SEAS NAVIGATOR	5/10/13	5:37:00 AM	6:16:39 AM	5/10/2013	5:55:00 PM	6:11:00 PM	11.64	P35N	Motor Diesel	6,600	12,291	0
9104005	GRAND PRINCESS	5/10/13	6:02:00 AM	6:41:39 AM	5/10/2013	6:07:00 PM	6:35:00 PM	11.42	P35S	Diesel-Electric	69,120	126,322	126,322
9362530	CELEBRITY SOLSTICE	5/11/13	5:37:00 AM	6:16:39 AM	5/11/2013	8:07:00 PM	8:43:00 PM	13.84	P35S	Diesel-Electric	57,120	126,478	126,478
9228186	SAPPHIRE PRINCESS	5/13/13	7:03:00 AM	7:42:39 AM	5/13/2013	7:56:00 PM	8:18:00 PM	12.22	P35S	Combined	60,700	118,704	118,704
9104005	GRAND PRINCESS	5/20/13	5:44:00 AM	6:29:00 AM	5/20/2013	4:11:00 PM	4:45:00 PM	9.70	P35S	Diesel-Electric	69,120	107,274	107,274
9126819	DISNEY WONDER	5/22/13	6:30:00 AM	7:00:00 AM	5/23/2013	5:15:00 PM	5:42:00 PM	34.25	P35S	Diesel-Electric	57,670	316,032	0
9104005	GRAND PRINCESS	5/30/13	5:31:00 AM	6:10:00 AM	5/30/2013	4:41:00 PM	5:14:00 PM	10.52	P35S	Diesel-Electric	69,120	116,306	116,306
9104005	GRAND PRINCESS	6/9/13	5:30:00 AM	6:15:00 AM	6/9/2013	4:15:00 PM	4:40:00 PM	10.00	P35S	Diesel-Electric	69,120	110,592	110,592
9104005	GRAND PRINCESS	6/19/13	5:31:00 AM	6:18:00 AM	6/19/2013	4:29:00 PM	5:01:00 PM	10.18	P35S	Diesel-Electric	69,120	112,620	112,620
9104005	GRAND PRINCESS	6/29/13	5:37:00 AM	6:17:00 AM	6/29/2013	4:26:00 PM	5:00:00 PM	10.15	P35S	Diesel-Electric	69,120	112,251	112,251
9104005	GRAND PRINCESS	7/9/13	5:34:00 AM	6:15:00 AM	7/9/2013	4:51:00 PM	5:07:00 PM	10.60	P35S	Diesel-Electric	69,120	117,228	117,228
9104005	GRAND PRINCESS	7/19/13	5:30:00 AM	6:05:00 AM	7/19/2013	4:15:00 PM	4:45:00 PM	10.17	P35S	Diesel-Electric	69,120	112,435	112,435
9104005	GRAND PRINCESS	7/29/13	5:09:00 AM	5:48:00 AM	7/29/2013	4:42:00 PM	5:12:00 PM	10.90	P35S	Diesel-Electric	69,120	120,545	120,545

IMO No	VESSEL NAME	Arrival Date	Golden Gate Arrival Time	Arrival Time	Departure Date	Departure Time	Golden Gate Departure Time	Elapsed Time (hr)	Berth Code	Drive Type	Power (kW)	Estimated (kW-hr)	Qualifying
9104005	GRAND PRINCESS	8/8/13	5:34:00 AM	6:15:00 AM	8/8/2013	5:18:00 PM	5:47:00 PM	11.05	P35S	Diesel-Electric	69,120	122,204	122,204
9104005	GRAND PRINCESS	8/18/13	5:20:00 AM	5:55:00 AM	8/18/2013	4:26:00 PM	4:56:00 PM	10.52	P35S	Diesel-Electric	69,120	116,306	116,306
9156474	REGATTA	8/22/13	6:19:00 AM	6:57:00 AM	8/22/2013	7:15:00 PM	7:40:00 PM	12.30	P35S	Diesel-Electric	18,600	36,605	0
9104005	GRAND PRINCESS	8/28/13	5:30:00 AM	6:05:00 AM	8/28/2013	4:45:00 PM	5:05:00 PM	10.67	P35S	Diesel-Electric	69,120	117,965	117,965
9064126	SEVEN SEAS NAVIGATOR	9/2/13	5:51:00 AM	6:28:00 AM	9/2/2013	5:10:00 PM	5:38:00 PM	10.70	P35S	Motor Diesel	6,600	11,299	0
9104005	GRAND PRINCESS	9/7/13	5:57:00 AM	6:34:00 AM	9/7/2013	4:39:00 PM	5:11:00 PM	10.08	P35S	Diesel-Electric	69,120	111,514	111,514
9126819	DISNEY WONDER	9/12/13	6:34:00 AM	7:10:00 AM	9/13/2013	2:19:00 AM	2:50:00 AM	19.15	P35S	Diesel-Electric	57,670	176,701	0
9362530	CELEBRITY SOLSTICE	9/15/13	9:38:00 AM	10:13:00 AM	9/16/2013	6:02:00 PM	6:41:00 PM	31.82	P35S	Diesel-Electric	57,120	290,779	290,779
9104005	GRAND PRINCESS	9/17/13	4:51:00 AM	5:30:00 AM	9/17/2013	4:31:27 PM	5:02:00 PM	11.02	P35S	Diesel-Electric	69,120	121,920	121,920
9218131	NORWEGIAN SUN	9/21/13	6:55:00 AM	7:30:00 AM	9/21/2013	5:24:00 PM	5:50:00 PM	9.90	P35S	Diesel-Electric	49,212	77,952	77,952
9304045	NORWEGIAN JEWEL	9/25/13	6:02:00 AM	6:39:00 AM	9/25/2013	6:10:00 PM	6:35:00 PM	11.52	P35N	Diesel-Electric	72,080	132,819	132,819
9230402	ISLAND PRINCESS	9/25/13	10:21:00 AM	10:59:00 AM	9/25/2013	5:44:00 PM	6:18:00 PM	6.75	P35S	Combined	62,683	67,698	67,698
9104005	GRAND PRINCESS	9/27/13	5:30:00 AM	6:05:00 AM	9/27/2013	4:37:00 PM	5:09:00 PM	10.53	P35S	Diesel-Electric	69,120	116,490	116,490
9192363	STAR PRINCESS	9/27/13	6:17:00 AM	6:55:00 AM	9/27/2013	4:13:00 PM	4:45:00 PM	9.30	P35N	Diesel-Electric	63,360	94,280	94,280
9192363	STAR PRINCESS	10/1/13	4:18:00 AM	5:00:00 AM	10/1/2013	10:41:00 PM	11:07:00 PM	17.68	P35N	Diesel-Electric	63,360	179,267	179,267
9221279	ZUIDERDAM	10/1/13	6:51:00 AM	7:27:00 AM	10/1/2013	6:34:00 PM	7:04:00 PM	11.12	P35S	Combined	75,140	133,649	0
9342281	NORWEGIAN PEARL	10/2/13	6:30:00 AM	7:15:00 AM	10/2/2013	7:19:00 PM	7:49:00 PM	12.07	P35S	Diesel-Electric	72,080	139,162	139,162
9072446	CELEBRITY CENTURY	10/3/13	5:15:00 AM	5:52:00 AM	10/3/2013	8:48:00 PM	9:11:00 PM	14.93	P35N	Motor Diesel	18,687	44,649	44,649
9228186	SAPPHIRE PRINCESS	10/3/13	6:12:00 AM	6:47:00 AM	10/3/2013	4:11:00 PM	4:46:00 PM	9.40	P35S	Combined	60,700	91,293	91,293
9104005	GRAND PRINCESS	10/4/13	5:30:00 AM	6:15:00 AM	10/4/2013	4:42:00 PM	5:09:00 PM	10.45	P35S	Diesel-Electric	69,120	115,569	115,569
9228186	SAPPHIRE PRINCESS	10/7/13	5:47:00 AM	6:35:00 AM	10/7/2013	10:54:00 PM	11:29:00 PM	16.32	P35S	Combined	60,700	158,467	158,467
9228186	SAPPHIRE PRINCESS	10/14/13	6:02:00 AM	6:45:00 AM	10/14/2013	11:19:00 PM	11:46:00 PM	16.57	P35S	Combined	60,700	160,895	160,895
9104005	GRAND PRINCESS	10/19/13	5:18:00 AM	6:02:00 AM	10/19/2013	4:17:00 PM	4:51:00 PM	10.25	P35S	Diesel-Electric	69,120	113,357	113,357
9104005	GRAND PRINCESS	10/26/13	5:31:00 AM	6:14:00 AM	10/26/2013	4:51:00 PM	5:20:00 PM	10.62	P35S	Diesel-Electric	69,120	117,412	117,412
9104005	GRAND PRINCESS	11/10/13	5:36:00 AM	6:07:00 AM	11/10/2013	4:49:00 PM	5:18:00 PM	10.70	P35S	Diesel-Electric	69,120	118,333	118,333
9104005	GRAND PRINCESS	11/25/13	5:20:00 AM	5:54:00 AM	11/25/2013	5:32:00 PM	6:03:00 PM	11.63	P35S	Diesel-Electric	69,120	128,655	128,655
9104005	GRAND PRINCESS	12/10/13	4:02:00 AM	5:03:00 AM	12/10/2013	2:56:00 PM	3:26:00 PM	9.88	P35S	Diesel-Electric	69,120	109,302	109,302
9188037	AMSTERDAM	12/18/13	6:17:00 AM	7:10:00 AM	12/18/2013	5:00:00 PM	5:27:00 PM	9.83	P35S	Diesel-Electric	56,416	88,761	0
9104005	GRAND PRINCESS	12/20/13	8:38:00 AM	9:11:00 AM	12/21/2013	11:30:00 PM	1:10:00 AM	38.32	P35S	Diesel-Electric	69,120	423,752	423,752
											Total	8,755,020	6,719,988

Table A-2. 2013 Cruise Ship Schedule

Vessel	Date	Time	Last Port	Date	Time	Scheduled At Berth (hrs)	Actual Table A-1 (hrs)	Difference (hrs)	Next Port	Berth	Cruise Line	Exempt
Aurora	29-Jan-13	7:00 AM	Cabo San Lucas	30-Jan-13	8:00 PM	37.00	39.67	2.67	Honolulu	Pier 35 South	Carnival UK	Y
Queen Victoria	03-Feb-13	5:30 AM	Huatulco	03-Feb-13	9:00 PM	15.50	15.91	0.41	Kahului	Pier 35 South	Carnival UK	Y
Arcadia	22-Mar-13	8:00 AM	Honolulu	23-Mar-13	4:00 PM	32.00	34.20	2.20	Huatulco	Pier 35 South	Carnival UK	Y
Celebrity Century	24-Apr-13	11:30 AM	Santa Barbara	24-Apr-13	11:00 PM	11.50	12.30	0.80	Ensenada	Pier 35 South	Celebrity	
Celebrity Century	30-Apr-13	7:00 AM	Monterey	01-May-13	6:00 PM	35.00	36.29	1.29	Astoria	Pier 35 South	Celebrity	
Celebrity Solstice	11-May-13	7:00 AM	Santa Barbara	11-May-13	8:00 PM	13.00	13.84	0.84	Astoria	Pier 35 South	Celebrity	
Celebrity Solstice	15-Sep-13	11:00 AM	Seattle	16-Sep-13	6:00 PM	31.00	31.82	0.82	Monterey	Pier 35 South	Celebrity	
Celebrity Century	03-Oct-13	7:00 AM	Astoria	03-Oct-13	8:00 PM	13.00	14.93	1.93	Monterey	Pier 35 North	Celebrity	
Costa Deliziosa	05-Feb-13	8:00 AM	Los Angeles	06-Feb-13	1:00 PM	29.00	29.63	0.63	Honolulu	Pier 35 South	Costa	Y
Crystal Symphony	04-May-13	8:00 AM	Astoria	04-May-13	4:45 PM	8.75	9.47	0.72	Santa Barbara	Pier 35 South	Crystal	Y
Disney Wonder	22-May-13	6:00 AM	Los Angeles	23-May-13	5:00 PM	35.00	34.25	-0.75	Victoria	Pier 35 South	Disney	Y
Disney Wonder	12-Sep-13	7:00 AM	Vancouver	12-Sep-13	10:00 PM	15.00	19.15	4.15	Los Angeles	Pier 35 South	Disney	Y
Zuiderdam	01-Oct-13	8:00 AM	Astoria	01-Oct-13	5:00 PM	9.00	11.12	2.12	Cabo San Lucas	Pier 35 South	Holland	Y
Amsterdam	18-Dec-13	7:00 AM	Drydock	18-Dec-13	5:00 PM	10.00	9.83	-0.17	San Diego	Pier 35 South	Holland	Y
Norwegian Pearl	07-May-13	8:00 AM	Los Angeles	07-May-13	5:00 PM	9.00	9.67	0.67	Astoria	Pier 35 South	Norwegian	
Norwegian Sun	08-May-13	8:00 AM	Los Angeles	08-May-13	5:00 PM	9.00	9.96	0.96	Astoria	Pier 35 South	Norwegian	
Norwegian Jewel	09-May-13	1:00 PM	Los Angeles	09-May-13	10:00 PM	9.00	9.19	0.19	Astoria	Pier 35 South	Norwegian	
Norwegian Sun	21-Sep-13	8:00 AM	Astoria	21-Sep-13	5:00 PM	9.00	9.90	0.90	Los Angeles	Pier 35 South	Norwegian	
Norwegian Jewel	25-Sep-13	8:00 AM	Astoria	25-Sep-13	6:00 PM	10.00	11.52	1.52	Los Angeles	Pier 35 North	Norwegian	
Norwegian Pearl	02-Oct-13	8:00 AM	Astoria	02-Oct-13	6:00 PM	10.00	12.07	2.07	Los Angeles	Pier 35 South	Norwegian	
Regatta	09-May-13	8:00 AM	San Diego	09-May-13	6:00 PM	10.00	10.76	0.76	Astoria	Pier 35 North	Oceania	Y
Regatta	22-Aug-13	7:00 AM	Astoria	22-Aug-13	5:00 PM	10.00	12.30	2.30	Cabo San Lucas	Pier 35 South	Oceania	Y
Grand Princess	16-Mar-13	7:00 AM	Cabo San Lucas	16-Mar-13	10:00 PM	15.00	15.87	0.87	Hilo	Pier 35 South	Princess	
Grand Princess	31-Mar-13	7:00 AM	Ensenada	31-Mar-13	4:00 PM	9.00	12.32	3.32	Catalina	Pier 35 South	Princess	
Sapphire Princess	31-Mar-13	*4:30 PM*	Los Angeles	01-Apr-13	1:00 PM	20.50	24.16	3.66	Santa Barbara	Pier 35 South	Princess	
Sapphire Princess	07-Apr-13	4:00 PM	Los Angeles	08-Apr-13	4:00 PM	24.00	24.52	0.52	Santa Barbara	Pier 35 South	Princess	
Grand Princess	10-Apr-13	7:00 AM	San Diego	10-Apr-13	4:00 PM	9.00	9.99	0.99	Honolulu	Pier 35 South	Princess	
Sapphire Princess	14-Apr-13	1:00 PM	Los Angeles	15-Apr-13	1:00 PM	24.00	22.77	-1.23	Santa Barbara	Pier 35 South	Princess	
Grand Princess	25-Apr-13	7:00 AM	Ensenada	25-Apr-13	4:00 PM	9.00	11.97	2.97	Honolulu	Pier 35 South	Princess	
Sapphire Princess	28-Apr-13	1:00 PM	Los Angeles	29-Apr-13	1:00 PM	24.00	25.52	1.52	Santa Barbara	Pier 35 South	Princess	
Sapphire Princess	05-May-13	1:00 PM	Los Angeles	06-May-13	1:00 PM	24.00	23.84	-0.16	Santa Barbara	Pier 35 South	Princess	
Grand Princess	10-May-13	7:00 AM	Ensenada	10-May-13	4:00 PM	9.00	11.42	2.42	Ketchikan	Pier 35 South	Princess	
Sapphire Princess	13-May-13	10:00 AM	Santa Barbara	13-May-13	8:00 PM	10.00	12.22	2.22	Astoria	Pier 35 South	Princess	
Grand Princess	20-May-13	7:00 AM	Victoria	20-May-13	4:00 PM	9.00	9.70	0.70	Juneau	Pier 35 South	Princess	
Grand Princess	30-May-13	7:00 AM	Victoria	30-May-13	4:00 PM	9.00	10.52	1.52	Sitka	Pier 35 South	Princess	
Grand Princess	09-Jun-13	7:00 AM	Victoria	09-Jun-13	4:00 PM	9.00	10.00	1.00	Ketchikan	Pier 35 South	Princess	

Vessel	Date	Time	Last Port	Date	Time	Scheduled At Berth (hrs)	Actual Table A-1 (hrs)	Difference (hrs)	Next Port	Berth	Cruise Line	Exempt
Grand Princess	19-Jun-13	7:00 AM	Victoria	19-Jun-13	4:00 PM	9.00	10.18	1.18	Juneau	Pier 35 South	Princess	
Grand Princess	29-Jun-13	7:00 AM	Victoria	29-Jun-13	4:00 PM	9.00	10.15	1.15	Ketchikan	Pier 35 South	Princess	
Grand Princess	09-Jul-13	7:00 AM	Victoria	09-Jul-13	4:00 PM	9.00	10.60	1.60	Juneau	Pier 35 South	Princess	
Grand Princess	19-Jul-13	7:00 AM	Victoria	19-Jul-13	4:00 PM	9.00	10.17	1.17	Victoria	Pier 35 South	Princess	
Grand Princess	29-Jul-13	7:00 AM	Skagway	29-Jul-13	4:00 PM	9.00	10.90	1.90	Juneau	Pier 35 South	Princess	
Grand Princess	08-Aug-13	7:00 AM	Victoria	08-Aug-13	4:00 PM	9.00	11.05	2.05	Ketchikan	Pier 35 South	Princess	
Grand Princess	18-Aug-13	7:00 AM	Victoria	18-Aug-13	4:00 PM	9.00	10.52	1.52	Ketchikan	Pier 35 South	Princess	
Grand Princess	28-Aug-13	7:00 AM	Victoria	28-Aug-13	4:00 PM	9.00	10.67	1.67	Juneau	Pier 35 South	Princess	
Grand Princess	07-Sep-13	7:00 AM	Victoria	07-Sep-13	4:00 PM	9.00	10.08	1.08	Ketchikan	Pier 35 South	Princess	
Grand Princess	17-Sep-13	7:00 AM	Victoria	17-Sep-13	4:00 PM	9.00	11.02	2.02	Cabo San Lucas	Pier 35 South	Princess	
Island Princess	25-Sep-13	11:30 AM	Vancouver	25-Sep-13	6:00 PM	6.50	6.75	0.25	Cabo San Lucas	Pier 35 South	Princess	
Star Princess	27-Sep-13	7:00 AM	Astoria	27-Sep-13	4:00 PM	9.00	9.30	0.30	Santa Barbara	Pier 35 North	Princess	
Grand Princess	27-Sep-13	7:00 AM	Puerto Vallarta	27-Sep-13	4:00 PM	9.00	10.53	1.53	Santa Barbara	Pier 35 South	Princess	
Star Princess	01-Oct-13	7:00 AM	Los Angeles	01-Oct-13	11:00 PM	16.00	17.68	1.68	Santa Barbara	Pier 35 North	Princess	
Sapphire Princess	03-Oct-13	7:00 AM	Astoria	03-Oct-13	4:00 PM	9.00	9.40	0.40	Santa Barbara	Pier 35 South	Princess	
Grand Princess	04-Oct-13	7:00 AM	Ensenada	04-Oct-13	4:00 PM	9.00	10.45	1.45	Hilo	Pier 35 South	Princess	
Sapphire Princess	07-Oct-13	7:00 AM	Los Angeles	07-Oct-13	11:00 PM	16.00	16.32	0.32	Santa Barbara	Pier 35 South	Princess	
Sapphire Princess	14-Oct-13	7:00 AM	Los Angeles	14-Oct-13	11:00 PM	16.00	16.57	0.57	Santa Barbara	Pier 35 South	Princess	
Grand Princess	19-Oct-13	7:00 AM	Ensenada	19-Oct-13	4:00 PM	9.00	10.25	1.25	Santa Barbara	Pier 35 South	Princess	
Grand Princess	26-Oct-13	7:00 AM	Ensenada	26-Oct-13	4:00 PM	9.00	10.62	1.62	Hilo	Pier 35 South	Princess	
Grand Princess	10-Nov-13	7:00 AM	Ensenada	10-Nov-13	4:00 PM	9.00	10.70	1.70	Hilo	Pier 35 South	Princess	
Grand Princess	25-Nov-13	7:00 AM	Ensenada	25-Nov-13	4:00 PM	9.00	11.63	2.63	Hilo	Pier 35 South	Princess	
Grand Princess	10-Dec-13	7:00 AM	Ensenada	10-Dec-13	11:00 AM	4.00	9.88	5.88	Victoria	Pier 35 South	Princess	
Grand Princess	20-Dec-13	7:00 AM	Victoria	20-Dec-13	4:00 PM	9.00	38.32	29.32	Hilo	Pier 35 South	Princess	
Seven Seas Navigator	10-May-13	7:00 AM	San Diego	10-May-13	6:00 PM	11.00	11.64	0.64	Astoria	Pier 35 North	Regent	Y
Seven Seas Navigator	02-Sep-13	7:00 AM	Astoria	02-Sep-13	5:00 PM	10.00	10.70	0.70	Cabo San Lucas	Pier 35 South	Regent	Y
Amadea	21-Feb-13	1:30 PM	Los Angeles	21-Feb-13	9:00 PM	7.50	8.68	1.18	Seattle	Pier 35 South	V.Ships	Y
Amadea	03-Mar-13	8:00 AM	Astoria	04-Mar-13	1:00 PM	29.00	29.07	0.07	Los Angeles	Pier 35 South	V.Ships	Y
						862.25	976.42	114.17 (+13%)				

Table A-3. 2014 Cruise Ship Schedule

IMO	Vessel	Arrival Date	Arrival Time	Departure Date	Departure Time	At Berth (hrs)	Next Port	Cruise Line	Type	Aux. kW	Estimated (kW-hr)	Exempt	Qualifying
9104005	Grand Princess	Jan-04-2014	7:00 AM	Jan-04-2014	4:00 PM	9.00	Hilo	Princess	Diesel-Electric	69,120	99,533		99,533
9104005	Grand Princess	Jan-19-2014	7:00 AM	Jan-19-2014	4:00 PM	9.00	Honolulu	Princess	Diesel-Electric	69,120	99,533		99,533
9169524	Aurora	Jan-25-2014	11:30 AM	Jan-26-2014	9:00 PM	33.50	Honolulu	Carnival UK	Diesel-Electric	56,000	300,160	Y	0
9104005	Grand Princess	Feb-03-2014	7:00 AM	Feb-03-2014	4:00 PM	9.00	Hilo	Princess	Diesel-Electric	69,120	99,533		99,533
9477438	Queen Elizabeth	Feb-05-2014	6:00 AM	Feb-06-2014	8:00 PM	38.00	Honolulu	Carnival UK	Diesel-Electric	64,000	389,120	Y	0
9398917	Costa Deliziosa	Feb-05-2014	8:00 AM	Feb-06-2014	1:00 PM	29.00	Honolulu	Costa	Diesel-Electric	54,400	252,416	Y	0
9210218	Azamara Quest	Feb-13-2014	9:00 AM	Feb-15-2014	10:00 PM	61.00	Ensenada	Azamara	Diesel-Electric	18,600	181,536	Y	0
9104005	Grand Princess	Feb-18-2014	7:00 AM	Feb-18-2014	4:00 PM	9.00	Honolulu	Princess	Diesel-Electric	69,120	99,533		99,533
9104005	Grand Princess	Mar-05-2014	7:00 AM	Mar-05-2014	4:00 PM	9.00	Cabo San Lucas	Princess	Diesel-Electric	69,120	99,533		99,533
9104005	Grand Princess	Mar-15-2014	7:00 AM	Mar-15-2014	4:00 PM	9.00	San Diego	Princess	Diesel-Electric	69,120	99,533		99,533
9104005	Grand Princess	Mar-22-2014	7:00 AM	Mar-22-2014	4:00 PM	9.00	Ensenada	Princess	Diesel-Electric	69,120	99,533		99,533
9072446	Celebrity Century	Mar-24-2014	2:00 PM	Mar-25-2014	8:00 PM	30.00	Monterey	Celebrity	Motor Diesel	18,687	89,698		89,698
9320556	Queen Victoria	Mar-31-2014	6:00 AM	Apr-01-2014	8:00 PM	38.00	Puntarenas	Carnival UK	Diesel-Electric	63,360	385,229	Y	0
9072446	Celebrity Century	Mar-31-2014	2:00 PM	Apr-01-2014	8:00 PM	30.00	Monterey	Celebrity	Motor Diesel	18,687	89,698		89,698
9104005	Grand Princess	Apr-06-2014	7:00 AM	Apr-06-2014	4:00 PM	9.00	Ensenada	Princess	Diesel-Electric	69,120	99,533		99,533
9293399	Crown Princess	Apr-07-2014	7:00 AM	Apr-07-2014	11:00 PM	16.00	Santa Barbara	Princess	Diesel-Electric	67,220	172,083		172,083
9072446	Celebrity Century	Apr-07-2014	2:00 PM	Apr-08-2014	8:00 PM	30.00	Monterey	Celebrity	Motor Diesel	18,687	89,698		89,698
9104005	Grand Princess	Apr-13-2014	7:00 AM	Apr-13-2014	4:00 PM	9.00	Honolulu	Princess	Diesel-Electric	69,120	99,533		99,533
9072446	Celebrity Century	Apr-14-2014	2:00 PM	Apr-15-2014	8:00 PM	30.00	Monterey	Celebrity	Motor Diesel	18,687	89,698		89,698
9293399	Crown Princess	Apr-21-2014	7:00 AM	Apr-21-2014	11:00 PM	16.00	Santa Barbara	Princess	Diesel-Electric	67,220	172,083		172,083
9072446	Celebrity Century	Apr-21-2014	2:00 PM	Apr-22-2014	8:00 PM	30.00	Monterey	Celebrity	Motor Diesel	18,687	89,698		89,698
9293399	Crown Princess	Apr-28-2014	7:00 AM	Apr-28-2014	11:00 PM	16.00	Santa Barbara	Princess	Diesel-Electric	67,220	172,083		172,083
9104005	Grand Princess	Apr-28-2014	7:00 AM	Apr-28-2014	*4:00 PM*	9.00	Hilo	Princess	Diesel-Electric	69,120	99,533		99,533
9072446	Celebrity Century	Apr-28-2014	*4:30 PM*	Apr-29-2014	8:00 PM	27.50	Monterey	Celebrity	Motor Diesel	18,687	82,223		82,223
9304045	Norwegian Jewel	May-05-2014	8:00 AM	May-05-2014	4:00 PM	8.00	Drydock	Norwegian	Diesel-Electric	72,080	92,262		92,262
9342281	Norwegian Pearl	May-05-2014	8:00 AM	May-05-2014	5:00 PM	9.00	Astoria	Norwegian	Diesel-Electric	72,080	103,795		103,795
9192363	Star Princess	May-06-2014	7:00 AM	May-06-2014	5:00 PM	10.00	Victoria	Princess	Diesel-Electric	63,360	101,376		101,376
9293399	Crown Princess	May-06-2014	8:00 AM	May-06-2014	8:00 PM	12.00	Astoria	Princess	Diesel-Electric	67,220	129,062		129,062
9064126	Seven Seas Navigator	May-09-2014	7:00 AM	May-09-2014	5:00 PM	10.00	Astoria	Regent	Motor Diesel	6,600	10,560	Y	0
9192363	Star Princess	May-12-2014	7:00 AM	May-12-2014	4:00 PM	9.00	Ketchikan	Princess	Diesel-Electric	63,360	91,238		91,238
9104005	Grand Princess	May-13-2014	7:00 AM	May-13-2014	4:00 PM	9.00	Astoria	Princess	Diesel-Electric	69,120	99,533		99,533
9072446	Celebrity Century	May-13-2014	8:00 AM	May-14-2014	1:00 PM	29.00	Seattle	Celebrity	Motor Diesel	18,687	86,708		86,708
9218131	Norwegian Sun	May-15-2014	8:00 AM	May-15-2014	5:00 PM	9.00	Astoria	Norwegian	Diesel-Electric	49,212	70,865		70,865
9156474	Regatta	May-17-2014	8:00 AM	May-17-2014	6:00 PM	10.00	Astoria	Oceania	Diesel-Electric	18,600	29,760	Y	0
9230402	Island Princess	May-18-2014	7:00 AM	May-18-2014	5:00 PM	10.00	Victoria	Princess	Combined	62,683	100,293		100,293
9126819	Disney Wonder	May-21-2014	6:00 AM	May-22-2014	2:00 AM	20.00	Victoria	Disney	Diesel-Electric	57,670	184,544	Y	0

IMO	Vessel	Arrival Date	Arrival Time	Departure Date	Departure Time	At Berth (hrs)	Next Port	Cruise Line	Type	Aux. kW	Estimated (kW-hr)	Exempt	Qualifying
9192363	Star Princess	May-23-2014	7:00 AM	May-23-2014	4:00 PM	9.00	Ketchikan	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Jun-03-2014	7:00 AM	Jun-03-2014	4:00 PM	9.00	Juneau	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Jun-14-2014	7:00 AM	Jun-14-2014	4:00 PM	9.00	Ketchikan	Princess	Diesel-Electric	63,360	91,238		91,238
8806204	Asuka II	Jun-16-2014	8:00 AM	Jun-16-2014	7:00 PM	11.00	Honolulu	NYK	Diesel-Electric	37,800	66,528	Y	0
9192363	Star Princess	Jun-25-2014	7:00 AM	Jun-25-2014	4:00 PM	9.00	Ketchikan	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Jul-06-2014	7:00 AM	Jul-06-2014	4:00 PM	9.00	Juneau	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Jul-17-2014	7:00 AM	Jul-17-2014	4:00 PM	9.00	Ketchikan	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Jul-28-2014	7:00 AM	Jul-28-2014	4:00 PM	9.00	Juneau	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Aug-08-2014	7:00 AM	Aug-08-2014	4:00 PM	9.00	Ketchikan	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Aug-19-2014	7:00 AM	Aug-19-2014	4:00 PM	9.00	Juneau	Princess	Diesel-Electric	63,360	91,238		91,238
9156474	Regatta	Aug-29-2014	7:00 AM	Aug-29-2014	5:00 PM	10.00	Cabo San Lucas	Oceania	Diesel-Electric	18,600	29,760	Y	0
9192363	Star Princess	Aug-30-2014	7:00 AM	Aug-30-2014	4:00 PM	9.00	Ketchikan	Princess	Diesel-Electric	63,360	91,238		91,238
9064126	Seven Seas Navigator	Sep-01-2014	7:00 AM	Sep-01-2014	6:00 PM	11.00	Cabo San Lucas	Regent	Motor Diesel	6,600	11,616	Y	0
9072446	Celebrity Century	Sep-04-2014	7:00 AM	Sep-04-2014	4:00 PM	9.00	Ketchikan	Celebrity	Motor Diesel	18,687	26,909		26,909
9192363	Star Princess	Sep-10-2014	7:00 AM	Sep-10-2014	4:00 PM	9.00	Ketchikan	Princess	Diesel-Electric	63,360	91,238		91,238
9072446	Celebrity Century	Sep-16-2014	7:00 AM	Sep-16-2014	5:00 PM	10.00	Honolulu	Celebrity	Motor Diesel	18,687	29,899		29,899
9293399	Crown Princess	Sep-18-2014	7:00 AM	Sep-18-2014	4:00 PM	9.00	Santa Barbara	Princess	Diesel-Electric	67,220	96,797		96,797
9192363	Star Princess	Sep-21-2014	7:00 AM	Sep-21-2014	4:00 PM	9.00	Juneau	Princess	Diesel-Electric	63,360	91,238		91,238
9293399	Crown Princess	Sep-22-2014	7:00 AM	Sep-22-2014	11:00 PM	16.00	Santa Barbara	Princess	Diesel-Electric	67,220	172,083		172,083
9304045	Norwegian Jewel	Sep-23-2014	8:00 AM	Sep-23-2014	6:00 PM	10.00	Los Angeles	Norwegian	Diesel-Electric	72,080	115,328		115,328
9192167	Silver Shadow	Sep-24-2014	8:00 AM	Sep-24-2014	5:00 PM	9.00	Hilo	Silversea	Motor Diesel	7,020	10,109	Y	0
9104005	Grand Princess	Sep-25-2014	8:00 AM	Sep-26-2014	1:00 PM	29.00	Santa Barbara	Princess	Diesel-Electric	69,120	320,717		320,717
9230402	Island Princess	Sep-27-2014	7:00 AM	Sep-27-2014	4:00 PM	9.00	Cabo San Lucas	Princess	Combined	62,683	90,264		90,264
9293399	Crown Princess	Sep-29-2014	7:00 AM	Sep-29-2014	11:00 PM	16.00	Santa Barbara	Princess	Diesel-Electric	67,220	172,083		172,083
9221279	Zuiderdam	Sep-30-2014	8:00 AM	Sep-30-2014	5:00 PM	9.00	Cabo San Lucas	Holland	Combined	75,140	108,202	Y	0
9226891	Westerdam	Sep-30-2014	1:00 PM	Sep-30-2014	11:59 PM	10.98	Catalina	Holland	Combined	75,140	132,046	Y	0
9192363	Star Princess	Oct-01-2014	7:00 AM	Oct-01-2014	4:00 PM	9.00	Cabo San Lucas	Princess	Diesel-Electric	63,360	91,238		91,238
9342281	Norwegian Pearl	Oct-01-2014	8:00 AM	Oct-01-2014	6:00 PM	10.00	Los Angeles	Norwegian	Diesel-Electric	72,080	115,328		115,328
9218131	Norwegian Sun	Oct-02-2014	11:00 AM	Oct-02-2014	8:00 PM	9.00	Los Angeles	Norwegian	Diesel-Electric	49,212	70,865		70,865
9293399	Crown Princess	Oct-06-2014	7:00 AM	Oct-06-2014	11:00 PM	16.00	Santa Barbara	Princess	Diesel-Electric	67,220	172,083		172,083
9192363	Star Princess	Oct-11-2014	7:00 AM	Oct-11-2014	4:00 PM	9.00	Ensenada	Princess	Diesel-Electric	63,360	91,238		91,238
9293399	Crown Princess	Oct-13-2014	7:00 AM	Oct-13-2014	11:00 PM	16.00	Santa Barbara	Princess	Diesel-Electric	67,220	172,083		172,083
9192363	Star Princess	Oct-18-2014	7:00 AM	Oct-18-2014	4:00 PM	9.00	Ensenada	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Oct-25-2014	7:00 AM	Oct-25-2014	4:00 PM	9.00	Cabo San Lucas	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Nov-04-2014	7:00 AM	Nov-04-2014	4:00 PM	9.00	Cabo San Lucas	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Nov-14-2014	7:00 AM	Nov-14-2014	4:00 PM	9.00	Cabo San Lucas	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Nov-24-2014	7:00 AM	Nov-24-2014	4:00 PM	9.00	Hilo	Princess	Diesel-Electric	63,360	91,238		91,238

IMO	Vessel	Arrival Date	Arrival Time	Departure Date	Departure Time	At Berth (hrs)	Next Port	Cruise Line	Type	Aux. kW	Estimated (kW-hr)	Exempt	Qualifying
9192363	Star Princess	Dec-09-2014	7:00 AM	Dec-09-2014	4:00 PM	9.00	Drydock	Princess	Diesel-Electric	63,360	91,238		91,238
9192363	Star Princess	Dec-19-2014	11:30 AM	Dec-19-2014	4:00 PM	4.50	Ensenada	Princess	Diesel-Electric	63,360	45,619		45,619
									Power (kW-hrs)		8,433,833		6,342,248
									Actual/Estimated Time Adjustment		9,550,549		7,182,019
									Ratio to 2013		1.09		1.07