PORT EVERGLADES
2015 BASELINE AIR EMISSIONS INVENTORY

PORT EVERGLADES
BROWARD COUNTY, FLORIDA

December 2016

Prepared by:

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

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ACRONYMS AND ABBREVIATIONS

AIS	automatic identification system
ATB	articulated tug and barge
BSFC	brake specific fuel consumption
CF	control factor
CI	compression ignition
CHE	cargo handling equipment
CFR	Code of Federal Regulations
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
D	distance
DF	deterioration factor
DPM	diesel particulate matter
DR	deterioration rate
E	emissions
ECA	emission control area
EF	emission factor
EI	emissions inventory
EIAPP	Engine International Air Pollution Prevention Certificate
EPA	U.S. Environmental Protection Agency
EEIA	Energy & Environmental Analysis, Inc.
FCF	fuel correction factor
FECR	Florida East Coast Railway
FPL	Florida Power and Light
FR	federal register
g/bhp-hr	grams per brake horsepower-hour
g/hr	grams per hour
g/kW-hr	grams per kilowatt-hour
g/mi	grams per mile
GIS	geographic information system
GHG	greenhouse gas
GTM	gross ton-miles
GWP	global warming potential
HC	hydrocarbons
HDV	heavy-duty vehicle
HFO	heavy fuel oil
hp	horsepower
hrs	hours
IARC	International Agency for Research on Cancer
ICTF	intermodal container transfer facility
IFO	intermediate fuel oil
IMO	International Maritime Organization
IHS	IHS Maritime World Register of Ships
IVL	Swedish Environmental Research Institute
kW	kilowatt
kW-hr	kilowatt hour
lbs/day	pounds per day
LF	load factor
LLA	low load adjustment
Lloyd's	Lloyd's Register of Ships
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MCR	maximum continuous rating
MDO	marine diesel oil
MGO	marine gas oil
mph	miles per hour
MMGTM	million gross ton-miles
MMSI	maritime mobile service identity
MOVES	Motor Vehicle Emissions Simulator, EPA model
MY	model year
MWhr	megawatt hour
N_2O	nitrous oxide
NEI	EPA National Emissions Inventory
nm	nautical miles
NONROAD	Module of EPA MOVES
NO_x	oxides of nitrogen
NR	not reported
OGV	ocean-going vessel
OTAQ	Office of Transportation and Air Quality, EPA
PM	particulate matter
PM_{10}	particulate matter less than 10 microns in diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
ppm	parts per million
RCAP	Regional Climate Action Plan
RIA	Regulatory Impact Analysis

RoRo	roll-on roll-off vessel
rpm	revolutions per minute
RTG	rubber tired gantry crane
S	sulfur
SCC	source classification code
SFC	specific fuel consumption
SO_2	Sulfur dioxide
SP31	Regional Climate Plan recommendation to incorporate climate adaption strategy
TEU	twenty-foot equivalent unit
tons	Short tons
tonnes	metric tons
tpy	tons per year
U.S.	United States
ULSD	ultra-low sulfur diesel
USCG	U.S. Coast Guard
VBP	vessel boarding program
VMT	vehicle miles of travel
VOC	volatile organic compound
ZH	zero hour
ZMR	zero-mile rate

OVERVIEW

What is the emissions inventory?
The Port Everglades 2015 Baseline Air Emissions Inventory identifies and quantifies pollutants emitted from maritime-related mobile diesel equipment operating within the Port jurisdictional boundary. It was conducted voluntarily and proactively, in advance of any regulatory directive, to provide a strong technical foundation to support future policy decisions. The inventory is not a policy document and does not include policy recommendations.

Who developed the emissions inventory?
The inventory was developed by Starcrest Consulting Group, LLC, in cooperation with local, state and federal agencies. It was funded by Port Everglades. A partnership agreement was developed jointly by Port Everglades and the Environmental Protection Agency's (EPA) Office of Transportation and Air Quality (OTAQ).

What will the partnership accomplish?
The partnership will allow the EPA to develop future methods, provide lessons learned, and provide practical examples that can be shared with other ports, related agencies, and stakeholders to support and encourage sustainable development. In addition, the EPA will develop separate emissions estimates for areas outside the Port jurisdictional boundaries, such as highways and railways used by Port Everglades customers.

Why was the inventory developed?
A long-term strategic clean air plan, incorporating real data, scientific projections, management solutions, and governmental outreach support/actions is necessary to maintain excellent air quality in and around the Port. This emissions inventory provides scientifically valid data to improve understanding of the nature and magnitude of emissions from maritime-related operations at the Port.

What does it measure?
It estimates tons per year of emissions from maritime-related activities for calendar year 2015. Pollutants in the inventory include relevant EPA criteria pollutants and precursors (carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic compounds and particulate matter); greenhouse gases (carbon dioxide, methane and nitrous oxide); and diesel particulate matter.

Data was gathered for the following mobile source categories associated with marine activities: ocean-going vessels (such as cargo and cruise ships, tankers); harbor vessels (towboats and yachts); cargo handling equipment (cranes, straddle carriers, forklifts, etc.); on-road vehicles (heavy-duty vehicles, light and medium duty vehicles that transport cruise passengers, and port-owned on-terminal fleet vehicles); and rail operations. It also includes emissions for electrical power consumption from public and private entities. It does not include point source emissions from the petroleum facilities located within port property as this is a mobile source inventory and does not include stationary sources.

EXECUTIVE SUMMARY

The Port Everglades Baseline Air Emissions Inventory study presents a detailed overview of port-related emissions based on 2015 activity levels at Port Everglades (the Port), Broward County, Florida. This activity-based emissions inventory provides detailed information on the major mobile source categories associated with the marine activities, which are ocean-going vessels, harbor vessels, cargo handling equipment, on-road heavy-duty and light-duty vehicles, and rail operations. It also includes greenhouse gas emissions from electrical power consumption for buildings and lighting. The geographical domain for the landside source categories is within the Port jurisdictional boundary and its associated terminals. The marine-side geographical domain includes the port jurisdiction and extends three nautical miles beyond the entrance channel.

In partnership with the U.S. Environmental Protection Agency (EPA), the Port undertook the development of this emissions inventory of Port-related mobile emission sources and is the first port in the U.S. to partner with EPA in this type of landmark air emissions study. Broward County currently meets environmental standards for air quality; however, the Port chose to create a benchmark or baseline by which to measure future changes in emissions to take necessary actions to maintain air quality standards in the future.

The total 2015 emissions for maritime-related mobile sources in Port Everglades are summarized in Table ES.1. Starting in 2015, the North American Emission Control Area (ECA) required all ocean-going vessels (OGV) to utilize fuels with 0.1% S or cleaner. The ocean-going vessel emissions were estimated using this lower sulfur fuel and therefore the OGV and overall SO_2 emissions are lower in 2015 than they would have been in previous years. The diesel fuel used by the other mobile source categories is ultra-low sulfur diesel (ULSD) with sulfur content at 15 parts per million (ppm).

Table ES.1: 2015 Mobile Source Emissions, tons and tonnes per year

Sources	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Ocean-going vessels	2,001	43.73	41.07	37.95	73.44	183.40	88.45	126,141
Harbor craft	184	5.06	4.67	5.06	7.07	72.73	0.12	11,834
Cargo handling equipment	218	13.83	13.40	13.82	24.81	89.17	0.17	24,729
On-road vehicles	54	3.96	3.65	3.94	5.99	26.96	0.11	10,783
Locomotives	1	0.02	0.02	0.02	0.04	0.36	0.00	136
Total	**2,458**	**66.60**	**62.82**	**60.78**	**111.36**	**372.61**	**88.85**	**173,623**

In order to illustrate the relative magnitude of maritime-related emissions at Port Everglades in 2015, the Port emissions are compared to the Broward County emissions based on the latest 2014 EPA's National Emissions Inventory[1] (NEI). The NEI includes point and nonpoint sources (i.e. stationary sources), and onroad and nonroad sources (ie. mobile sources) for the entire Broward County. Comparing 2015 Port Everglades emissions to the latest 2014 NEI is not a complete apples to apples comparison since they are different inventory years which represent different activities. In addition, the 2015 port emissions are assuming the vessels are using the lower sulfur fuel per the North American Emissions Control Area (ECA), while the 2014 NEI are assuming non-ECA compliant fuel, thus the SO_2 emissions are not fully comparable.

Table ES.2 shows Port Everglades 2015 emissions as compared to Broward County 2014 emissions may vary from 0.2% to 7%, depending on the pollutant. The percentages serve as an illustration of the relative percentage of port emissions compared to county emissions, with the caveat of different inventory year and methodologies. The CO_2 emissions are not included in the comparison since the 2014 NEI has an incomplete inventory of CO_2 emissions.

Table ES.2: 2015 Port Emissions Compared to County and State Emissions, tons and %

Sources	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons
Port	2,458	67	63	61	111	373	89
Broward County	35,829	12,310	7,052	937	56,344	247,792	2,420
Florida	575,648	511,657	231,334	12,855	2,437,354	4,217,171	164,437
Port compared to Broward County, %	**6.9%**	**0.5%**	**0.9%**	**6.5%**	**0.2%**	**0.2%**	**3.7%**

For this study, the electrical power consumption from public and private facilities was collected to calculate greenhouse gas emissions for this source. The electrical power consumption is a measure of the electricity generated for buildings and facilities that is used to light the buildings, provide outdoor lighting, and to power air conditioners and computers. The resulting GHG emission estimate was 14,397 tonnes of CO_2e and the electric energy consumed in 2015 is estimated at 38.4 million kW-hr.

[1] County and state emissions are from the latest 2014 National Emissions Inventory, *www.epa.gov/air-emissions-inventories*, released September, 2016.

SECTION 1 INTRODUCTION

The Port Everglades Baseline Air Emissions Inventory study presents a detailed overview of port-related emissions based on 2015 activity levels at Port Everglades (the Port), Broward County, Florida. This activity-based emissions inventory provides detailed information on the major mobile source categories associated with the marine activities, which are ocean-going vessels, harbor vessels, cargo handling equipment, on-road heavy-duty and light-duty vehicles, and rail operations. It also includes greenhouse gas emissions from electrical power consumption for buildings and lighting.

1.1 Reason for Study

A long-term strategic clean air plan, incorporating real data, scientific projections, management solutions, and governmental outreach support/actions is necessary to maintain excellent air quality in and around the Port. In addition, Regional Climate Action Plan (RCAP)[2] recommendation number SP31 calls for incorporating climate adaptation strategies and greenhouse gas emissions inventories into Seaport Master Plans. In support of these needs, and in partnership with the U.S. Environmental Protection Agency (EPA), the Port undertook the development of this emissions inventory of Port-related mobile emission sources.

Port Everglades is the first port in the U.S. to partner with EPA in this type of landmark air emissions study. Broward County currently meets environmental standards for air quality; however, the Port chose to create a benchmark or baseline by which they can measure future changes in emissions so that they can take necessary actions to maintain air quality standards in the future.

The partnership agreement was developed jointly by the Port and EPA's Office of Transportation and Air Quality. The partnership will allow EPA to develop future methodologies, provide lessons learned, and provide practical examples that can be shared with other ports, agencies and stakeholders to support and encourage sustainable development. In addition to this inventory that is funded by Port Everglades, EPA will develop a separate emissions assessment for areas outside the Port's jurisdictional boundaries such as highways and railways used by Port customers. This inventory will help identify where emission reductions could provide the best public health and environmental benefits.

[2] Southeast Florida Regional Climate Change Compact Counties, Regional Climate Action Plan, October 2012. See: *www.southeastfloridaclimatecompact.org/wp-content/uploads/2014/09/regional-climate-action-plan-final-ada-compliant.pdf*

1.2 Port Overview

Port Everglades, located in the cities of Hollywood, Ft. Lauderdale, and Dania Beach in Broward County, Florida, is a diverse seaport capable of handling many types of cargo. Port Everglades is Florida's leading container port, it is ranked among the largest cruise ports in the world, and it is also South Florida's main seaport for receiving petroleum products. In 2015, Port Everglades welcomed over 3.7 million cruise passengers and moved intermodal containers totaling over 1 million twenty-foot equivalent units (TEUs).

The Port breaks downs its operation into 3 business lines: cargo, cruise and petroleum. Table 1.1 lists the public and private facilities and entities included in this emissions inventory by business line and general facility type. The typical mobile emission sources are summarized in Table 1.2 and explained in paragraphs below. The intermodal container transfer facility (ICTF), in which containers are transferred onto and off railcars for transport by Florida East Coast Railway (FECR), is located within port property and thus included in this inventory under "other" facility type.

Cargo includes auto, yachts, containers, and dry bulk. Container facilities generally receive and ship cargo in containers and tend to use cargo handling equipment more than other facility types. The two dry bulk facilities at the Port are cement facilities which operate using conveyor systems. General cargo facilities handle a mix of bulk, breakbulk and containerized cargo. These facilities may load/unload vessels that carry breakbulk and containerized cargo, so they maintain a variety of cargo handling equipment to be able to handle any cargo. The equipment at general cargo facilities that is used for specialized cargo may not be used as often, and have lower annual operating hours, compared with typical cargo handling equipment.

The cruise business line includes all the cruise ships that visit the Port. The cruise terminals at Port Everglades are home to many of the largest cruise vessels in the world. These terminals use forklifts to load/unload supplies, perishables, and passengers' luggage needed for the cruise.

The petroleum business line includes the liquid bulk facilities that are situated inside of the Port boundary. The liquid bulk facilities handle petroleum products, which may be stored at the facility and/or transferred to or from barges and tankers. Liquid bulk facilities do not generally use cargo handling equipment since the materials are moved by pipeline.

Table 1.1: List of Facilities

Business Line	Facility Type	Facility	Typical Mobile Emission Sources
Cargo	Container	Crowley Liner Services Florida International Terminal Port Everglades Terminal	OGV, harbor craft, CHE, on-road vehicles, locomotives
	Dry bulk	Cemex Lehigh Cement	OGV, harbor craft, on-road vehicles
	General Cargo	Horizon Terminal Svcs. Host Terminals Hyde Shipping King Ocean Services Portus PEV Seacor Island Lines Coleary Transport Co. Sol Shipping Services Sun Terminals	OGV, harbor craft, CHE, on-road vehicles
Cruise		Cruise Terminals	OGV, harbor craft, CHE
Petroleum	Liquid bulk	Buckeye Chevron Citgo ExxonMobil High Sierra Energy Kinder Morgan Marathon Petroleum Motiva Enterprises Vecenergy/Valero Targa TransMontaigne	OGV, harbor craft, on-road vehicles
Other	Other	Florida East Coast Railway ICTF	CHE, locomotives

1.3 Scope of Study

The scope of the study is described in terms of the pollutants estimated, the source categories included, and the geographical domain. The activity year for this study is calendar year 2015.

1.3.1 Pollutants Estimated

Exhaust emissions of the following pollutants have been estimated:

- Criteria pollutants, surrogates, and precursors:
  - Oxides of nitrogen (NO_x)
  - Particulate matter (PM) (10-micron, 2.5-micron)
  - Volatile organic compounds (VOC)
  - Carbon monoxide (CO)
  - Sulfur dioxide (SO_2)
- Diesel particulate matter (DPM)[3], which is the particulate matter emitted from diesel-fueled internal combustion engines and is considered a toxic air pollutant
- Fuel combustion-related greenhouse gas (GHG) emissions are also included:
  - Carbon dioxide (CO_2)
  - Nitrous oxide (N_2O)
  - Methane (CH_4)

Because each greenhouse gas differs in its effect on the atmosphere, estimates of greenhouse gas emissions are presented in units of carbon dioxide equivalents (CO_2e), which weight each gas by its global warming potential (GWP) value. To normalize these values into a single greenhouse gas value, CO_2e, the GHG emission estimates are multiplied by the following GWP values[4] and summed. The resulting CO_2e emissions are presented in metric tons (tonnes) throughout the report.

- CO_2 – 1
- CH_4 – 25
- N_2O - 298

[3]Diesel particulate matter is on EPA's Mobile Sources List of Toxics. See: *www.epa.gov/otaq/toxics.htm*
[4]U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, April 2016.

Table 1.2 provides a description of the pollutants and greenhouse gases.

Table 1.2: Pollutant and Greenhouse Gases Description

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

Table 1.2: Pollutant and Greenhouse Gases Description (cont'd)

Pollutant	Sources	Health & Environmental Effects
Sulfur dioxide (SO_2) is a colorless, corrosive gas produced by burning fuel containing sulfur, such as coal and oil, and by industrial processes such as smelters, paper mills, power plants and steel manufacturing plants.	SO_2 emissions are primarily a result of combustion fuels in cars, trucks, vessels, locomotives and equipment. Over the past decade, levels of sulfur in diesel and gasoline fuels have decreased dramatically due to federal regulations set by the EPA, which resulted in decreasing SO_2 emissions.	SO_2 is associated with a variety of respiratory diseases. Inhalation of SO_2 can cause increased airway resistance by constricting lung passages. Some of the SO_2 become sulfate particles in the atmosphere adding to measured PM levels.
Diesel particulate matter (DPM) is a significant component of PM. Diesel exhaust also includes more than 40 substances that are listed as hazardous pollutants. DPM is considered a surrogate for the effects of both the PM and gaseous component of diesel exhaust. Because of their microscopic size, DPM can become trapped in the small airways of the lungs.	Sources of diesel emissions include diesel-powered trucks, buses and cars (on-road sources); diesel-powered marine vessels, construction equipment, trains and aircraft support equipment (non-road sources).	DPM and diesel exhaust has been shown to contribute up to 80% of the carcinogenic health risk related to the portion of outdoor air pollutants classified as "toxics" (based on CA risk estimate). DPM is linked with health effects typical of all PM, including heart problems, aggravated asthma, chronic bronchitis and premature death.
Greenhouse gases (GHG) included in this emissions inventory are carbon dioxide, methane, and nitrous oxide. Additional gases that are not significantly emitted by maritime-related sources or included in this inventory also contribute to climate change.	GHG come from both natural processes and human activities, although increases of human-made GHG are most responsible for disrupting the balance of the atmosphere. Most GHG come from transportation and electricity generation.	Climate change, also referred to as global warming, occurs when excessive amounts of GHG accumulate in our atmosphere. These gases trap heat, causing the temperature of the earth to rise.

1.3.2 Emission Source Categories

This study includes the following port-related emission source categories, described below. Except for the electrical power consumption emissions, the port-related emissions included in this study are for mobile sources only, and are consistent with source categories included in other Air Emission Inventory reports for Port Authorities. Since this is mainly a mobile source emissions inventory, it does not include stationary source emissions that are within the port security parameter and under port jurisdiction, such as petroleum facilities, asphalt plant, and power plant. The stationary sources from the petroleum facilities, power plant and other stationary sources are accounted for in separate annual operating reports submitted to the regional and federal environmental agencies.

Ocean-going Vessels

Ocean-going vessels (OGVs) that called or visited the Port in 2015 have been included. A vessel call is when a vessel makes first arrival to a berth. The vessel types included are auto carrier, bulk carrier, container ship, cruise ship, general cargo, roll-on roll off (RoRo) vessel, tanker, and a miscellaneous category for vessels that cannot be grouped under the other vessel types.

Harbor Craft

Diesel-fueled harbor craft that work at the Port, such as pilot boats and assist tugs, plus domestic vessels that called the Port in 2015, such as articulated tug barges (ATB), towboats, and yachts have been included. Yachts have significant activity in Broward County and only the yachts that called the Port in 2015 are included in this source category. Emissions from domestic transitory marine traffic through the Atlantic Intracoastal Waterway are included in Appendix A of this report. The transitory emissions are not part of the harbor craft source category since these vessels did not call the Port, but just passed through.

Cargo Handling Equipment

Cargo handling equipment (CHE) has been included. This category includes equipment used to move cargo, passenger luggage, products and supplies, material handling equipment and any other equipment that is essential to port facility operations. Some examples of equipment are forklifts, cranes, loaders, reach stackers, rubber tired gantry (RTG) cranes, top loaders, trucks and yard tractors.

On-road Vehicles

On-road vehicles have been included, specifically heavy-duty vehicles used to move cargo into and out of the Port, light and medium-duty vehicles that transport passengers to and from the cruise terminals, and the Port's fleet vehicles that operate within the Port.

Locomotives

The locomotives used by Florida East Coast Railway (FECR) at the new Intermodal Container Transfer Facility (ICTF) and to move cargo between the Port and FECR's interface with other railroads were included.

Electrical Power Consumption

Grid emissions from the electricity consumed in 2015 by public and private buildings and terminals at the Port were included. These grid emissions were generated at power plants in Florida, but outside the study area. The emissions from the FPL power plant that was being built in 2015, was not included, nor were the emissions for the older power plant that was demolished in 2013.

1.4 Geographical Domain

The geographic areas included in the inventory on the marine-side (for OGVs and harbor craft) and on the land-side (for CHE, on-road vehicles, and locomotives) are described below, followed by a discussion and list of the Port facilities included in the inventory.

1.4.1 Marine-side Geographical Domain

The marine-side geographical domain includes the Port jurisdiction and extends three nautical miles (nm) beyond the entrance channel. The 3 nm boundary is the same as the over the water boundary for the county. Figure 1.1 presents an aerial view of the entrance channel facing southwest, while Figure 1.2 illustrates the marine-side geographical domain.

Figure 1.1: Aerial View of the Entrance Channel

Figure 1.2 shows the marine-side geographical domain which includes the Port jurisdiction in green, the main turning basin, the entrance channel, the coastal zone which extends 3 nm from the shore, and the anchorage area in dark blue.

Figure 1.2: Marine-Side Geographical Domain

1.4.2 Land-side Geographical Domain

The geographical domain for the landside source categories is within the boundary (yellow lines) of the Port jurisdiction and its associated terminals, as indicated in Figure 1.3[5].

Figure 1.3: Aerial View of Port Everglades Boundary

[5] Created from Google Earth.

SECTION 2 SUMMARY RESULTS

The total 2015 emissions for maritime-related mobile sources in Port Everglades are summarized in Table 2.1. As discussed in Section 1, the CO_2e emissions are presented in metric tons or tonnes rather than short tons, and have been calculated using the GWP values listed in Section 1. Starting in 2015, the North American Emission Control Area (ECA) required all ocean-going vessels (OGV) to utilize fuels with 0.1% S or cleaner. The ocean-going vessel emissions were estimated using this lower sulfur fuel and therefore the OGV and overall SO_2 emissions are lower in 2015 than they would have been in previous years.

Table 2.1: 2015 Mobile Source Emissions, tons and tonnes per year

Sources	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Ocean-going vessels	2,001	43.73	41.07	37.95	73.44	183.40	88.45	126,141
Harbor craft	184	5.06	4.67	5.06	7.07	72.73	0.12	11,834
Cargo handling equipment	218	13.83	13.40	13.82	24.81	89.17	0.17	24,729
On-road vehicles	54	3.96	3.65	3.94	5.99	26.96	0.11	10,783
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Total	**2,458**	**66.60**	**62.82**	**60.78**	**111.36**	**372.61**	**88.85**	**173,623**

In order to illustrate the relative magnitude of maritime-related emissions at Port Everglades in 2015, the Port emissions are compared to the Broward County stationary and mobile source emissions based on the latest 2014 EPA's National Emissions Inventory[6] (NEI). Comparing 2015 Port Everglades emissions to the latest 2014 NEI is not a complete apples to apples comparison since they are different inventory years which represent different activities and due to the different sulfur content ECA compliance for vessels between 2014 and 2015. Table 2.2 shows Port Everglades 2015 emissions as compared to Broward County 2014 emissions may vary from 0.2% to 7%, depending on the pollutant.

Table 2.2: 2015 Port Emissions Compared to County and State Emissions, tons and %

Sources	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons
Port	2,458	67	63	61	111	373	89
Broward County	35,829	12,310	7,052	937	56,344	247,792	2,420
Florida	575,648	511,657	231,334	12,855	2,437,354	4,217,171	164,437
Port compared to Broward County, %	**6.9%**	**0.5%**	**0.9%**	**6.5%**	**0.2%**	**0.2%**	**3.7%**

[6] County and state emissions are from the latest 2014 National Emissions Inventory, *www.epa.gov/air-emissions-inventories*, released September, 2016.

The following figures show the emission distribution by mobile source category for each pollutant.

Figure 2.1: NO_x Emissions Distribution by Mobile Source Category

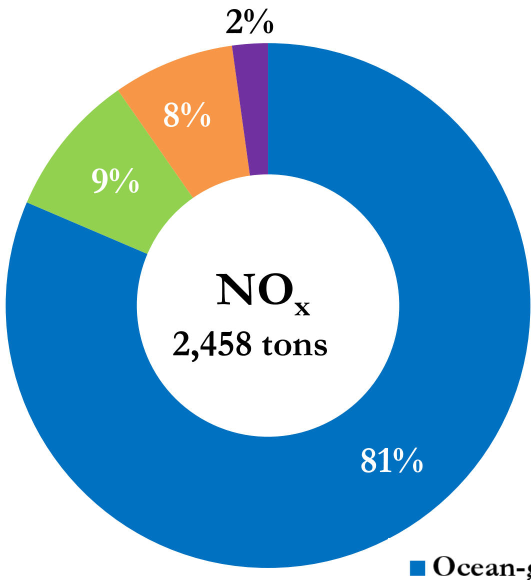


Figure 2.2: PM_{10} Emissions Distribution by Mobile Source Category

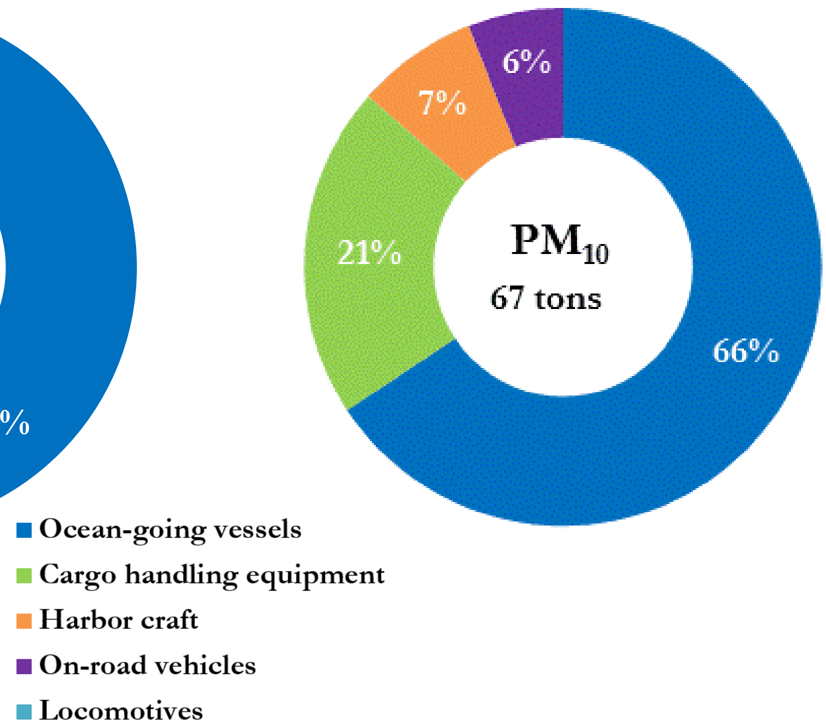


Figure 2.3: $PM_{2.5}$ Emissions Distribution by Mobile Source Category

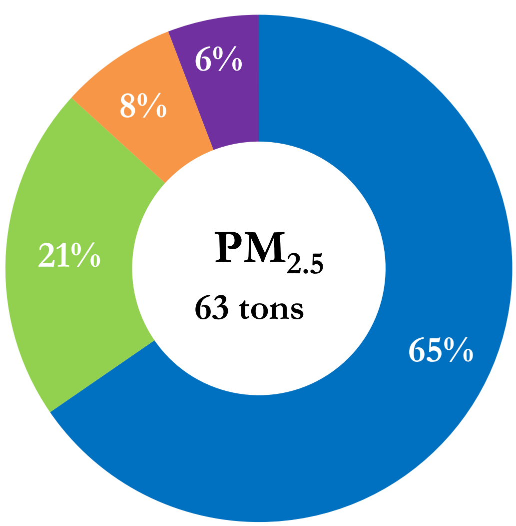


Figure 2.4: DPM Emissions Distribution by Mobile Source Category

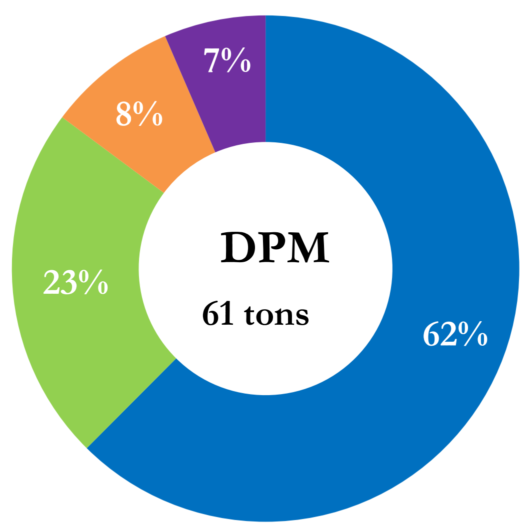


Figure 2.5: VOC Emissions Distribution by Mobile Source Category

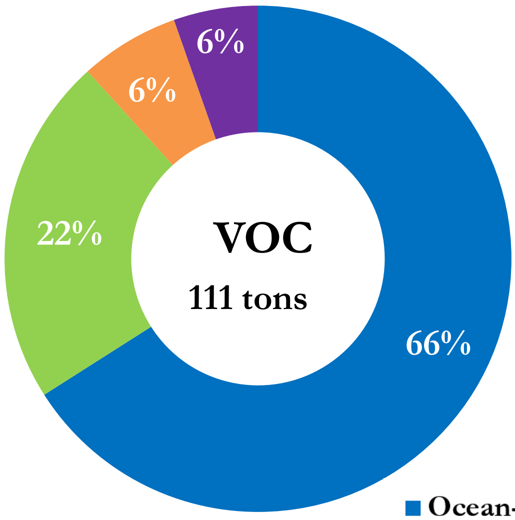
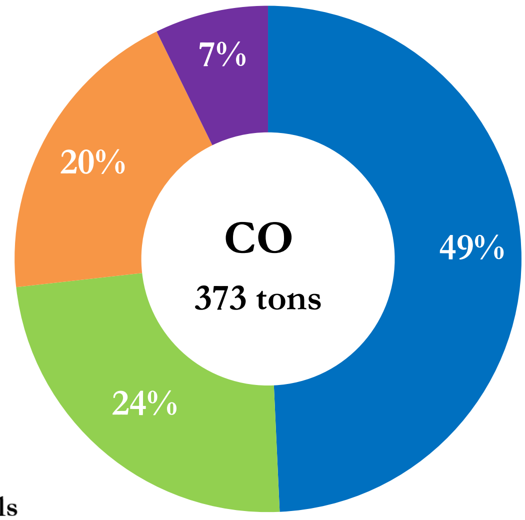


Figure 2.6: CO Emissions Distribution by Mobile Source Category



- Ocean-going vessels
- Cargo handling equipment
- Harbor craft
- On-road vehicles
- Locomotives

Figure 2.7: SO_2 Emissions Distribution by Mobile Source Category

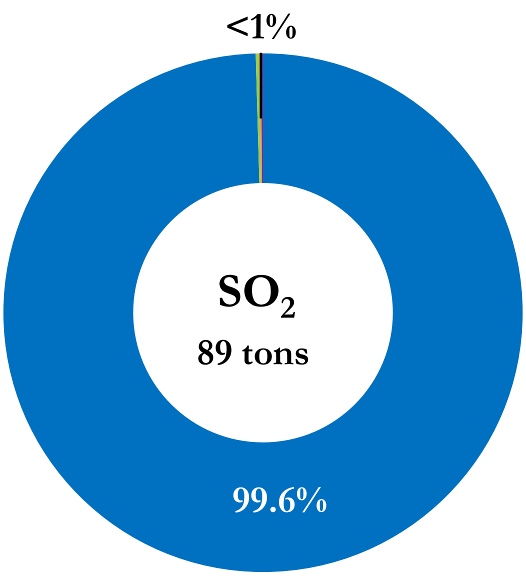
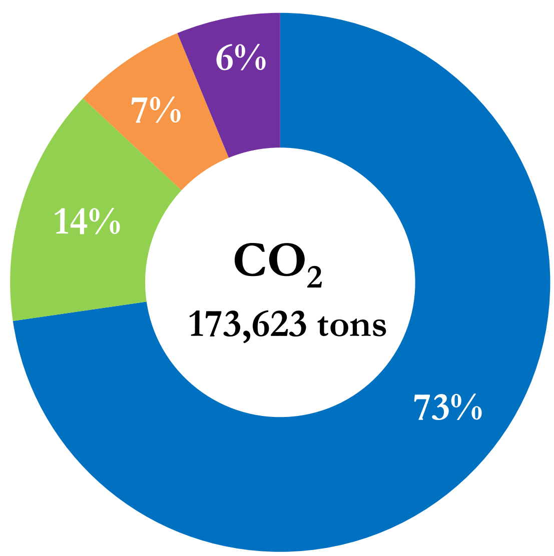


Figure 2.8: CO_2e Emissions Distribution by Mobile Source Category



The following figures illustrate the Port Everglades 2015 emissions as compared to Broward County 2014 emissions.

Figure 2.9: NO_x Comparison

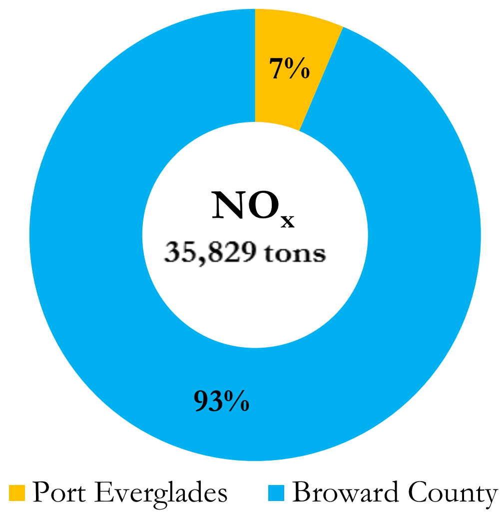


Figure 2.10: PM_{10} Comparison

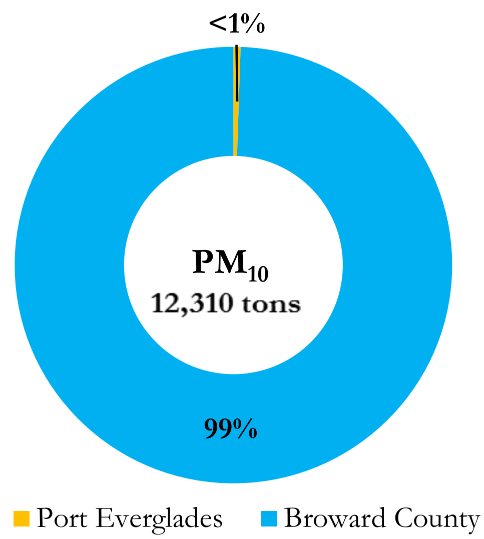


Figure 2.11: $PM_{2.5}$ Comparison

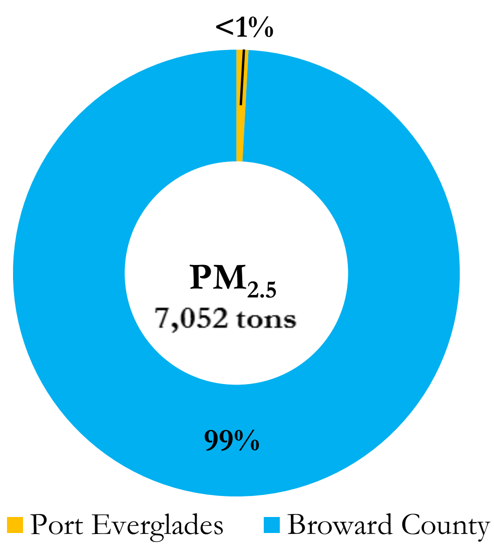


Figure 2.12: DPM Comparison

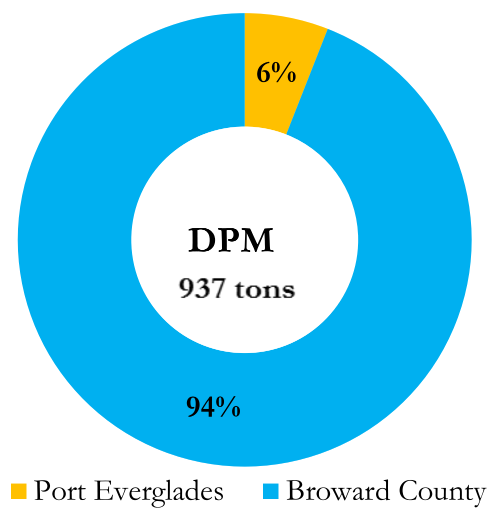


Figure 2.13: VOC Comparison

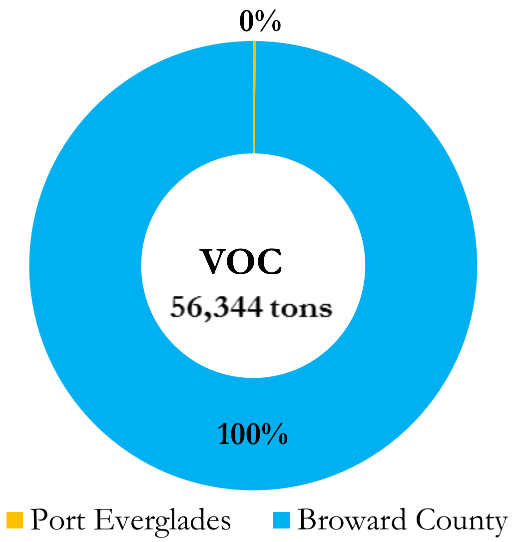


Figure 2.14: CO Comparison

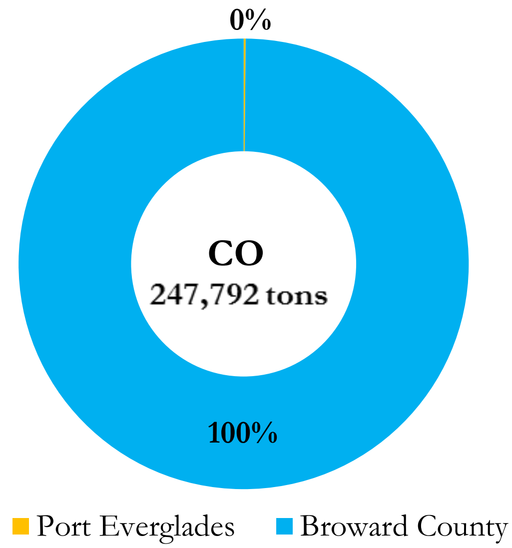
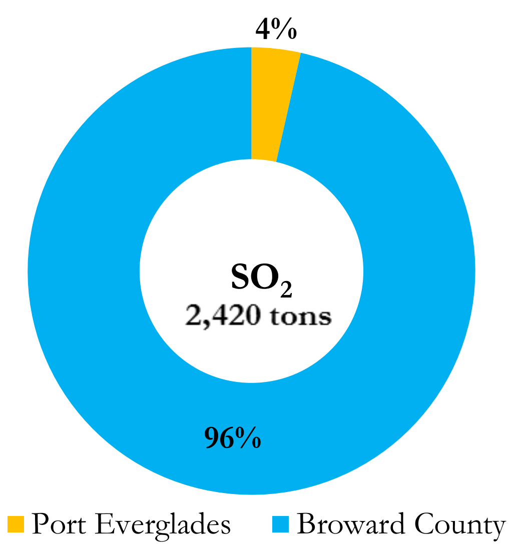


Figure 2.15: SO_2 Comparison



For this study, the electrical power consumption from public and private facilities was collected to calculate greenhouse gas emissions for this source. The electrical power consumption is a measure of the electricity generated for buildings and facilities that is used to light the buildings, provide outdoor lighting, and to power air conditioners and computers. Port Everglades and facilities included in this study provided the actual electric power usage for the inventory year from electric bill data. The resulting GHG emission estimate with the electric energy consumed in 2015 are listed in Table 2.3.

Table 2.3: 2015 Energy Consumption and GHG Emission Estimate

	Energy Consumption kW-hr	CO_2e tonnes
Total	38,425,754	14,397

SECTION 3 OCEAN-GOING VESSELS

This section presents emission estimates for the ocean-going vessel (OGV) source category organized into the following subsections: source description (3.1), geographical domain (3.2), data and information acquisition (3.3), operational profiles (3.4), emissions estimation methodology (3.5), and OGV emission estimates (3.6).

3.1 Source Description

Vessels that called the Port are grouped by the type of cargo they are designed to carry. The following vessel types called the Port in 2015:

- **Auto carrier** – vessels that transport vehicles.
- **Bulk carrier** – vessels with open holds to carry various bulk dry goods, such as grain, salt, sugar, petroleum coke, and other fine grained commodities.
- **Containership** – vessels that primarily carry goods in 20 and 40-foot containers in their holds and on their decks. Containerships are categorized into subtypes based on their carrying capacity.
- **Cruise ships** – vessels that carry passengers for pleasure voyages.
- **General cargo** – vessels that are designed to carry a diverse range of cargo in their hold and on their decks, such as bulk metals, machinery, yachts, and palletized goods.
- **Miscellaneous vessel** – includes various vessels that cannot be categorized under any of the other vessel type categories.
- **Roll-on roll-off vessel** – commonly known as RoRos, these vessels can accommodate vehicles and large wheeled equipment.
- **Tanker** –vessels that transport liquids in bulk, such as oil, chemicals, or other specialty goods such as molasses or asphalt. Tankers are classified based on their size.

The emissions associated with barges and articulated tug barges (ATBs) are addressed in Section 4, Harbor Craft. Figures 3.1 through 3.4 show various types of ocean-going vessels that call at Port Everglades, including containerships, cruise vessels, general cargo and tankers. The images shown are for illustrative purposes only.

Figure 3.1: Container Ship at Port Everglades

Figure 3.2: Cruise Vessels at Port Everglades

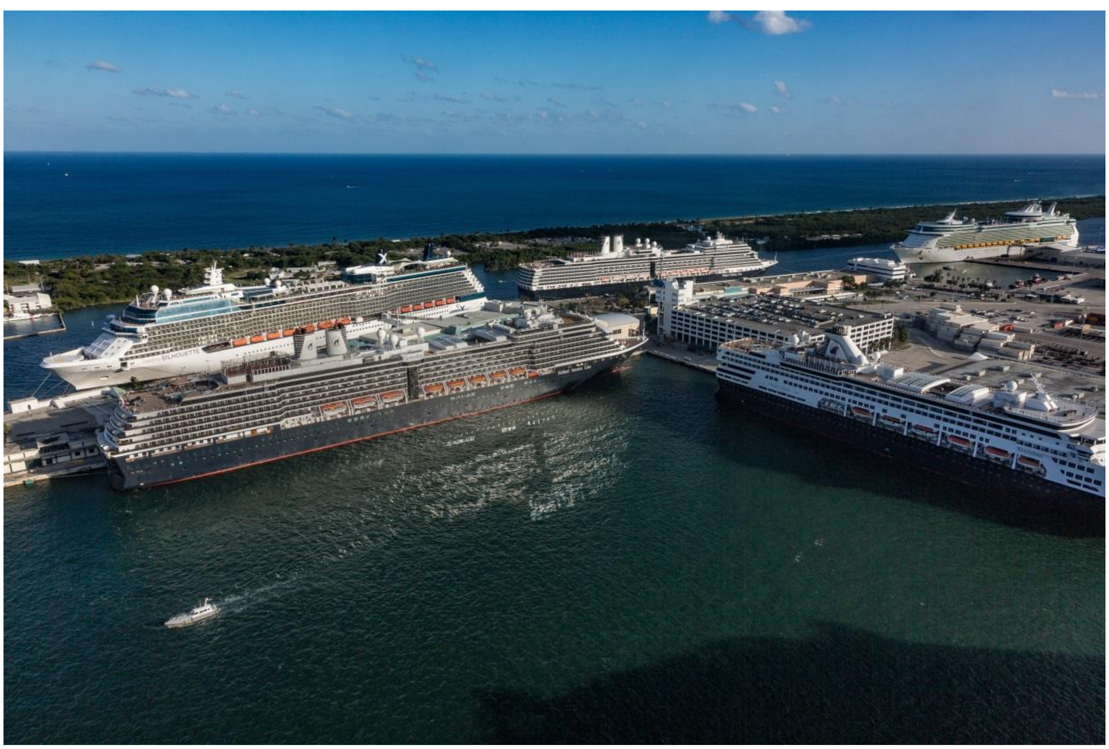
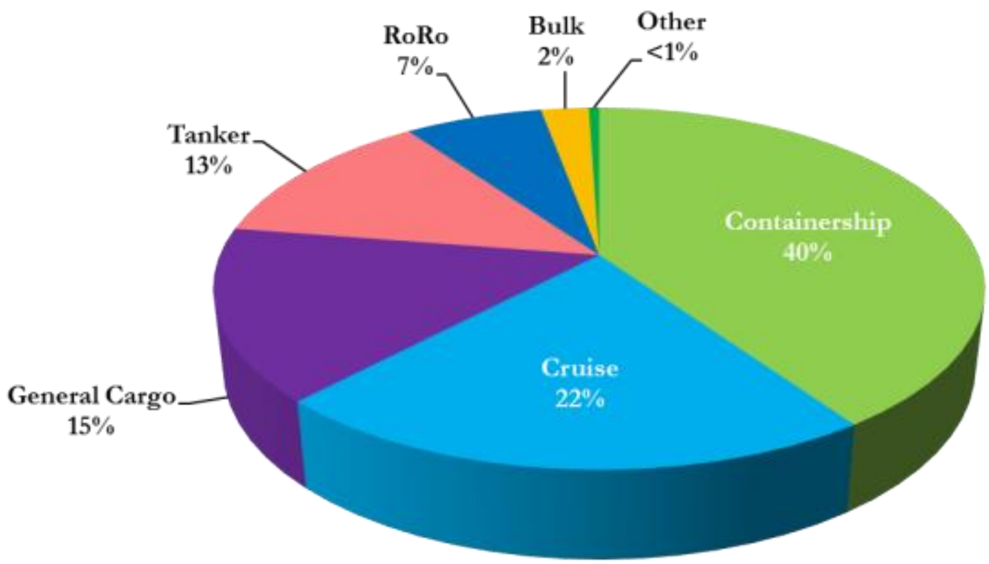


Figure 3.3: General Cargo Vessel at Port Everglades

Figure 3.4: Tanker at Port Everglades

Vessels made a total of 2,877 calls to the Port in 2015, based on vessel activity processed from Automatic Identification System (AIS) data as described in Section 3.3. A call is counted when a vessel makes first arrival to a berth, excluding shifts between berths. Figure 3.5 shows the percentage of calls by vessel type. Containerships made up the majority of the calls (40%), followed by cruise (22%); general cargo (15%); tanker (13%); RoRo (7%); bulk carriers (2%); and other vessels (<1%) including auto carriers and miscellaneous vessels.

Figure 3.5: 2015 Distribution of Calls by Vessel Type



The number of cruise ship calls to the Port is notable, as Port Everglades ranks among the world's top cruise ports. More than 3.7 million cruise passengers visited the Port during the 2015 fiscal year[7]. Additionally, there is a frequent ferry service with a vessel traveling to and from Grand Bahama Island, which has been classified as a RoRo in this report due to the vessel's ability to carry vehicles and other cargo.

[7] *www.porteverglades.net/cruising*

3.2 Geographical Domain

The geographical domain includes the berths and waterways within the Port jurisdiction boundary and extends three nautical miles beyond the Broward County shoreline. The three nautical mile line defines the edge of the water boundary.

The following operational modes define the characteristics of a vessel's operation within the emissions inventory geographical domain:

1. *Maneuvering* — Vessel movements inside the geographical domain, including the coastal zone. Additional power is typically brought online since the vessel is preparing to travel in, or is traveling in, restricted waters.
2. *At-Berth* — When a vessel is stationary at the dock/berth.
3. *At-Anchorage* — When a vessel is stationary within the anchorage area. The anchorage area is located in the coastal zone.

Due to the unique short entrance, the Port's operational modes are slightly different than other ports which include a long transit. As an example for comparison, the entrance channel to Port Everglades is less than 1 nm, while some vessels at the Port of Houston Authority transit approximately 58 nm from the sea buoy to reach some berths.

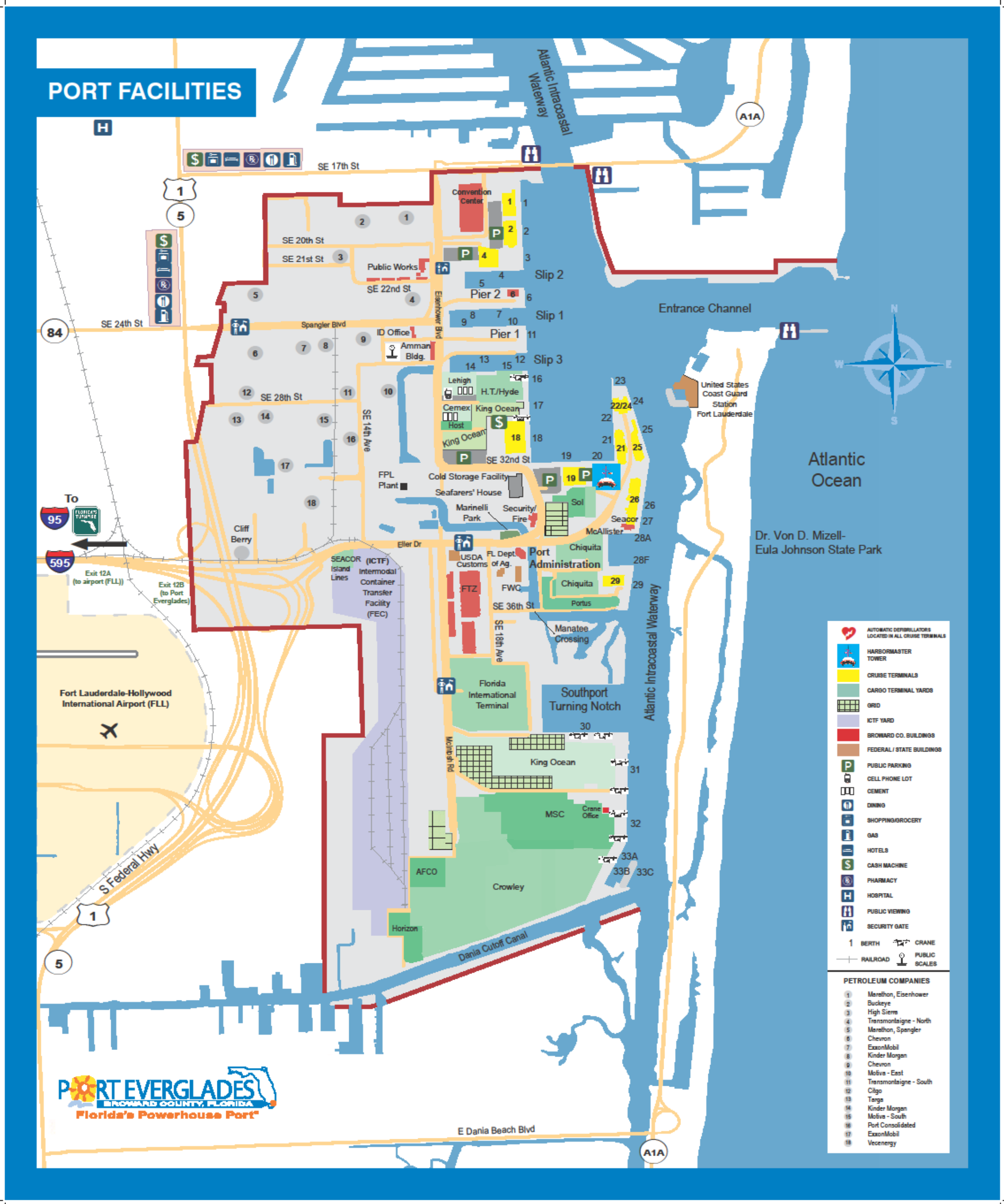
For Port Everglades' geographical boundary, there is no transit or "at-sea" mode, only a maneuvering mode. The maneuvering mode is comprised of the coastal zone, the main turning basin and the area inside the shoreline along the Atlantic Intracoastal Waterway. Most vessels travel from the coastal zone through the entrance channel and enter the main turning basin when traveling to or from a berth. Ships operating in the coastal zone are considered to be traveling in restricted waters as there is a precautionary area near the entrance channel, an anchorage area, and a pilot boarding area near the edge of the zone.

Figure 3.6 illustrates the outer limit of the geographic domain for OGVs with the location of the anchorage area, coastal zone, the entrance channel, and the main turning basin.

Figure 3.6: Marine-Side Geographical Domain

Figure 3.7 shows the berths and terminal areas within the Port boundary. The figure was provided by Port Everglades.

Figure 3.7: Port Everglades Berths and Terminal Areas



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3.3 Data and Information Acquisition

The OGV emission estimates presented in this report are based on vessel activity data, vessel operational data, and vessel parameter data.

Activity data sources include AIS data and wharfinger vessel call data. The AIS data was used for identifying vessel movements within the geographical domain and processed to determine discrete vessel activity parameters including actual speed over water. This data was collected by the U.S, Coast Guard (USCG) AIS receiver network, and compiled into files comprised of unique AIS records for individual vessels. The Port also provided wharfinger data detailing vessel calls to berths, which was used as a secondary data source to verify the vessel activity that was processed from the AIS data. AIS data points contain vessel specific geographical and temporal information including, but not limited to: IMO number, MMSI number, geographic coordinates, speed over water, heading, date, and time.

Vessel operational data includes Starcrest Vessel Boarding Program (VBP) data collected from ships at various ports to determine auxiliary engine and boiler loads, by the various operational modes. The discrete vessel operational data collected during VBP is confidential, but the averages used for defaults are listed in sections 3.5.8 and 3.5.9 of this report. Additional discussions with Port Everglades Pilots (the Pilots) provided insight into vessel maneuvering operations from the pilot boarding location to when the pilot disembarks the vessel. The vessel specific parameter data is obtained through the IHS Fairplay (Lloyd's) register of ships and includes: vessel type, engine type, propulsion engine horsepower, keel laid date, vessel max rated speed, and other parameters needed to estimate ship emissions. VBP program data also provided vessel specific International Maritime Organization's (IMO) Engine International Air Pollution Prevention Certificate (EIAPP) for propulsion and auxiliary engines. For ships with a valid propulsion engine EIAPP, the engine's actual NO_x emissions value (g/kW-hr) is used in place of the default NO_x emission factor, which is the same as the applicable engine's IMO Tier NO_x requirement.

The raw AIS data was processed into vessel call activity through a combination of database processing and Geographic Information System (GIS) spatial analysis. The initial processing step is to evaluate the raw AIS data and remove any duplicate records or data anomalies, such as erroneous speeds and geographical coordinates. The next processing step is to spatially analyze the AIS data using GIS to determine where the AIS records are located within the study area. After the AIS data has been spatially analyzed, the next step is to process the AIS data using a database to generate vessel activities from concurrent AIS records. Vessel activity records generated from AIS data processing contain vessel specific speed profiles and the amount of time spent operating in the coastal and maneuvering zones, as well as hotelling time at a berth or anchorage. Only the vessel activities that were determined to have called at the Port based on the spatial analysis of the AIS data were compiled and used for this emissions inventory. Additionally, vessel calls listed in the wharfinger data were linked to the AIS data vessel calls to confirm the inclusion of all vessel activity. If the AIS activity did not contain a trip listed in the wharfinger data due to a temporal AIS data gap resulting in an incomplete AIS activity, the wharfinger data was manually added to the AIS activity to complete a trip. The AIS data contained relatively few data gaps, so less than 1% of the total vessel calls were gap-filled using the wharfinger data.

Figure 3.8 shows a spatial representation of the AIS data collected, processed, and analyzed for this inventory within the geographical domain.

Figure 3.8: Processed AIS Dataset

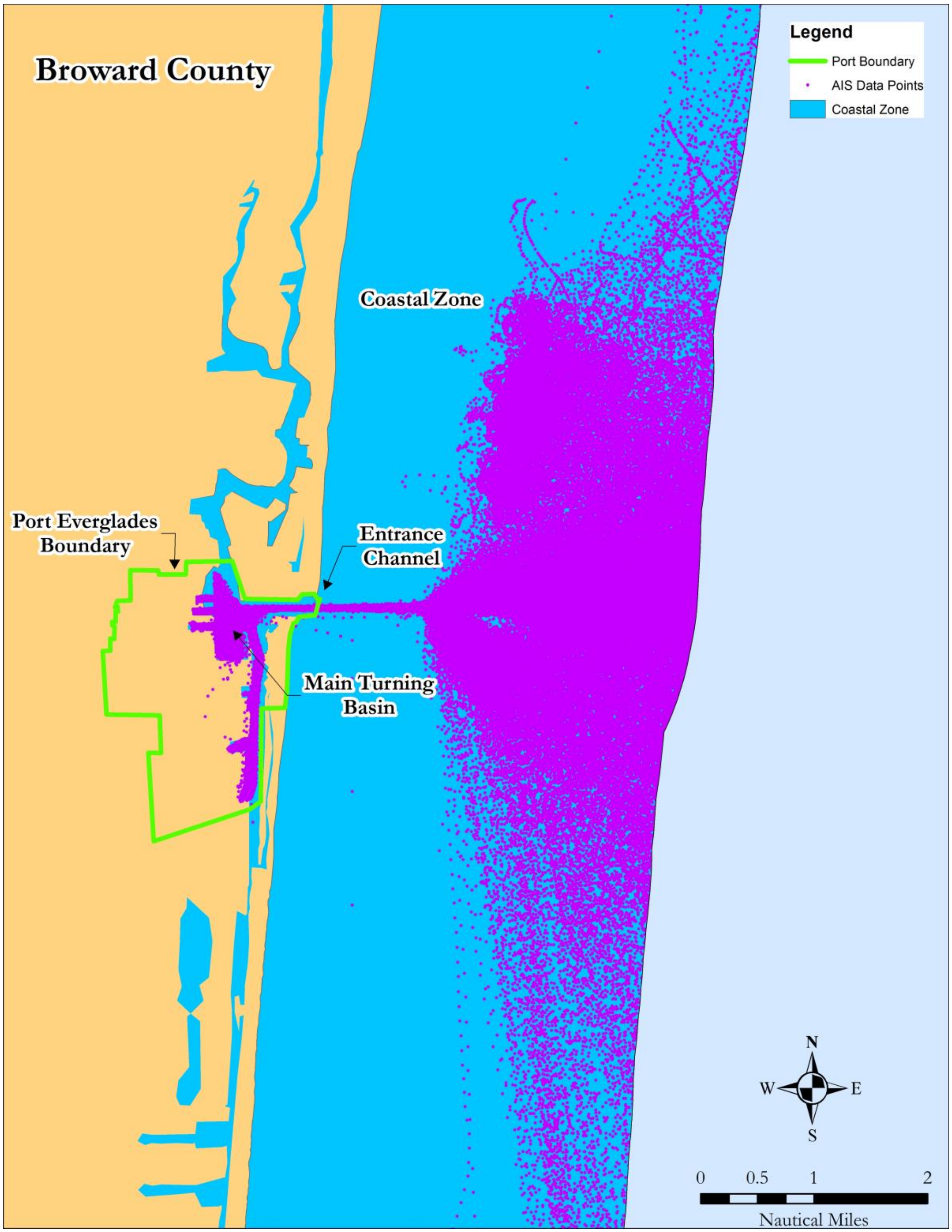
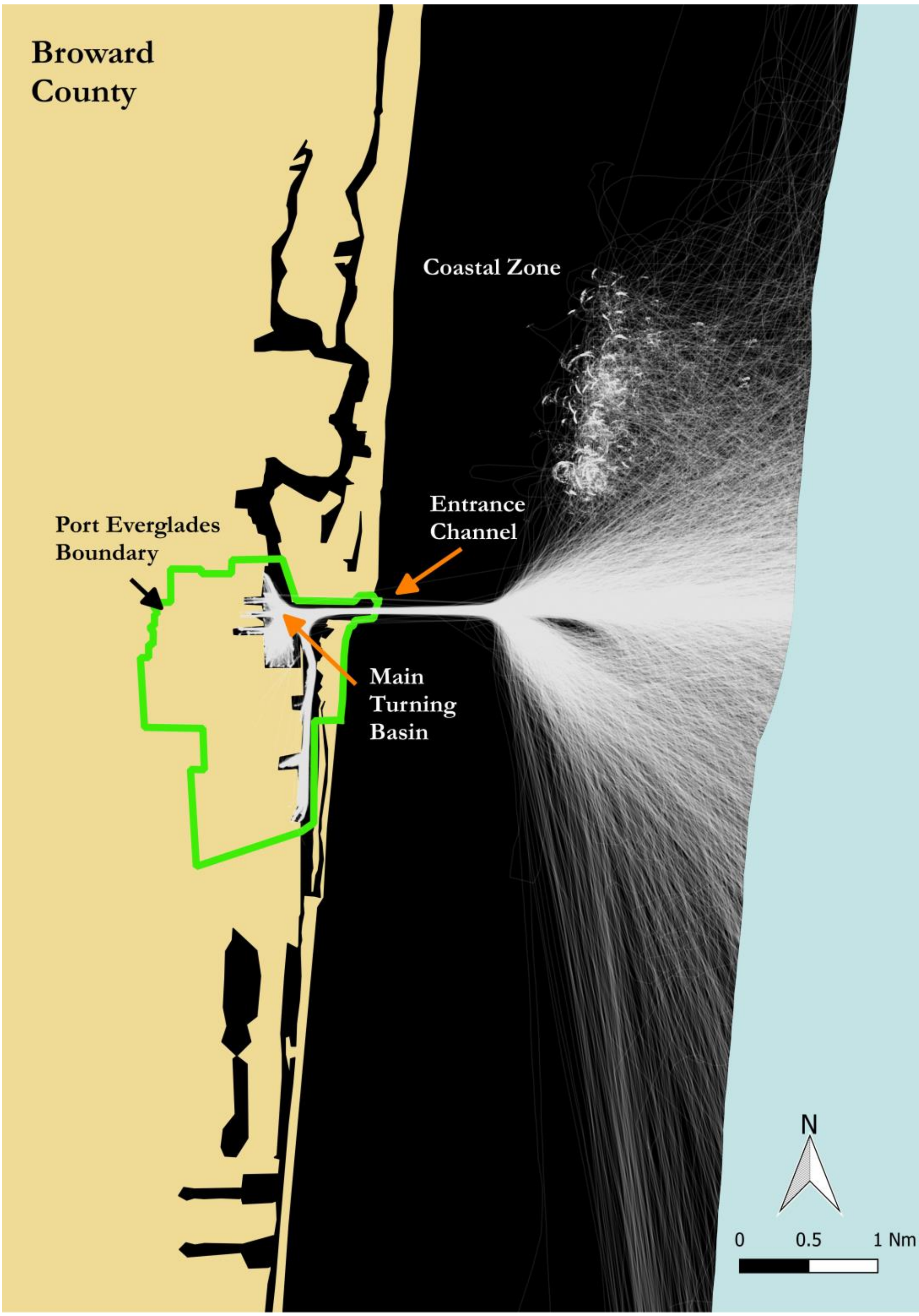


Figure 3.9 presents the vessel tracks of the individual vessel activities generated from the AIS dataset that called the Port within the geographical domain. The varying shades of white lines represent the variation in density of the vessel tracks.

Figure 3.9: Processed AIS Vessel Tracks



3.4 Operational Profiles

Vessel movements derived from AIS data were assigned one of the following trip types:

- Arrival – inbound trip from the coastal zone boundary to berth
- Departure – outbound trip from a berth or anchorage area to the inventory boundary
- Shift – intra-port trips between berths and/or the anchorage area that is within the inventory boundary

For this study, an inbound trip from the inventory boundary to the anchorage area was included in the emission estimates if the next movement after the anchorage was a berth at the Port. Containerships are classified into subtypes using a standardized unit to describe their carrying capacity, which is called a twenty-foot equivalent unit (TEU) and is based on the size of a 20-foot shipping container. In this inventory, a containership classified as Container-1000 vessel can accommodate up to 1,999 TEUs. Table 3.1 presents the number of arrivals, departures, and shifts associated with vessels that called at the Port in 2015.

Table 3.1: 2015 Arrivals, Departures, and Shifts by Vessel Type

Vessel Type	Arrivals	Departures	Shifts	Total
Auto carrier	5	5	2	12
Bulk	60	61	42	163
Bulk - heavy load	9	9	1	19
Container - 1000	784	785	160	1,729
Container - 2000	88	88	9	185
Container - 3000	85	85	1	171
Container - 4000	109	109	1	219
Container - 5000	49	49	0	98
Container - 6000	45	45	1	91
Container - 9000	1	1	0	2
Cruise	625	625	3	1,253
General cargo	443	444	128	1,015
Miscellaneous	10	10	1	21
RoRo	199	199	20	418
Tanker - handysize	56	56	25	137
Tanker - panamax	41	43	23	107
Tanker - suezmax	1	1	0	2
Tanker - chemical	267	266	96	629
Total	**2,877**	**2,881**	**513**	**6,271**

Table 3.2 shows the hoteling time at berth by vessel type in hours, as determined by the AIS data analysis.

Table 3.2: 2015 Hotelling Times at Berth, hours

Vessel Type	Min Time	Max Time	Average Time	Vessel Count
Auto carrier	9	17	13	3
Bulk	2	489	97	42
Bulk - heavy load	9	101	46	3
Container - 1000	2	399	20	46
Container - 2000	1	27	17	15
Container - 3000	5	27	11	10
Container - 4000	4	30	10	26
Container - 5000	10	31	17	10
Container - 6000	9	31	19	15
Container - 9000	63	63	63	1
Cruise	2	53	10	45
General cargo	2	180	23	83
Miscellaneous	16	141	76	5
RoRo	1	226	16	5
Tanker - handysize	9	74	32	36
Tanker - panamax	1	72	40	41
Tanker - suezmax	40	40	40	1
Tanker - chemical	1	120	33	98

Table 3.3 shows the hoteling time at anchorage by vessel type in hours, as determined by the AIS data analysis.

Table 3.3: 2015 Hotelling Times at Anchorage, hours

Vessel Type	Min Time	Max Time	Average Time	Vessel Count
Auto carrier	9	10	10	2
Bulk	6	235	44	17
Bulk - heavy load	10	10	10	1
Container - 1000	2	211	48	19
Container - 2000	10	31	18	4
Container - 3000	38	38	38	1
Container - 4000	14	14	14	1
Container - 5000	na	na	na	na
Container - 6000	na	na	na	na
Container - 9000	na	na	na	na
Cruise	na	na	na	na
General cargo	2	402	37	27
Miscellaneous	na	na	na	na
RoRo	15	212	51	1
Tanker - handysize	9	74	32	36
Tanker - panamax	4	78	24	19
Tanker - suezmax	na	na	na	na
Tanker - chemical	1	500	34	49

3.5 Emission Estimation Methodology

Vessel activity data and the methods of estimating emissions are discussed below for propulsion engines, auxiliary engines and boilers. Differences in methods of estimation between the various modes of operation, at-berth and maneuvering for this study, are discussed where applicable. Emission estimates were made assuming all vessels calling the Port were compliant with the IMO North American Emissions Control Area (ECA) requirement to use marine gas oil (MGO) with 0.1% sulfur (S) content fuel.

In general, emissions are estimated as a function of vessel power demand with energy expressed in kW-hr multiplied by an emission factor, where the emission factor is expressed in terms of grams per kilowatt-hour (g/kW-hr). Emission factors and emission factor adjustments for different fuel usage (see section 3.5.4) and for low propulsion engine load (see section 3.5.5), are then applied to the various activity data.

Equations 3.1 and 3.2 report the basic equations used in estimating emissions by mode.

Equation 3.1

$$\boldsymbol{E_i = Energy_i \times EF \times FCF}$$

Where:

E_i = Emissions by mode
$Energy_i$ = Energy demand by mode, calculated using Equation 3.2 below as the energy output of the engine(s) or boiler(s) over the period of time, kW-hr
EF = emission factor, expressed in terms of g/kW-hr
FCF = fuel correction factor, dimensionless

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

Equation 3.2

$$\boldsymbol{Energy_i = Load \times Activity}$$

Where:

$Energy_i$ = Energy demand by mode, kW-hr
Load = maximum continuous rated (MCR) times load factor (LF) for propulsion engine power (kW); reported operational load of the auxiliary engine(s), by mode (kW); or operational load of the auxiliary boiler, by mode (kW)
Activity = activity, hours

The emissions estimation methodology for propulsion engines can be found in subsections 3.5.1 to 3.5.6, for auxiliary engines can be found in subsections 3.5.7 and 3.5.8, and for auxiliary boilers can be found in subsection 3.5.9. Propulsion engines are also referred to as main engines. Incinerators are not included in the emissions estimates because incinerators are not used within the study area. Information collected from interviews with the vessel operators and marine industry personnel indicate that vessels do not use their incinerators while at-berth or near coastal waters.

3.5.1 Propulsion Engine Maximum (MCR) Continuous Rated Power

MCR is used to determine load by mode for propulsion engines. For this study, it is assumed that the Lloyd's 'Power' value is the best surrogate for MCR power and is reported in kilowatts. For diesel-electric configured ships, MCR is the combined rated electric propulsion motor(s) rating, in kW.

3.5.2 Propulsion Engine Load Factor

Load factor for propulsion engines is estimated using the ratio of actual speed compared to the ship's maximum rated speed. Propulsion engine load factor is estimated using the Propeller Law, which shows that propulsion engine load, varies with the cube of vessel speed. Therefore, propulsion engine load at a given speed is estimated by taking the cube of that speed divided by the vessel's maximum speed, as illustrated by the following equation.

Equation 3.3

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

Where:

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

For the purpose of estimating emissions, the load factor has been capped to 1.0 so that there are no calculated propulsion engine load factors greater than 100% (i.e., calculated load factors above 1.0 are assigned a load factor of 1.0).

3.5.3 Propulsion Engine Activity

Activity is measured in hours of operation within the geographical boundary. At-berth times are determined from the date and time stamps in the AIS data when a vessel is determined to be at a terminal. The maneuvering time within the geographical boundary is estimated using equation 3.4, which divides the segment distance traveled by ship at its over water speed.

Equation 3.4

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

Where:

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

Distance and actual speeds are derived from AIS data point geographical coordinate locations and the associated over the water speed between points.

3.5.4 Propulsion Engine Emission Factors

The main engine emission factors used in this study were reported in the ENTEC 2002 study,[8] except for PM, CO and greenhouse gas emission factors. An IVL Swedish Environmental Research Institute 2004 study[9] was the source for the PM emission factors for gas turbine and steamship vessels, as well as the CO and greenhouse gas emission factors for CO_2, and N_2O. Per IVL 2004 study data, CH_4 were assumed to be 0.2% of HC emission factors.

The main and auxiliary engine particulate matter (PM_{10}) and SO_x emission factors are based on the following equations[10] for HFO fuel with 2.7% sulfur content:

Equation 3.5

$$\boldsymbol{PM_{10}\ EF\ (g/kW - hr) for\ HFO = 1.35 + BSFC\ x\ 7\ x\ 0.02247\ x\ (Fuel\ Sulfur\ Fraction - 0.0246)}$$

Where:

BSFC = brake specific fuel consumption in g/kW-hr

Equation 3.6

$$\boldsymbol{SO_2\ EF\ (g/kW - hr) = BSFC\ x\ 2\ x\ 0.97753\ x\ (Fuel\ Sulfur\ Fraction)}$$

Where:

0.97753 is the fraction of fuel sulfur converted to SO_2 and 2 is the ratio of molecular weights of SO_2 and S.

The base emission factors are based on residual fuel oil/ heavy fuel oil (HFO) with average sulfur content of 2.7%. Starting in 2015, the North American Emission Control Area (ECA) requires all ships to utilize fuels with 0.1% S or cleaner. The emission factors were corrected using fuel correction factors (FCFs) from the baseline HFO 2.7% S to MGO 0.1% S. Table 3.4 lists the FCFs used[11].

Table 3.4: OGV Fuel Correction Factors

Actual Fuel Used Content	Sulfur Content by weight %	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2	N_2O	CH_4
MGO	0.1%	0.94	0.17	0.20	0.17	1.00	1.00	0.04	0.95	0.94	1.00

[8] ENTEC, *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community, Final Report*, July 2002

[9] IVL, *Methodology for Calculating Emissions from Ships: Update on Emission Factors,* 2004. (IVL 2004)

[10] Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report, April 2009

[11] ARB, *www.arb.ca.gov/regact/2011/ogv11/ogv11appd.pdf*

The two predominant propulsion engine types are:

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

Vessel specific NO_x emission factors from EIAPP certificates collected as part of the VBP program were used for propulsion and auxiliary engines. In this inventory, there were 6 vessels had EIAPP NO_x emission factors. The default emission factors were used for vessels that did not have EIAPP certificates available. NO_x emission factors are based on the IMO Tier of the vessel engines, which is based on the keel laid date provided in the IHS data. Table 3.5 list the adjusted emission factors for propulsion engines using 0.1% sulfur MGO. The 0.1% sulfur MGO emission factors were calculated by multiplying the 2.7% sulfur HFO base emission factors by the appropriate pollutant FCF (see Table 3.4).

Table 3.5: Emission Factors for Propulsion Engines using 0.1 %S MGO, g/kW-hr

Engine Category	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	DPM	HC	CO	SO_2	CO_2	N_2O	CH_4
Slow speed main (Tier 0)	1999 and older	17.0	0.24	0.23	0.24	0.60	1.40	0.38	589	0.029	0.012
Slow speed main (Tier 1)	2000 to 2011	16.0	0.24	0.23	0.24	0.60	1.40	0.38	589	0.029	0.012
Slow speed main (Tier 2)	2011 to 2016	14.4	0.24	0.23	0.24	0.60	1.40	0.38	589	0.029	0.012
Medium speed main (Tier 0)	1999 and older	13.2	0.24	0.23	0.24	0.50	1.10	0.42	649	0.029	0.010
Medium speed main (Tier 1)	2000 to 2011	12.2	0.24	0.23	0.24	0.50	1.10	0.42	649	0.029	0.010
Medium speed main (Tier 2)	2011 to 2016	10.5	0.24	0.23	0.24	0.50	1.10	0.42	649	0.029	0.010
Gas turbine	All	5.7	0.01	0.01	0.00	0.10	0.20	0.60	922	0.075	0.002
Steam main engine and boiler	All	2.0	0.16	0.15	0.00	0.10	0.20	0.60	922	0.075	0.002

3.5.5 Propulsion Engines Low Load Emission Factors

In general terms, diesel-cycle engines are not as efficient when operated at low loads. An EPA study[12] prepared by Energy and Environmental Analysis, Inc. (EEAI) established a formula for calculating emission factors for low engine load conditions such as those encountered during harbor maneuvering and when traveling slowly at sea (e.g. in the reduced speed zone.) While mass emissions, pounds per hour, tend to go down as vessel speeds and engine loads decrease, the emission factors, g/kW-hr increase. This is based on observations that compression-cycle combustion engines are less efficient at low loads.

[12] EPA, *Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data,* February 2000

The following equations describe the low-load effect where emission rates can increase, based on a limited set of data from Lloyd's Maritime Program and the USCG. The low load effect was also described in a study conducted for the EPA by ENVIRON.[13] Equation 3.7 is the equation developed by EEAI to generate emission factors for the range of load factors from 2% to <20% for each pollutant:

Equation 3.7

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

Where:

y = emission factor, g/kW-hr
a = coefficient
b = intercept
x = exponent (negative)
fractional load = propulsion engine load factor (2% - <20%), derived by the Propeller Law, percent (see equation 3.3)

Table 3.6 presents the variables for equation 3.7.

Table 3.6: Low-Load Emission Factor Regression Equation Variables

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

[13] EPA, *Commercial Marine Inventory Development,* July 2002

Table 3.7 lists the low-load adjustment multipliers used for diesel propulsion engines. Adjustments to N_2O and CH_4 emission factors are made based on the NO_x and HC low load adjustments, respectively. The LLA adjustment is not applied at engine loads greater than 20%. For main engine loads below 20%, the LLA increases to reflect increased emissions on a g/kW-hr basis due to engine inefficiency. Low load emission factors do not apply to steamships or ships having gas turbines because the EPA study only observed an increase in emissions from diesel engines.

Table 3.7: Low Load Adjustment Multipliers for Emission Factors[14]

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

The LLA multipliers are applied to the at-sea emission factors for diesel propulsion engines only. The low load emission factor is calculated for each pollutant using Equation 3.8. In keeping with the emission estimating practice of assuming a minimum main engine load of 2%, the table of LLA factors does not include values for 1% load.

Equation 3.8

$$EF = Adjusted\ EF \times LLA$$

Where:

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

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

3.5.6 Propulsion Engine Power Rating

OGVs calling the Port were matched using the most current Lloyd's data to determine propulsion engine power ratings. For vessels missing propulsion engine power rating, vessel class specific average value was used.

3.5.7 Auxiliary Engine Emission Factors

The adjusted auxiliary engine emission factors using 0.1% S MGO, based on ENTEC 2002 and IVL 2004, are presented in Table 3.8. Vessel specific NO_x emission factors from EIAPP certificates collected from VBP data were utilized. Vessel that did not have EIAPP NO_x emission factors used the default NO_x emission factors. Similar to the propulsion engine emission factors, the 2.7% sulfur HFO base emission factors are multiplied by the appropriate pollutant FCF (see Table 3.3) to calculate the 0.1% S MGO emission factors. PM_{10} and SO_x emission factors are based on equations 3.5 and 3.6 described in earlier sections. In 2015, the auxiliary engines used 0.1% S fuel due to the ECA requirement.

Table 3.8: Emission Factors for Auxiliary Engines using 0.1% S MGO, g/kW-hr

Engine Category	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	DPM	HC	CO	SO_2	CO_2	N_2O	CH_4
Medium speed auxiliary (Tier 0)	1999 and older	13.8	0.24	0.23	0.24	0.4	1.1	0.44	686	0.029	0.008
Medium speed auxiliary (Tier 1)	2000 to 2011	12.2	0.24	0.23	0.24	0.4	1.1	0.44	686	0.029	0.008
Medium speed auxiliary (Tier 2)	2011 to 2016	10.5	0.24	0.23	0.24	0.4	1.1	0.44	686	0.029	0.008
High speed auxiliary (Tier 0)	1999 and older	10.9	0.24	0.23	0.24	0.4	0.9	0.44	656	0.029	0.008
High speed auxiliary (Tier 1)	2000 to 2011	9.8	0.24	0.23	0.24	0.4	0.9	0.44	656	0.029	0.008
High speed auxiliary (Tier 2)	2011 to 2016	7.7	0.24	0.23	0.24	0.4	0.9	0.44	656	0.029	0.008

3.5.8 Auxiliary Engine Load Defaults

The primary data source for auxiliary load data is from the greater VBP program where vessels are boarded at various ports and data is collected on vessel operations by mode. Vessel data for sister-ships of the boarded vessels are also collected and utilized. VBP operational data is important for auxiliary engine emission estimates because the Lloyd's database contains very limited installed power information for auxiliary engines and no information on use by mode. VBP data relating to auxiliary engine use is acquired by vessel type, emission source, and by mode of operation. When estimating auxiliary engine emissions, VBP operational data is first applied on a vessel by vessel basis if the vessel was boarded or it is a sister-ship to a boarded vessel. If the vessel is not in the VBP data, average auxiliary engine load defaults are derived from the VBP data and applied by vessel type. For certain vessel types, if the VBP data was limited or not found, auxiliary engine default loads from the Port of Long Beach's 2015 Emissions Inventory, which was also based on VBP data, was utilized. The fleet mix that called the Port in 2015 was compared to other ports and it was determined that the Port of Long Beach default loads would be suitable surrogates when VBP data is not available. Table 3.9 summarizes the auxiliary engine load defaults by mode used for this study by vessel subtype.

Table 3.9: Average Auxiliary Engine Load Defaults, kW

Vessel Type	Maneuvering	Berth Hotelling	Anchorage Hotelling
Auto carrier	2,391	1,284	1,079
Bulk	822	210	313
Bulk - heavy load	1,223	272	462
Container - 1000	2,245	720	839
Container - 2000	2,372	1,039	1,036
Container - 3000	2,562	641	694
Container - 4000	2,472	1,136	1,270
Container - 5000	4,487	1,107	1,220
Container - 6000	2,624	938	886
Container - 9000	2,323	924	1,191
General cargo	1,060	572	421
Miscellaneous	1,260	467	793
RoRo	396	229	132
Tanker - handysize	768	605	559
Tanker - panamax	801	679	596
Tanker - suezmax	1,288	2,509	860
Tanker - chemical	771	1,057	570

Since vessels operating in the coastal zone were considered to be in restricted waters, there were no transit engine loads applied in this inventory, and it was assumed that all vessels operated under maneuvering auxiliary engine loads when moving within the inventory geographical domain.

Cruise ships typically have one of two configurations. The most common is 'full' diesel-electric in which all the power for the ship's propulsion and auxiliary usage comes from a common set of diesel-electric generators. The other type is where dedicated propulsion engines are used for propulsion power in a geared or direct drive configuration and the auxiliary diesel-electric engines are used only for auxiliary functions (house loads). Most cruise ships calling the Port are full diesel electric configured cruise ships.

The auxiliary engine load defaults for cruise ships were derived from VBP data and interviews with the cruise vessel industry contacts. The cruise defaults, by mode, vary based on passenger capacity ranges. Cruise ship auxiliary assumptions by mode are presented in Table 3.10.

Table 3.10: Cruise Ship Average Auxiliary Engine Load Defaults, kW

Passenger Range	Maneuvering	Hotelling
0-1,499	4,000	3,000
1,500-1,999	8,000	6,500
2,000-2,499	11,500	9,500
2,500-2,999	12,000	10,000
3,000-3,499	13,000	10,500
3,500-3,999	13,500	11,000
4,000-4,499	14,000	12,000
4,500-4,999	14,500	13,000
5,000-5,499	15,500	13,500
5,500-5,999	16,000	14,000
6,000-6,499	16,500	14,500
6,500+	17,000	15,000

The hotel auxiliary load assumptions are intended to be conservative and are based on VBP data. The maneuvering auxiliary load assumptions were calculated by increasing the hoteling load by amounts that vary by passenger capacity range: 1,000 kWs for 0-1,499 passengers, 1,500 kW for 1,500-3,999 passengers, and 2,000 kW for vessels in the 4,000+ passenger range. Similar to the hoteling assumptions, these are intended to be conservative and cover the additional power needs associated with the fore and aft thrusters for the cruise ships, as they typically do not use tugs to arrive or depart the berth.

3.5.9 Auxiliary Boiler Emission Factors and Load Defaults

In addition to the auxiliary engines that are used to generate electricity for on-board uses, most OGVs have one or more boilers used for fuel heating and for producing hot water and steam. Table 3.11 shows the adjusted emission factors used for the auxiliary boilers based on ENTEC 2002 and IVL 2004 studies. Similar to the propulsion and auxiliary engine emission factors, the 2.7% sulfur HFO base emission factors are multiplied by the appropriate pollutant FCF (see Table 3.4) to calculate the 0.1% sulfur MGO emission factors.

Table 3.11: Emission Factors for Auxiliary Boilers using 0.1% S MGO, g/kW-hr

Engine Category	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	DPM	HC	CO	SO_2	CO_2	N_2O	CH_4
Steam main engine and boiler	All	2.0	0.16	0.15	0.00	0.1	0.2	0.60	922	0.075	0.002

The boiler fuel consumption data collected from vessels during the VBP was converted to equivalent kilowatts using specific fuel consumption (SFC) factors found in the ENTEC 2002 study. The average SFC value based on residual fuel is 305 grams of fuel per kW-hour. The average kW for auxiliary boilers was calculated using the following equation.

Equation 3.9

$$\boldsymbol{Average\ kW\ =\ ((daily\ fuel/24) \times 1,000,000)/305}$$

Where:

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

As with auxiliary engines, the primary source of load data is from the VBP, and direct values for vessels boarded are used on an individual basis for vessels boarded and their sister ships. There is no load data from the Lloyds database by mode. For vessels not boarded or vessels that did not have any sister vessels boarded through the VBP, average loads from Port of Long Beach 2015 Emissions Inventory were used as defaults.

Auxiliary boilers are not typically used when the main engine load is greater than approximately 20% due to heat recovery systems that are used to produce heat while the ship is underway. If the main engine load is less than or equal to 20%, the maneuvering boiler load defaults shown in the table are used. As discussed in section 3.5.8, no at-sea boiler loads have been applied in this inventory because it has been assumed that heat recovery systems provide needed heat while at sea. Auxiliary boiler energy defaults in kilowatts used for each vessel type are presented in Table 3.12.

Table 3.12: Auxiliary Boiler Load Defaults, kW

Vessel Type	Maneuvering	Berth Hotelling	Anchorage Hotelling
Auto Carrier	351	351	351
Bulk	132	132	132
Bulk - Heavy Load	132	132	132
Container - 1000	241	241	241
Container - 2000	325	325	325
Container - 3000	474	474	474
Container - 4000	492	492	492
Container - 5000	628	628	628
Container - 6000	600	600	600
Container - 9000	705	705	705
General Cargo	135	135	135
Miscellaneous	137	137	137
RoRo	243	243	243
Tanker - Handysize	371	2,586	371
Tanker - Panamax	371	3,293	371
Tanker - Suezmax	371	5,843	371
Tanker - Chemical	371	832	371

Full diesel electric cruise ships utilize scavenged heat (heat recovered from engine exhaust) to provide steam needed within the inventory boundary. The boilers in diesel electric cruise ships are therefore assumed to be off during hoteling and maneuvering modes.

3.6 OGV Emission Estimates

The emission estimates presented in this document are listed in various ways to provide as much information to the reader as possible. The emissions are presented by business line, vessel type, emission source, and operating mode. Due to rounding, not all of the totals in the tables may match.

Table 3.13: 2015 OGV Emissions by Business Line

Business Line	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Cargo	639	14	13	12	27	60	28	39,267
Cruise	1,072	21	20	21	35	95	39	55,258
Petroleum	290	9	8	5	12	28	22	31,616
Total	**2,001**	**44**	**41**	**38**	**73**	**183**	**88**	**126,141**

Table 3.14: 2015 OGV Emissions by Vessel Type

Vessel Type	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Auto Carrier	3	0.06	0.06	0.05	0.15	0.29	0.11	151
Bulk	36	0.87	0.81	0.66	1.36	3.34	1.94	2,767
Containership	450	9.89	9.29	8.44	20.70	44.12	19.03	27,163
Cruise	1,072	21.29	20.00	21.16	34.93	95.32	38.85	55,258
General Cargo	139	2.86	2.68	2.51	4.41	11.74	5.83	8,309
Miscellaneous	7	0.14	0.13	0.12	0.20	0.55	0.29	409
RoRo	5	0.13	0.12	0.08	0.17	0.41	0.33	468
Tanker	290	8.51	7.99	4.93	11.53	27.63	22.08	31,616
Total	**2,001**	**43.73**	**41.07**	**37.95**	**73.44**	**183.40**	**88.45**	**126,141**

Table 3.15: 2015 OGV Emissions by Emission Source Type

Emission Source	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Main Engines	135	2.71	2.55	2.70	12.20	17.71	2.85	4,082
Auxiliary Engines	1,793	35.24	33.11	35.24	57.59	158.37	63.82	90,745
Boilers	72	5.78	5.41	0.00	3.66	7.31	21.78	31,314
Total	**2,001**	**43.73**	**41.07**	**37.95**	**73.44**	**183.40**	**88.45**	**126,141**

Table 3.16: 2015 OGV Emissions by Operating Mode

Operating Mode	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Hotelling, Berth	1,526	33.86	31.79	28.76	50.22	135.68	71.29	101,674
Hotelling, Anchorage	94	2.21	2.07	1.73	3.13	8.38	4.93	7,036
Maneuvering	381	7.67	7.21	7.46	20.09	39.34	12.23	17,431
Total	**2,001**	**43.73**	**41.07**	**37.95**	**73.44**	**183.40**	**88.45**	**126,141**

SECTION 4 HARBOR CRAFT

This section presenting emission estimates for the harbor vessels source category is organized into the following subsections: source description (4.1), data and information acquisition (4.2), emissions estimation methodology (4.3), and harbor craft emission estimates (4.4).

4.1 Source Description

Emissions from the following types of diesel-fueled harbor craft were quantified:

- **Assist tug** – The main task for these tugs is to assist and escort the marine vessels that call at the Port. The tugs may provide other towing work when not assisting and escorting arriving or departing vessels.
- **Articulated tug barge (ATB)** – ATBs consist of tank barges coupled with high-horsepower tugs.
- **Pilot boat** – The pilot boats are used to take or pick up pilots to the ocean-going vessels approximately 3-4 nm from the coastline.
- **Towboat** – Towboats include self-propelled ocean tugs, pushboats, and towboats that tow/push barges. They can be used to move bulk liquids, scrap metal, bulk materials, rock, sand, and other materials. The towboat category in this study also includes tugboats, such as an inland vessel supply tugboat.
- **Yacht** – Yacht activity is a significant business at Port Everglades and thus included in this emissions inventory. Only those yachts that stopped at a berth (i.e. called the Port) are included in this emissions inventory.

The geographical domain for harbor craft is the same as for the ocean-going vessels (see Section 3.2). This section includes activity and emissions for harbor craft that called the port or worked at the Port in 2015. Activity and emissions for transitory marine traffic through the Atlantic Intracoastal Waterway is included in Appendix A of this report.

Figures 4.1 through 4.5 shows the various harbor craft. The images shown in the figures may not be photographs of actual harbor craft while at the Port, but are for illustrative purposes only.

Figure 4.1: Assist Tug

Figure 4.2: Articulated Tug Barge

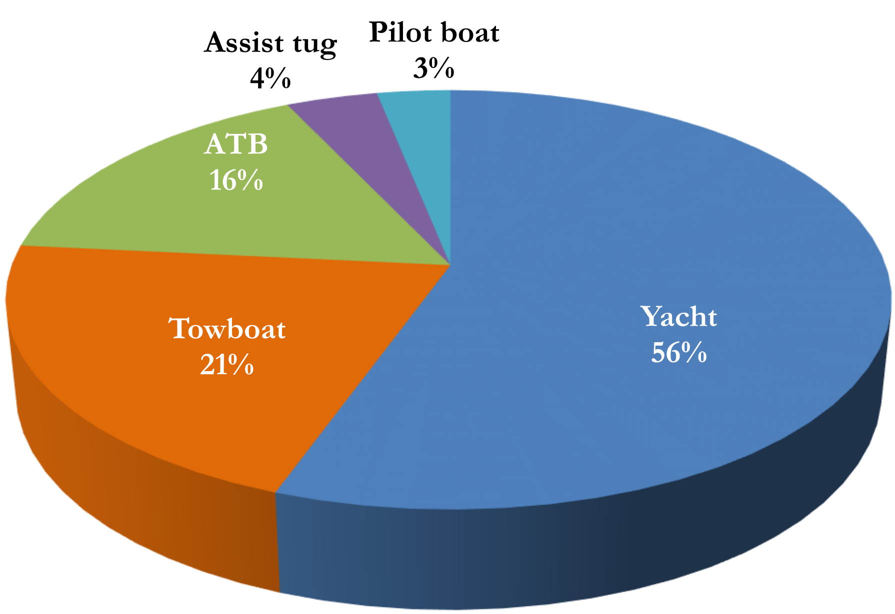
Figure 4.3: Pilot Boat

Figure 4.4: Towboat

Figure 4.5: Yacht

Figure 4.6 presents the distribution of the 100 harbor craft that called or worked within the study area in 2015. The vessel count is per discrete vessel and not for numerous trips they may have made throughout the year. The Fort Lauderdale area is called "the yachting capital of the world" and yachts are often hauled across the Atlantic to the area's boatyards for maintenance and repairs between cruising seasons. Many yachts are shipped in and out of the Port Everglades annually. The yachts included in this inventory arrived or departed from a Port Everglades berth.

Figure 4.6: 2015 Distribution of Discrete Vessel Count for Harbor Craft



4.2 Data and Information Acquisition

The operational hours and engine characteristics data for assist tugs and pilot boats was acquired by contacting individual entities/companies and they in turn provided annual hours of use and engine characteristics for each vessel. Tables 4.1 and 4.2 summarize the characteristics of propulsion and auxiliary engines respectively, by vessel type for vessels that worked and/or called the Port in 2015. For some assist tugs, hours of operations were not available. To estimate emissions, average operating hours shown in tables 4.1 and 4.2 were used as defaults.

For ATBs, towboats and yachts, AIS data was used to identify activity (hours) in three zones by Maritime Mobile Service Identity (MMSI) numbers. The three zones are defined as at berth, maneuvering, and in the coastal zone.

- At berth - Hours in this zone were assumed for one auxiliary engine.
- Maneuvering - Hours in this zone were assumed for one auxiliary engine and total installed propulsion engine horsepower.
- Coastal zone - Hours in this zone were assumed for one auxiliary engine and total installed propulsion engine horsepower.

The domestic vessel AIS data was compared against call data received from the port and the data was divided into harbor craft that made calls to the port and those that were in transit. The emissions and activity for the harbor craft that called the port in 2015 are included in this section. For transitory marine traffic emissions, please see Appendix A.

For ATBs, towboats, and yachts, a combination of AIS data for activity and Lloyd's data and website searches for engine information were used. For vessel and engine information, activity data by IMO number was joined with Lloyd's data to determine vessel keel laid date which represented vessel model year and engine horsepower. Lloyd's data provided number and total installed propulsion engine horsepower for the vessel. Total propulsion horsepower was divided by number of engines and assigned to each propulsion engine. The auxiliary engine horsepower, for majority of the engines, was not available through Lloyd's data. This information was obtained for several vessels via various towboat operators website. Averages within each vessel type were used where no data was available. For ATBs, towboats, and yachts, the vessel model year was used as a surrogate for engine year for lack of specific information on whether these vessels had been repowered. Therefore, the emission results will be conservative since some vessels may have replaced old engines with new ones, but the original engine is being used to estimate emissions.

Table 4.1: 2015 Propulsion Engine Characteristics by Harbor Craft Type

Harbor craft	Model year			Horsepower			Annual operating hours		
Type	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Assist tug	1995	2014	2001	2,000	3,000	2,365	1,850	1,900	1,875
ATB	1971	2009	1999	1,923	8,046	4,604	0	54	14
Pilot boat	2010	2014	2011	500	650	620	744	3,202	1,707
Towboat	1961	2007	1980	662	3,386	2,111	1	71	12
Yacht	1957	2014	2001	497	4,920	1,592	0	56	7

Table 4.2: 2015 Auxiliary Engine Characteristics by Harbor Craft Type

Harbor craft	Model year			Horsepower			Annual operating hours		
Type	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Assist tug	1995	2014	2001	98	133	119	1,800	1,900	1,850
ATB	1971	2009	1999	100	144	129	0	1,065	253
Pilot boat	na	na	na	na	na	na	na	na	na
Towboat	1961	2007	1980	40	201	113	1	5,971	339
Yacht	1957	2014	2001	7	575	214	4	809	59

4.3 Emission Estimation Methodology

The basic equation used to estimate harbor craft emissions for all vessel types is:

Equation 4.1

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

Where:

E = emissions, grams or tons or tonnes /year
Power = rated power of the engine, hp or kW
Activity = engine operating time, hr/year
LF = load factor (ratio of average load used during normal operations as compared to full load at maximum rated horsepower, it is an estimate of the average percentage of an engine's rated power output that is required to perform its operating tasks), dimensionless
EF = emission factor, grams of pollutant per unit of work, g/hp-hr or g/kW-hr
FCF = fuel correction factor, dimensionless

Table 4.3 summarizes the annual average engine load factors that were used in this inventory and the source.

Table 4.3: Load Factors

Harbor Vessel Type	Propulsion Engine	Source	Auxiliary Engine	Source
Assist tug	0.31	2001 POLA EI[15]	0.43	EPA NONROAD[16]
ATB	0.68	Same as towboat	0.43	EPA NONROAD
Pilot boat	0.51	CARB[17]	0.43	EPA NONROAD
Towboat	0.68	CARB	0.43	EPA NONROAD
Yacht	0.35	EPA MOVES2014a	0.35	EPA MOVES2014a

Harbor craft engines, except yachts, with known model year and horsepower are categorized by EPA marine engine standards. Engine information gathered from harbor craft operators or websites does not usually identify the specific EPA certification standards or "tier" level, thus, the tier level is assumed for the engines based on the model year and horsepower.[18]

In 2015, all of the harbor vessels used ULSD fuel. Fuel correction factors are applied to reflect the effect of change in fuel formulation on emissions when the actual fuel used in the emissions inventory year is different than the fuel used to develop the emission factors. Table 4.4 summarizes the fuel correction factors used.

Table 4.4: Fuel Correction Factors

Fuel and Engine Type	NO_x	PM	VOC	CO	SO_2	CO_2	N_2O	CH_4
ULSD, Tier 0-2	1.0	0.86	1.0	1.0	0.005	1.0	1.0	1.0
ULSD, Tier 3	1.0	1.00	1.0	1.0	0.005	1.0	1.0	1.0

The emission factors for all harbor craft, except yachts, used for this study are listed in Table 4.5 for diesel-fueled main propulsion and auxiliary engines. Please note that the fuel correction factors have not been applied yet to the emission factors listed. Emissions from engines equipped in yachts are governed by EPA's "Recreational Marine Diesel Emission Standards"[19] and are included in NONROAD module of EPA's MOVES2014a model. MOVES2014a was run to obtain yacht emission rates by hp for each pollutant.

[15] POLA, Baseline Air Emissions Inventory 2001, July 2005, *www.portoflosangeles.org/DOC/REPORT_Final_BAEI.pdf*
[16] EPA, *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling*, EPA 420-P-02-014.
[17] CARB, Carl Moyer Program Guidelines, Part IV, 17 Nov 2005.
[18] CFR (Code of Federal Regulation), 40 CFR, subpart 94.8 for Tier 1 and 2 and subpart 1042.101 for Tier 3.
[19] EPA, Emission Standards for New Nonroad Engines, *www3.epa.gov/nonroad/2002/f02037.pdf.*

Table 4.5: Harbor Craft (Except Yachts) Emission Factors for Diesel Engines, g/kW-hr

kW Range	Year Range	NO_x	PM	VOC	CO	SO_2	CO_2	N_2O	CH_4
Tier 0 engines									
0 to 8	<2000	10.23	1.00	0.27	8.0	1.3	690	0.031	0.01
8 to 19	<2000	9.23	0.80	0.27	6.6	1.3	690	0.031	0.01
19 to 37	<1999	9.23	0.80	0.27	6.6	1.3	690	0.031	0.01
37 to 76	<2000	10.0	0.40	0.27	1.7	1.3	690	0.031	0.01
76 to 131	<2000	10.0	0.40	0.27	1.5	1.3	690	0.031	0.01
131 to 1,001	<2000	10.0	0.30	0.27	1.5	1.3	690	0.031	0.01
1,000+	<2000	13.0	0.30	0.27	2.5	1.3	690	0.031	0.01
Cat 2 Engines	<2000	13.2	0.72	0.50	1.1	1.3	690	0.031	0.01
Tier 1 engines									
0 to 8	2000-2005	10.23	0.90	0.27	2.0	1.3	690	0.031	0.01
8 to 19	2000-2005	9.23	0.80	0.27	2.0	1.3	690	0.031	0.01
19 to 37	2000-2004	9.23	0.80	0.27	2.0	1.3	690	0.031	0.01
37 to 76	2000-2004	9.8	0.40	0.27	1.7	1.3	690	0.031	0.01
76 to 131	2000-2004	9.8	0.40	0.27	1.5	1.3	690	0.031	0.01
131 to 1,001	2000-2004	9.8	0.30	0.27	1.5	1.3	690	0.031	0.01
1,000+	2000-2007	9.8	0.30	0.27	2.5	1.3	690	0.031	0.01
Cat 2 Engines	2000-2007	9.8	0.72	0.50	1.1	1.3	690	0.031	0.01
Tier 2 engines									
0 to 8	2005-2009	7.3	0.80	0.20	5.0	1.3	690	0.031	0.01
8 to 19	2005-2009	7.3	0.80	0.20	5.0	1.3	690	0.031	0.01
19 to 37	2004-2009	7.3	0.60	0.20	5.0	1.3	690	0.031	0.01
131 to 1,001	2004-2013	7.0	0.20	0.20	5.0	1.3	690	0.031	0.01
1,000+	2007-2013	7.0	0.20	0.20	5.0	1.3	690	0.031	0.01
Cat 2, <3,300	2007-2013	8.2	0.50	0.50	5.0	1.3	690	0.031	0.01
Cat 2, >3,300	2007-2013	9.3	0.50	0.50	5.0	1.3	690	0.031	0.01
Tier 3 engines									
0 to 8	2009+	7.3	0.40	0.20	5.0	1.3	690	0.031	0.01
8 to 19	2009+	7.3	0.40	0.20	5.0	1.3	690	0.031	0.01
19 to 37	2009+	7.3	0.30	0.20	5.0	1.3	690	0.031	0.01
37 to 76	2013+	7.3	0.30	0.20	5.0	1.3	690	0.031	0.01
76 to 1,001	2013+	5.2	0.12	0.20	5.0	1.3	690	0.031	0.01
1,000+	2013+	7.3	0.14	0.20	5.0	1.3	690	0.031	0.01
Cat 2, <3,300	2013+	7.3	0.14	0.50	5.0	1.3	690	0.031	0.01

The sources for the harbor craft emission factors are as follows:

- For NO_x and PM, 73FR 37243, June 30, 2008, as amended at 75 FR 23012, April 30, 2010[20]
- MARPOL for Category 2 Tier 1 NO_x[21]
- EPA 1999 RIA for criteria pollutants[22]
- ENTEC 2002 for CO_2[23]
- IVL 2004 for N_2O and CH_4[24]
- 40 CFR Part 94; Table 1 of 1042.101 for Tier 3 criteria pollutant EF[25]

4.4 Harbor Craft Emission Estimates

Table 4.6 presents the emissions for harbor craft that called or worked at the Port in 2015. For transitory marine traffic emissions, please see Appendix A.

Table 4.6: 2015 Emissions from Harbor Craft that Called the Port

Vessel type	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Assist tug	131	3.60	3.31	3.60	5.25	49.14	0.08	7,713
ATB	17	0.44	0.41	0.44	0.51	7.45	0.01	1,177
Pilot boat	15	0.36	0.33	0.36	0.48	11.40	0.01	1,446
Towboat	11	0.32	0.29	0.32	0.33	2.80	0.01	597
Yacht	11	0.34	0.33	0.34	0.50	1.94	0.01	900
Total	**184**	**5.06**	**4.67**	**5.06**	**7.07**	**72.73**	**0.12**	**11,834**

[20] Control of Emissions of Air Pollution from New CI Marine Engines at or above 37 kW, 40 CFR Parts 89, 92, 64 FR 64 73300-73373, 29 Dec 1999

[21] See: *www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Air-Pollution.aspx*

[22] Final Regulatory Impact Analysis: Control of Emissions from Marine Diesel Engines; EPA420-R-99-026, November 1999

[23] Entec, UK Limited, Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community, Final Report, July 2002. Prepared for the European Commission.

[24] IVL, Methodology for Calculating Emissions from Ships: Update on Emission Factors," February 2004. Prepared by IVL Swedish Environmental Research Institute for the Swedish Environmental Protection Agency. (IVL 2004)

[25] See: *www.ecfr.gov,* Title 40, Part 1042, Control of Emissions from New and In-use Nonroad Compression-ignition Engines.

SECTION 5 NON-ROAD CARGO HANDLING EQUIPMENT

This section includes emission estimates for non-road cargo handling equipment, a term used for equipment that moves cargo, passenger luggage, products, and supplies, material handling equipment, and other equipment that is essential to port facility operations. This section is organized into the following subsections: source description (5.1), data and information acquisition (5.2), emissions estimation methodology (5.3), and the cargo handling equipment emission estimates (5.4).

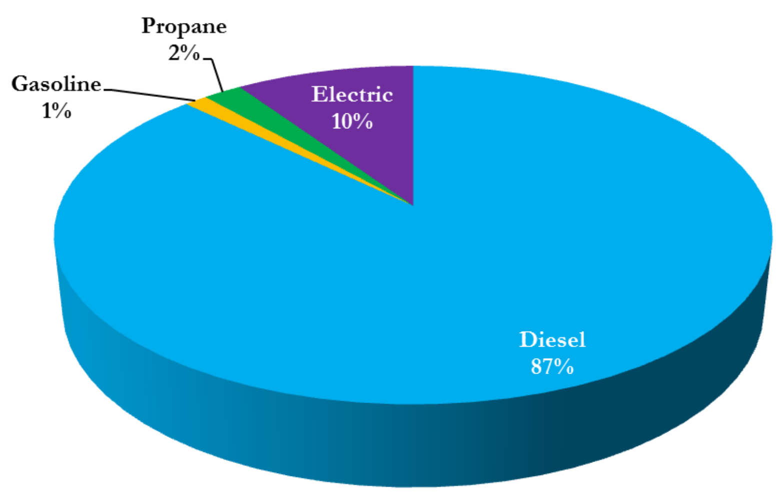
5.1 Source Description

The following types of equipment were inventoried:

- Forklift
- Yard tractor
- Top loader
- Scissor lift
- Crane
- Sweeper
- Loader
- Manlift
- Aerial lift and boom lift
- Truck
- Power pack
- Reach stacker
- RTG crane
- Excavator

Out of the 485 pieces of equipment inventoried, 87% are diesel, 10% are electric, 2% are propane and 1% is gasoline. Electric equipment is included in the count to show that there is electric equipment used within the Port boundary, but there are no emissions associated with electric equipment in this section.

Figure 5.1: 2015 Distribution of Equipment Engine Type



5.2 Data and Information Acquisition

The maintenance and/or equipment operating staff of each terminal/facility were contacted to obtain equipment count, engine characteristics, and activity information on the equipment specific to their terminal or facility operations for the 2015 calendar year.

Due to confidentiality reasons, one terminal chose not to provide data. The Port staff helped the data collector make assumptions for that particular terminal's equipment based on their knowledge of operations. Another similar terminal's equipment list was used as a default and the hours were pro-rated based on the two terminals throughput.

Since this was the first inventory conducted at Port Everglades, most of the facilities had equipment lists, but not all of the data fields requested. For example, some knew equipment and/or engine make and model, but not horsepower. Most provided average hours of operation for the year, but not actual hours since they do not normally keep actual hours in a log where it would be easy to calculate the actual annual hours for a given year.

For the equipment with unknown engine horsepower, additional research was done by the data collector prior to completing data collection. For forklifts and yard tractors, which make up the majority of the equipment for this study, the engine horsepower was included using the following techniques:

- For forklifts, the horsepower was estimated based on engine type, engine make and model, and/or lift capacity provided. For those forklifts that lacked sufficient data to estimate horsepower, it was left blank and defaults were used to estimate emissions.
- For yard tractors, if the make/model was known, the horsepower was included based on the company web search.

There are several equipment types in this inventory that only have one piece of equipment with an unknown horsepower. These equipment types were researched and an assumed horsepower was included from other port inventories or from engine specifications found on manufacturers' websites.

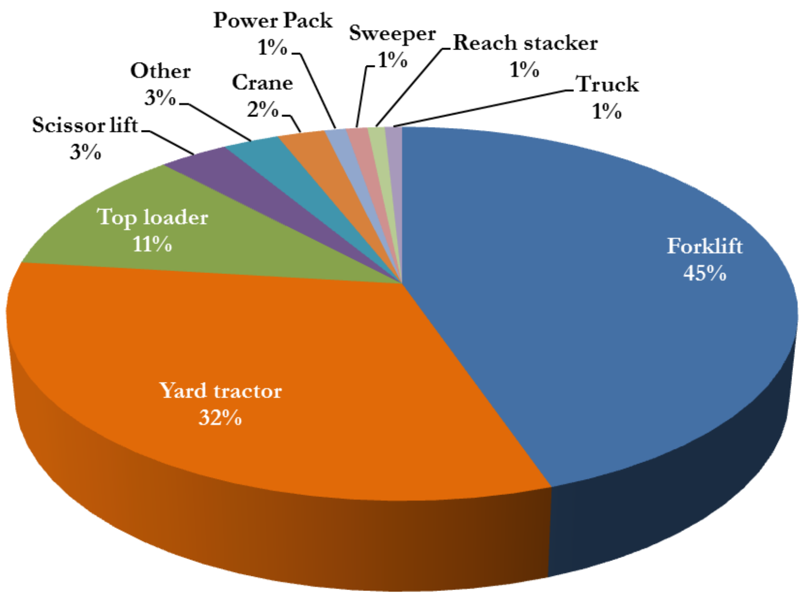
Table 5.1 summarizes the engine characteristics and operating hours of yard equipment operating at the Port in 2015. Averages of the model year, horsepower, or operating hours are used as default values when equipment specific data is not available. The "na" in the tables means that data was not available at time of data collection. Electric equipment does not have emissions associated with it, but are included in the count.

Table 5.1: 2015 Equipment Characteristics

Equipment	Engine Type	Count	Model Year Average	Horsepower Average	Annual Hours Average
Aerial lift	Diesel	3	2003	147	300
Crane	Diesel	4	2009	2,013	1,433
Empty container handler	Diesel	2	2006	155	na
Excavator	Diesel	1	2008	370	300
Forklift	Diesel	177	2006	76	659
Loader	Diesel	1	2007	290	300
Manlift	Diesel	1	na	78	300
Power pack	Diesel	5	1996	458	3,600
Reach stacker	Diesel	4	2012	365	1,650
RTG crane	Diesel	3	2014	300	2,000
Scissor lift	Diesel	4	2003	30	300
Skid steer loader	Diesel	1	1997	68	300
Sweeper	Diesel	3	2010	74	300
Top loader	Diesel	54	2003	331	1,972
Truck	Diesel	4	2011	150	288
Yard tractor	Diesel	156	2003	175	1,333
Forklift	Gasoline	4	1994	54	900
Sweeper	Gasoline	2	na	74	300
Forklift	Propane	10	2004	54	352
Forklift	Electric	26	na	na	na
Scissor lift	Electric	12	na	na	na
Boom lift	Electric	1	na	na	na
Crane	Electric	7	na	na	na
Total		**485**			

Figure 5.2 presents the distribution of the 485 equipment inventoried for the Port in 2015, including 46 pieces of electric equipment. The "other" category in the figure includes: aerial lift, RTG crane, empty container handler, excavator, loader, manlift, skid steer loader, and boom lift.

Figure 5.2: 2015 Distribution of Equipment Count



5.3 Emission Estimation Methodology

Emissions were estimated using the MOVES2014a emission estimating model.[26] The MOVES2014a model newly incorporates the functions of the NONROAD2008 model that was the standard stand-alone emissions estimating model for non-road equipment for many years. These models have been designed to accommodate a wide range of off-road equipment types and recognize a defined list of equipment designations. The pieces of terminal equipment were matched with equipment types recognized by the model.

The equipment identified by survey was categorized into the most closely corresponding MOVES2014a/NONROAD equipment type, as illustrated in Table 5.2, which presents equipment types by Source Classification Code (SCC), load factor, and MOVES2014/NONROAD category common name.

[26] See: *www.epa.gov/otaq/models/moves/*

The general form of the equation used for estimating equipment emissions is:

Equation 5.1

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

Where:

E = emissions, grams or tons or tonnes/year
Power = rated power of the engine, hp or kW
Activity = equipment's engine operating time, hr/year
LF = load factor (ratio of average load used during normal operations as compared to full load at maximum rated horsepower, it is an estimate of the average percentage of an engine's rated power output that is required to perform its operating tasks), dimensionless
EF = emission factor obtained by running the NONROAD module of MOVES2014a for CY 2015, grams of pollutant per unit of work, g/hp-hr or g/kW-hr

For each calendar year, MOVES2014/NONROAD can be run by state/county to output emissions factors in grams/hp-hr by fuel type, equipment types, by horse power groups and model year. These emission factors represent the average emissions in grams/hp-hr that takes into account the characteristic of the non-road fuel available in that year and the change in engine emission (in general increase in emissions) as the engine parts get older and less efficient. The horse power groups are aligned with EPA's non-road equipment emissions standards.

Per equation 5.1 above, CHE emissions in tons per year from each piece of equipment were calculated using model year, horsepower rating, annual hours of operation information collected for 2015 port operation, equipment-specific load factor assumptions described above and MOVES2014/NONROAD emission factors output.

MOVES2014a/NONROAD was run with default conditions to obtain emission factors in grams/hp-hr. ULSD fuel with a sulfur content of 15 ppm was used for diesel equipment operated in 2015.

Table 5.2: MOVES2014a/NONROAD Engine Source Categories

Equipment Type	Engine Type	SCC	Load Factor	NONROAD Category
Aerial lift	Diesel	2270003010	0.21	Aerial lift
Crane	Diesel	2270003010	0.21	Crane
Excavator	Diesel	2270002036	0.59	Excavator
Empty container handler	Diesel	2270003040	0.43	General industrial equipment
Forklift	Diesel	2270003020	0.59	Forklift
Forklift	Gasoline	2265003020	0.30	Forklift
Forklift	Propane	2267003020	0.30	Forklift
Manlift	Diesel	2270003010	0.21	Aerial lift
Power pack	Diesel	2270006005	0.43	Generator
Skid-steer loader	Diesel	2270002072	0.21	Skid-steer loader
Sweeper	Diesel	2270003030	0.43	Sweeper / scrubber
Sweeper	Gasoline	2265003030	0.43	Sweeper / scrubber
Top loader, reach stacker	Diesel	2270003040	0.43	General industrial equipment
Trucks, fuel truck	Diesel	2270002051	0.59	Off-highway trucks
RTG crane	Diesel	2270003050	0.21	Other material handling equipment
Loader	Diesel	2270003040	0.21	Tractors/Loaders/Backhoes
Tractor	Diesel	2270003070	0.59*	Terminal tractor

* Note:
Using a load factor of 0.39 for yard tractors based on San Pedro Bay Ports Yard Tractor Load Factor Study[27]

The MOVES2014/NONROAD model assumes a load factor for each NONROAD piece of equipment as listed in Table 5.2. Except for yard tractors, load factors for all other equipment were obtained from MOVES2014/NONROAD. For yard tractors, a load factor of 0.39 is used based on a 2008 study[28] prepared for the Port of Los Angeles and Port of Long Beach by Starcrest Consulting Group., LLC. This load factor is the most current and appropriate load factor representing diesel yard tractors operating at port terminals. MOVES2014/NONROAD uses a load factor of 0.59 for yard hustlers based on a 1997 study prepared for the EPA.

[27] EPA, Evaluation of Power Systems Research (PSR) Nonroad Population Data Base, 1997.
[28] Ports of Los Angeles and Long Beach, San Pedro Bay Ports Yard Tractor Load Factor Study, December 2008.

5.4 Emission Estimates

Table 5.3 presents the estimated equipment emissions for 2015.

Table 5.3: 2015 Equipment Emissions

Equipment Type	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Aerial lift	0.16	0.02	0.02	0.02	0.03	0.12	0.00	17
Crane	13.72	0.70	0.68	0.70	1.07	4.89	0.02	2,654
Empty container handler	1.24	0.06	0.06	0.06	0.11	0.27	0.00	141
Excavator	0.19	0.02	0.02	0.02	0.01	0.10	0.00	35
Forklift	28.06	2.84	2.75	2.83	4.86	31.64	0.02	3,240
Loader	0.07	0.01	0.01	0.01	0.01	0.03	0.00	12
Manlift	0.03	0.00	0.00	0.00	0.01	0.03	0.00	3
Power pack	22.90	1.08	1.04	1.08	1.92	7.85	0.01	1,894
Reach stacker	1.28	0.04	0.04	0.04	0.19	0.29	0.00	554
RTG crane	0.12	0.00	0.00	0.00	0.06	0.08	0.00	239
Scissor lift	0.05	0.01	0.01	0.01	0.01	0.05	0.00	5
Skid steer loader	0.04	0.01	0.01	0.01	0.01	0.05	0.00	3
Sweeper	0.14	0.01	0.01	0.01	0.01	0.31	0.00	31
Top loader	74.01	2.67	2.59	2.67	4.30	18.43	0.06	8,106
Truck	0.26	0.04	0.03	0.04	0.02	0.13	0.00	55
Yard tractor	75.89	6.32	6.13	6.32	12.19	24.90	0.06	7,740
Total	**218.16**	**13.83**	**13.40**	**13.82**	**24.81**	**89.17**	**0.17**	**24,729**

SECTION 6 ON-ROAD VEHICLES

This section presents emission estimates for on-road vehicles associated with Port activity, which include the heavy-duty vehicle (HDV) emission source category and the light and medium-duty vehicles that transport passengers to and from the Port's extensive cruise facilities and that the Port operates on facilities within the Port. The section is organized into the following subsections: emission source description (6.1), data and information acquisition (6.2), emissions estimation methodology (6.3), and the on-road vehicles emission estimates (6.4).

6.1 Source Description

The vehicle types included in this inventory are heavy-duty trucks that move cargo, passenger vehicles that transport cruise passengers to and from the port, and passenger cars and light-duty trucks and vans owned by the Port and used on Port facilities.

Heavy-duty trucks move cargo to and from the terminals and facilities that serve as the bridge between land and sea transportation. They are primarily driven on the public roads on and near the port and on highways. The vehicles are usually not under the direct control of the ports, the terminals, or the shippers who use the terminals, but are usually either owner-operated or are components of a carrier fleet. The most common configuration of HDVs in maritime freight service is the articulated tractor-trailer (truck and semi-trailer) having five axles, including the trailer axles. Common trailer types in the study area include container trailer or chassis, built to accommodate standard-sized cargo containers, tankers, boxes, and flatbeds. As examples of typical HDVs, Figure 6.1 shows trucks waiting outside a terminal and Figure 6.2 shows a pair of tanker trucks at a loading facility. The images shown in the figures may not be photographs of actual pieces of equipment used at the surveyed terminals, but are for illustrative purposes only.

In addition to the heavy-duty on-road vehicles that serve the Port's terminals, Port roadways are used by passenger cars and medium-duty buses and vans to transport cruise passengers to and from the Port's cruise terminals. Like the HDVs, these vehicles are generally not associated with the Port or the cruise terminals but are largely privately owned cars and shuttle vehicles operated by area hotels, parking facilities, and other businesses that support the cruise industry. A third category of on-road vehicles included in the inventory consists of the light-duty vehicles such as passenger cars, pickup trucks, and vans owned and operated by the Port within the facilities on the Port. While tenants also own and operate vehicles of these types, not enough information on these vehicles was collected to support a meaningful estimate of emissions. Therefore, only Port-owned vehicles have been included in this inventory.

Figure 6.1: Trucks at Port Everglades

Figure 6.2: Liquid Tanker Trucks

6.2 Data and Information Acquisition

On-road vehicle emission estimates are based on the number of miles traveled within the Port, which is a function of the number of trips made to and from the Port's terminals and facilities and the distance traveled within the domain on each trip. The other major variable that contributes to the emission estimates is the range of model years of the vehicles making the trips, since emission standards cause newer vehicles to emit lower levels of some pollutants than earlier model year vehicles.

Information on the number of truck trips was obtained by contacting each facility directly and requesting information on whether their operations included truck traffic and, if so, how many truck visits they had during 2015. Truck visits were estimated for facilities that declined to provide specific numbers by averaging the number of trips from reporting terminals. The average distance traveled between the Port boundary and a terminal gate has been estimated to be one mile (meaning a two-mile round trip), using the aerial imaging provided by "Google Earth."[29] While not an exact measurement method, this provides a reasonable overall estimate of travel distances considering the variety of facility locations and potential routes to and from those locations, and the relatively short overall on-Port distances. Vehicle miles of travel (VMT) were calculated by multiplying the round trip distance by the number of trips.

In addition to VMT, another component of truck operations that results in on-Port emissions is idling in place, such as when waiting to unload or load cargo. The emission factors for on-road travel include idling that is incidental to routine driving, but idling for longer periods while stationary is not included. Truck engines can idle at low speed when waiting in line, for example, or at a higher speed when idling for extended periods and the engine power is needed to run heating or cooling for driver safety or comfort. Emission estimates have been made for low speed idling at the facilities to account for wait times on loading and unloading. The amount of on-site idling is difficult to determine since few, if any, locations monitor or record duration of idling or wait times. Information was requested of the facilities regarding the amount of time trucks were on site, including waiting to enter, time unloading and loading, and waiting to exit. They were also asked about idling practices and whether trucks are allowed to idle during the unloading/loading operation. In general, liquid terminals require trucks to be shut off during unloading/loading. The times reported by each facility were assumed to represent idling times except for the facilities that reported they require vehicles to be shut off. This is likely to over-estimate idling since trucks may, in fact, be shut off during some of the time they are on a facility. Table 6.1 summarizes the estimates of truck-related VMT and idling hours.

Table 6.1: Estimated 2015 HDV Vehicle Miles Traveled and Idling

Component of Operation	Miles/hours	
Short-term idle	533,224	hours
On-terminal	253,319	miles
On-road	2,133,400	miles

[29] See: *www.google.com/earth/*

Estimates of vehicle traffic to and from the cruise terminals in 2015 were made using information from a variety of sources including Port records on the numbers of cruise passengers, taxis and vans, and parking garage exits. A cruise passenger survey conducted in 2015 and cruise vessel call data for 2015 were also used to refine the estimates of cruise related traffic. The results of this analysis are summarized in Table 6.2, which lists the types of vehicles and the estimated number of trips made by each type.

Table 6.2: Estimated Cruise Traffic Trips

Vehicle type	Round trip counts
Personal vehicle	67,985
Rental car/ride share	40,494
Taxi	163,153
Hotel shuttle	139,031
Off-port parking shuttle	13,498
Shuttle van	8,987
Bus	26,996
Other/unknown	18,897
Estimated total 2015 round trips	**479,042**

For emissions modeling purposes, as described below, the personal vehicles (including no-parks), rental cars, and taxis were modeled as passenger cars, the three types of shuttle were modeled as light duty truck/vans, buses were modeled as transit buses, and the "other/unknown" category was modeled as light duty truck/vans.

The 105 Port-owned fleet vehicles for which information was provided traveled an estimated 370,597 miles in 2015, an average of 3,529 miles per vehicle.

6.3 Emission Estimation Methodology

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

Equation 6.1

$$E = EF \times Activity$$

Where:

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

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

The emission factors have been developed using the EPA model MOVES2014a, which estimates emissions and emission factors for on-road vehicles of all types. The MOVES2014a model is EPA's latest iteration in a series of on-road vehicle emission estimating models. The model can be run in such a way as to produce emission estimates for different vehicle types in a given county, and the estimated total number of miles driven in the county. These model outputs are used to calculate g/mile and g/hr emission factors that are used to estimate driving and idling emissions from a particular type of vehicle such as the trucks serving the Port terminals and the automobiles transporting cruise passengers to and from the cruise terminals.

The MOVES2014a model was run for Broward County using the model's own data related to average road speeds and distribution of vehicle model years. The emission factors estimated for "urban unrestricted access" roads were used to estimate on-road emissions. These represent driving on surface streets in urban areas and are generally the highest of the road type options (which are urban and rural restricted and unrestricted access for a total of four options). On-site low-speed emissions were modeled at 15 miles per hour. The model's design dictates that idling and speed-specific emissions are estimated for single hours rather than a one-year period, so the model was run for a January morning hour and a July afternoon hour to cover the range of typical temperature conditions, and the results of the two runs were averaged to estimate average hourly idling emissions. To take into account the seasonal nature of port traffic, the average for each type of vehicle was weighted to account for higher activity in winter months versus summer months. As noted above, the cruise terminal related vehicles were modeled as passenger cars, light duty truck/vans, and transit buses. The trucks were modeled as a weighted average of combination short-haul and combination long-haul trucks (weighted by the model's internal VMT data).

Table 6.3 lists the emission factors used to estimate on-road emissions for the various vehicle types, while Table 6.4 presents the emission factors used for on-terminal emission estimates for heavy-duty trucks and for Port-owned fleet vehicles.

Table 6.3: Emission Factors for On-Road Vehicle Operations

Vehicle Type	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_2	CO_2	N_2O	CH_4
	grams per mile									
Passenger car	0.479	0.005	0.005	0.000	0.437	4.750	0.009	453	0.004	0.007
Light truck	0.730	0.012	0.011	0.007	0.398	5.894	0.011	545	0.006	0.011
Transit bus	8.775	0.310	0.285	0.310	0.728	3.512	0.012	1,392	0.003	0.031
Combination truck	8.212	0.497	0.457	0.497	0.535	2.499	0.019	2,158	0.003	0.050

Table 6.4: Emission Factors for On-Site (On-terminal) Vehicle Operations

Activity Type	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_2	CO_2	N_2O	CH_4
	grams per mile or grams per hour									
Diesel combination trucks										
Short-term idle (g/hr)	50.25	4.31	3.96	4.31	6.36	16.69	0.066	8,450	0.000	0.519
On-terminal (g/mi)	11.35	0.74	0.68	0.74	0.83	3.56	0.022	2,691	0.000	0.081
Fleet vehicles on-terminal (g/mi)										
Passenger car	0.591	0.010	0.009	0.000	0.300	6.436	0.011	585	0.000	0.010
Light truck, gasoline	0.782	0.010	0.009	0.000	0.349	8.097	0.013	684	0.000	0.015
Light truck, diesel	3.150	0.180	0.166	0.180	0.620	5.311	0.008	956	0.000	0.029

6.4 Emission Estimates

The estimated emissions from heavy-duty trucks, cruise terminal-related vehicles, and Port-owned fleet vehicles are presented in Table 6.5. Since virtually all of the trucks involved with port-related transportation are diesel fueled, DPM is the same as PM_{10} for these vehicles. Almost all of the passenger cars and vans are gasoline powered so no DPM is reported for these vehicle categories.

Table 6.5: 2015 Estimated Emissions from Onroad Vehicles

Component of Operation	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Heavy-Duty Trucks								
Short-term idle	29.5	2.50	2.30	2.50	3.70	9.80	0.039	4,513
On-terminal	3.2	0.20	0.20	0.20	0.20	1.00	0.006	683
On-road	19.3	1.20	1.10	1.20	1.30	5.90	0.044	4,610
Subtotal	**52.0**	**3.90**	**3.60**	**3.90**	**5.20**	**16.70**	**0.089**	**9,805**
Cruise-Related Vehicles								
Passenger car	0.39	0.004	0.004	0.000	0.35	3.84	0.007	333
Light truck/van	0.39	0.010	0.010	0.000	0.21	3.16	0.006	267
Transit bus	0.71	0.020	0.020	0.020	0.06	0.28	0.001	101
Subtotal	**1.49**	**0.034**	**0.034**	**0.020**	**0.62**	**7.28**	**0.014**	**701**
Port-Owned Fleet Vehicles								
Passenger car	0.01	0.000	0.000	0.000	0.01	0.15	0.000	12
Light truck, gasoline	0.22	0.003	0.003	0.000	0.10	2.29	0.004	176
Light truck, diesel	0.32	0.018	0.017	0.018	0.06	0.54	0.001	89
Subtotal	**0.56**	**0.021**	**0.020**	**0.018**	**0.17**	**2.98**	**0.005**	**277**
Total	**54.05**	**3.96**	**3.65**	**3.94**	**5.99**	**26.96**	**0.108**	**10,783**

SECTION 7 RAIL LOCOMOTIVES

This section presenting emissions estimates for the railroad locomotives source category is organized into following subsections: source description (7.1), data and information acquisition (7.2), emissions estimation methodology (7.3), and the locomotive emission estimates (7.4).

7.1 Source Description

Rail service is provided to the Port by the Florida East Coast Railway (FECR) at the Intermodal Container Transfer Facility (ICTF) located in the southwestern portion of the Port. Opened in 2014, the ICTF is the starting point for international cargo destined for eastern U.S. markets by rail, and is the arrival point at the port for export cargo brought in from eastern U.S. origins. The facility also handles domestic cargo that arrives by rail for local delivery by truck or that is brought to the port by truck from local sources for rail shipment to eastern U.S. markets. The ICTF has 9,000 feet of processing track for building trains, 12,000 feet of storage track, and three rubber-tired gantry cranes (RTGs) for loading and unloading railcars.[30] FECR moves cargo between the Port and Jacksonville, FL where the railroad connects with CSX and Norfolk Southern, the railroad companies that service the eastern part of the U.S.

7.2 Data and Information Acquisition

FECR provided information on their locomotives and on typical operating characteristics within the port. The locomotives operated by FECR are 4,400 horsepower diesel locomotives meeting Tier 3 emission requirements and equipped with idling shutoff devices. They are used in sets of two to move trains between the Port and Jacksonville. The schedule is one northbound train and two southbound trains per day, each train remaining on port from four to six hours.

The Port provided container throughput information in terms of in-bound and outbound international and domestic containers on a monthly basis. A total of 53,202 international and 37,868 domestic containers were moved by rail through the ICTF in 2015, a total of 91,070 containers.

[30] ICTF information from: *www.porteverglades.net/expansion/ship-to-rail/*

7.3 Emission Estimation Methodology

The following text provides a description of the methods used to estimate emissions from locomotives operating within the Port.

While EPA's MOVES2014a model, as described in a preceding section, was used for estimating non-road equipment such as CHE, it does not estimate emissions from locomotives. Therefore, estimates of emissions from locomotives have been based on the horsepower-hours of work performed by locomotives operating in the inventory domain and on emission factors published by EPA.[31] The estimate of horsepower-hours uses the available information in the following steps:

1. Estimate the average number of containers per train (northbound and southbound) by dividing the annual number of containers in each direction by the annual number of trains.
2. Estimate the average number of double-stack platforms per train in each direction by dividing the number of containers per train by two containers per platform and multiplying by a "density factor" (assumed to be 80%) to account for platforms that do not contain two containers.
3. Estimate average train weights in each direction by combining the weights of two locomotives, the estimated number of platforms, and the estimated number of containers.
4. Estimate gross ton-miles (GTM) per year in each direction by multiplying the average train weights by the number of trains per year and the on-port travel distance (estimated to be 1.5 miles).
5. Estimate horsepower-hours in each direction by multiplying annual ton-miles by a fuel consumption factor (gallons per thousand ton-miles) derived from east coast railroads' annual reports to the U.S. Department of Transportation[32] and multiplying by brake-specific fuel consumption (BSFC) in units of horsepower-hours per gallon of fuel published by EPA in the previously cited document.

The results of these steps are summarized in the following tables. Table 7.1 lists 2015 domestic and international container throughput in each direction, the number of trains based on one per day northbound and two per day southbound, and the average number of containers per train.

Table 7.1: ICTF Container Throughput and Number of Containers per Train

Direction	Domestic	International	Total	Trains per year	Containers per train
Northbound (out)	24,909	24,351	49,260	365	135
Southbound (in)	12,959	28,851	41,810	730	57
Totals	**37,868**	**53,202**	**91,070**		

[31] EPA, *Emission Factors for Locomotives*: EPA-420-F-09-025, Office of Transportation and Air Quality, April 2009 and *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, April 2015

[32] Obtained from: *www.stb.dot.gov/stb/industry/econ_reports.html*

Table 7.2 presents the train make-up information and assumptions, train weight characteristics, and annual power estimates.

Table 7.2: Estimate of Running Horsepower-Hours

Characteristic		Northbound	Southbound
Train make-up		unit count	unit count
Locomotives per train		2	2
Avg containers/train		135	57
Containers/platform		2	2
Platforms per railcar		5	5
Average density		80%	80%
Platforms per train		85	36
Train weight	tons each	tons/train	tons/train
Locomotive	210	420	420
Platform	27	2,295	972
Container	14	1,889	802
Gross tons per train		4,604	2,194
Horsepower-hours			
Miles per trip	1.50		
Trains/year		365	730
Ton-miles/year		2,520,923	2,402,250
Gal/thousand GTM	1.12		
BSFC hp-hr/gal	20.80		
Annual hp-hr		**58,727**	**55,963**

In addition to the estimates of horsepower-hours from locomotives moving into and out of the Port, an activity component was added to estimate horsepower-hours (and emissions) from the locomotives as they idle during their time on the Port. Idling time is limited by the devices on the locomotives that shut off their engines after 15 minutes of idling, but idling occurs on arrival and at times during the port stay when the locomotives must be started to change location. For these calculations, it has been assumed that there is one 15-minute idling event every hour a train is on- port. In addition to the idling time, the estimate of idling horsepower-hours uses the locomotive horsepower (4,400 hp per locomotive) and a load factor assumption, which has been derived from data published by EPA in support of prior rule-making. The average idling load of the 17 locomotives for which data was provided was 0.4% (0.004). As a measure of being conservatively high, this was rounded up to 1.0% for the calculations.

Table 7.3 summarizes the data and assumptions used in estimating idling horsepower-hours, with the final calculation being idling hours per year multiplied by 4,400 horsepower and 0.01 (the 1% idling load factor assumption).

Table 7.3: Estimate of Idling Horsepower-Hours

Characteristic	Northbound	Southbound
Horsepower	4,400	4,400
Assumed idling load factor	1.0%	1.0%
Number of trains		
per day	1	2
per year	365	730
Locomotives per train	2	2
Time on port (max hours)	6	6
Idling time per event (hrs)	0.25	0.25
Number of events per train (assume 1 per hour)	6	6
Idling hours/year	1,095	2,190
Annual hp-hr	**48,180**	**96,360**

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

Equation 7.1

$$\boldsymbol{E} = \frac{\boldsymbol{Annual\ hp \cdot hr\ \times\ EF}}{\boldsymbol{(453.59\ g/lb \times 2,000\ lb/ton)}}$$

Where:

E = emissions, tons per year
Annual hp-hr = annual work, hp-hrs/yr
EF = emission factor, grams pollutant per horsepower-hour
(453.59 g/lb x 2,000 lb/ton) = tons per year conversion factor

A modification to this equation is used for the greenhouse gases in which the gram-per-tonne factor of 1,000,000 is used in place of (453.59 g/lb x 2,000 lb/ton). The result of this modification is the calculation of tonnes (metric tons) of emissions, the customary reporting units for greenhouse gases.

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

Equation 7.2

$$\frac{15\ g\ S}{1,000,000\ g\ fuel} \times \frac{3,200\ g\ fuel}{gal\ fuel} \times \frac{2\ g\ SO_2}{g\ S} \times \frac{gal\ fuel}{20.8\ hp\ hr} = 0.005\ g\ SO_2/hphr$$

In this calculation, 15 ppm S is written as 15 g S per million g of fuel. The value of 20.8 hp-hr/gallon of fuel is the average brake specific fuel consumption (BSFC) noted in EPA's technical literature on locomotive emission factors (EPA, 2009). Two grams of SO_2 is emitted for each gram of sulfur in the fuel because the atomic weight of sulfur is 32 while the molecular weight of SO_2 is 64, meaning that the mass of SO_2 is two times that of sulfur.

Greenhouse gas emission factors from EPA references[33] have been used to estimate emissions of the greenhouse gases CO_2, CH_4, and N_2O from locomotives. Additionally, all particulate emissions are assumed to be PM_{10} and DPM. $PM_{2.5}$ emissions have been estimated as 92% of PM_{10} emissions to be consistent with the $PM_{2.5}$ ratio used by MOVES in estimating $PM_{2.5}$ emissions from other types of nonroad engines.

Table 7.4 lists the emission factors, as g/hphr, used in calculating locomotive emissions. The emission factors in the row labelled "TIER 2+ & TIER 3" have been used to estimate emissions from the Tier 3 locomotives used by FECR. The hydrocarbon (HC) emission factor was converted to VOC using an EPA-published conversion factor of 1.053.[34]

Table 7.4: EPA Tier Level Emission Factors for Locomotives

Tier Level	PM_{10} g/hp-hr	HC g/hp-hr	NO_x g/hp-hr	CO g/hp-hr
Uncontrolled	0.32	0.48	13	1.28
Tier 0	0.32	0.48	8.6	1.28
Tier 0+	0.2	0.3	7.2	1.28
Tier 1	0.32	0.47	6.7	1.28
Tier 1+	0.2	0.29	6.7	1.28
Tier 2	0.18	0.26	4.95	1.28
Tier 2+ & Tier 3	0.08	0.13	4.95	1.28
Tier 4	0.015	0.04	1.00	1.28

[33] EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013,* April 2015

[34] Conversion Factors for Hydrocarbon Emission Components. EPA-420-R-10-015 NR-002d July 2010

Table 7.5 lists emission factors used for all pollutants, in grams per horsepower hour.

Table 7.5: Summary of Locomotive Emission Factors

Units	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_2	CO_2	N_2O	CH_4
g/hp-hr	4.95	0.08	0.07	0.08	0.14	1.28	0.005	494	0.013	0.040

7.4 Emission Estimates

The estimated running and idling emissions are presented in Table 7.6. Since locomotives are diesel fueled, DPM is the same as PM_{10}. With rounding, the $PM_{2.5}$ is also the same as PM_{10}.

Table 7.6: 2015 Estimated Emissions from Locomotives

Activity Component	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	VOC tons	CO tons	SO_2 tons	CO_2e tonnes
Running	0.63	0.01	0.01	0.01	0.02	0.16	0.0006	57
Idling	0.79	0.01	0.01	0.01	0.02	0.20	0.0008	79
Total	1.42	0.02	0.02	0.02	0.04	0.36	0.0014	136

SECTION 8 ELECTRICAL POWER CONSUMPTION

This section presenting emissions estimates for the electrical power consumption is organized into following subsections: source description (8.1), data and information acquisition (8.2), emissions estimation methodology (8.3), and the electrical power consumption emission estimates (8.4).

8.1 Source Description

For this study, the electrical power consumption from public and private facilities was collected to calculate greenhouse gas emissions for this source. The electrical power consumption is a measure of electricity generated for buildings and facilities that is used to light the buildings, provide outdoor lighting, and to power air conditioners and computers.

8.2 Data and Information Acquisition

Data was requested from private terminals, such as the petroleum facilities, and from Port Everglades. The electricity consumption, in kW-hrs, was provided for both the public and private terminals. The data provided was actual electricity usage from the electricity bills for the year 2015. A few facilities did not provide electricity consumption. An average was included for the facilities that were not able to provide data prior to summing up the total electricity consumption.

The amount of refrigerant used to cool buildings or the fuel used by stationary generators was also part of data collection. Since this was the first time producing an inventory, and data related to the amount of refrigerant used per year or fuel consumed by mobile and stationary sources operated by the port for administrative duties was not easily available. Therefore, the emissions from these sources are not quantified for this study due to data not being readily available for the 2015 calendar year.

8.3 Emission Estimation Methodology

GHG emissions from energy usage were estimated using the following general equation.

Equation 8.1

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

Where:

E = mass of emissions per defined period (such as a year), metric tons (tonnes)
EF = emission factor (mass per unit of energy produced), g/MWhr
Activity = activity, measured in energy consumption, MWhr

The CO_2 emission rates for the local utility company, Florida Power and Light (FPL), were provided by the Broward County staff for calendar years 2011 to 2014[35]. To ensure that the FPL CO_2 emissions were in line with the eGrid, the Climate Registry[36] recommended GHG emission estimate source, the 2012 FPL values were compared to the 2012 emission rates reported in eGrid2012 (the latest version available). The emission rates were consistent with those reported in the eGrid2012, therefore the latest CO_2 emission rate provided by FPL was used along with the eGrid2012 CH_4 and N_2O values since there were no current year FPL values for CH_4 and N_2O.

Table 8.1 summarizes the emission rates used in g/kW-hr and lists the source and calendar year for each pollutant. The CO_2 emission rate includes 9.2% transmission distribution loss adjustment for the eastern region based on eGrid2012[37] documentation.

Table 8.1: GHG Emission Rates (g/kW-hr) and Source

Pollutant	g/kW-hr	Year	Source
CO_2	374.5	2014	FP&L
CH_4	0.0201	2012	eGrid
N_2O	0.0028	2012	eGrid
CO_2e	375.8		Calculated

8.4 Emission Estimates

The resulting GHG emission estimate with the electric energy consumed in 2015 are listed in Table 8.2.

Table 8.2: 2015 Energy Consumption and GHG Emission Estimate

	Energy Consumption kW-hr	CO_2e tonnes
Total	38,425,754	14,397

[35] Personal communication with Albert Lee, Environmental Protection and Growth Management Department, Broward County Florida, July 28, 2016 email.

[36] See: *www.theclimateregistry.org/tools-resources/reporting-protocols/general-reporting-protocol/*

[37] See: *www.epa.gov/sites/production/files/2015-10/documents/egrid2012_technicalsupportdocument.pdf*, Table 3.5.

APPENDIX A – TRANSIT EMISSIONS

Emissions from domestic transitory marine traffic through the Atlantic Intracoastal Waterway (ICW) are included in this appendix. As part of the scope for the project, the Port requested that the impact from other commercial marine traffic in the ICW be identified. Recreational vessels and private yachts were not part of the scope and thus not included in this report.

In 2015, there were 91 activities for transitory towboats that traveled through the study area, but did not call at the Port. The same emission calculation methodology discuss in Section 4.3 was used to estimate the transitory towboat emissions. The transitory towboat emissions are listed in Table A.1.

Table A.1: 2015 Transitory Towboat Emissions

Vessel type	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_2	CO_2e
	tons	tons	tons	tons	tons	tons	tons	tonnes
Towboat	71	2.45	2.25	2.45	2.92	26.60	0.04	4,045

APPENDIX B - GLOSSARY

Air toxics **–** Toxic air pollutants, also known as hazardous air pollutants, are those pollutants that are known or suspected to cause cancer or other serious, chronic health effects, such as reproductive effects or birth defects, or adverse environmental effects.

Auxiliary engine **–** A small engine often used when a ship is in-transit, maneuvering, or hotelling.

Baseline Air Emissions Inventory **–** For a given air emission source category, a baseline inventory establishes a reference point with more detailed emission data than previously existed. An established baseline allows comparison with future inventories of similar precision to describe changes to the characteristics of the source category and intensity of the emissions.

Brake Specific Fuel Consumption **–** A way to measure the efficiency of an engine by dividing rate of fuel consumption by the rate of power production.

Cargo Handling Equipment (CHE) **–** Equipment used to move cargo to and from marine vessels, railcars and trucks. This includes equipment such as cranes, rubber tired gantry cranes, terminal trucks, container handlers, bulk loaders, and forklifts.

Criteria pollutants **–** A regulatory term that refers specifically to six outdoor air pollutants for which EPA is required to develop National Ambient Air Quality Standards (NAAQS), as codified in the federal Clean Air Act. These six are carbon monoxide (CO), lead, nitrogen dioxide (NO_2), particulate matter (PM_x), ozone, and sulfur oxides (SO_x).

Deterioration factor **–** For use in emission or performance calculation, this number accounts for the effect of gradual wear in the internal engine components during normal operation.

Diesel **–** In standard use, this refers to a specific fractional distillate of fuel oil that is used as fuel in a combustion-ignition (CI) engine. Practically, diesel can refer generally to any hydrocarbon-dense oil with relatively low volatility that can be used as a combustion fuel. In common maritime use, diesel can refer to several varieties of distillate fuels including "Marine Diesel Oil" (MDO, aka DMB or DMC) and "Marine Gas Oil" (MGO, aka DMA or DMX) as specified by ISO 8217. Diesel can also be referred to by its sulfur content, such as the case of LSD (low sulfur diesel with less than 500 ppm sulfur) or ULSD (ultra-low sulfur diesel with less than 15 ppm sulfur).

Diesel electric **–** Refers to equipment that uses electric motive systems that rely on electricity from diesel generators.

Diesel Particulate Matter (DPM) **–** Refers to particulate components of combustion products that are directly emitted from diesel engines. These include soot ("elemental" or "black" carbon) and other aerosols that are complex aggregates of hydrocarbons, metals, silicates, and other chemicals. In recent years, exposure to diesel DPM has been singled out as posing a likely carcinogenic risk. The International Agency for Research on Cancer (IARC) has designated diesel engine emissions as carcinogenic to humans. This risk is of greatest concern to people who regularly work in proximity to diesel equipment over the course of many years.

Emission factor **–** A number specific to an engine or system that describes the amount of a pollutant that is generated per unit of activity, e.g. mg/mile or g/hr.

Fuel correction factor (FCF) **–** A number used in emission inventory models to reflect the impact on emissions of commercially dispensed fuel compared to fuel used during the certification process. These factors are derived as the ratio of the impact of the dispensed fuel to the impact of the certification fuel.

Fuel Oil **–** A general term for viscous liquid fuels used for powering engines. In the maritime industry the following classifications are used.

- ***MGO (Marine gas oil)*** **–** A purely distillate fuel (see "diesel")
- ***MDO (Marine diesel oil)*** **–** A blend of gas oil and heavy fuel oil
- ***IFO (Intermediate fuel oil)*** **–** A blend of gas oil and heavy fuel oil, with less gas oil than marine diesel oil
- ***MFO (Medium fuel oil)*** **–** A blend of gas oil and heavy fuel oil, with less gas oil than intermediate fuel oil
- ***HFO (Heavy fuel oil)*** **–** Pure or nearly pure residual oil (bunker fuel)

Greenhouse Gas **–** Substances in the atmosphere that absorb radiated heat form the earth's surface and also radiate heat back to the surface, causing a net retention of heat energy. Carbon dioxide, methane, and nitrous oxide are common examples.

Harbor craft **–** A term that generally refers to vessels that do not make regular ocean passage. These include fishing boats, tug boats, ferries, and other commercial workboats. For the purpose of this report, any craft that is not an ocean-going vessel, recreational vessel, or tank barge, has been categorized as a harbor craft.

Heavy-duty vehicle **–** A class 8 truck fueled by diesel and has a gross vehicle weight of 33,001 lbs or higher.

Hotelling **–** The period during which a vessel is secured at berth.

Hydrocarbon **–** A chemical term referring to compounds that consists of carbon and hydrogen in various structures. Most common liquid fuels are primarily comprised of some form of hydrocarbon.

Intermediate fuel oil (IFO) **–** See Fuel Oil

Intermodal Container Transfer Facility – A rail yard that is located close to a port facility and is where a cargo transition between two different transportation modes (e.g. trucks, trains, or ships) occurs.

Light duty vehicle (LDV) **–** Class 1 and 2 vehicles that can use gas or diesel fuel and have a gross vehicle weight of 6,000 lbs or less (class 1) or between 6,001 and 10,000 lbs (class 2).

Load Factor (LF) **–** A ratio of an engine's average actual power used to its maximum power rating.

***Main propulsion engine* –** The engines on a vessel that are dedicated to movement of a ship over long distances.

***Marine Diesel Oil (MDO)* –** See "Fuel Oil"

Maximum continuous rating – A value assigned to a piece of equipment by its manufacturer that sets a guideline for which the equipment can be operated for an unlimited period of time without damage.

Mobile Source – emissions from motor vehicles, airplanes, locomotives, vessels, harbor craft, cargo handling equipment and any other equipment that can be moved from one location to another.

Ocean-going vessel (OGV) – Vessels that operate in open oceanic waters.

Nonpoint source – Any source of pollution that does not meet the definition of point source.

Particulate Matter (PM) – A general term for any substance, except pure water, that exists as a liquid or solid in the atmosphere under normal conditions and is of microscopic or sub-microscopic size but larger than molecular dimensions. Airborne PM can result from direct emissions of particles (primary PM) or from condensation of certain gases that have themselves been directly emitted or chemically transformed in the atmosphere (secondary PM). PM is often classified by size:

- ***$PM_{2.5}$*** – Also known as "fine" particulate matter, $PM_{2.5}$ refers to the fraction of PM in a sample that is 2.5 microns in diameter or less. This size of PM is commonly associated with combustion and secondary PM.
- ***PM_{10}*** – Also known as "coarse" particulate matter, PM_{10} refers to the fraction of PM in a sample that is 10 microns in diameter or less.

Point source – A single, stationary point source of emissions that is immoveable for all practical purposes.

***Residual oil* –** "Residual Fuel Oil" or "Bunker Fuel" – See 'Fuel Oil"

Roll-on/Roll-off (RoRo) – A vessel featuring a built-in ramp for wheeled cargo to be 'rolled-on' and 'rolled-off" of the vessel.

Rubber Tired Gantry (RTG) Crane – A common piece of cargo handling equipment at marine terminals used to transfer containers from stacked storage to a vehicle.

***Selective Catalytic Reduction (SCR)* –** A process where a gaseous or liquid reductant (most commonly ammonia or urea) is added to the flue or exhaust gas stream and absorbed onto a catalyst. The reductant reacts with NO_x in the exhaust gas to form H_2O (water vapor) and N_2 (nitrogen gas).

Stationary source – large, fixed sources of air pollution and include power plants, refineries and factories. Stationary sources include both point and nonpoint sources.

Switching locomotive **–** A locomotive that is used exclusively in a facility where rail cars are organized and assembled into trains.

Twenty-foot Equivalent Unit (TEU) **–** A measure used for containerized cargo. One TEU is equivalent to one standard cargo container measured 20' x 8' x 8'6".

Two-stroke engines – A type of internal combustion engine that completes the same four processes as a four-stroke engine (intake, compression, power, and exhaust) in only two strokes of the piston rather than four. This is accomplished by using the space below the piston for air intake and compression, thus allowing the chamber above the piston to be used for just the power and exhaust strokes. This results in a power stroke with every revolution of the crank, instead of every second revolution as in a four-stroke engine. For this reason, two-stroke engines provide high specific power, so they are valued for use in portable, lightweight applications. Two stoke diesel engines are common in large marine vessels.

Ultra-Low Sulfur Diesel (ULSD) **–** See "diesel"

Volatile Organic Compound (VOC) **–** A very broad term used to describe the entire set of vapor-phase atmospheric organic chemicals except CO and CO_2.