South Carolina Ports

2011

AIR EMISSIONS INVENTORY UPDATE

APRIL 1, 2013

PREPARED BY

moffatt & nichol | 3780 KILROY AIRPORT WAY, SUITE 600 | LONG BEACH, CA 90806

South Carolina State Ports Authority

2011 Emissions Inventory Update

Prepared for:

South Carolina Ports

Prepared by:

MOFFATT & NICHOL

April 1, 2013

TABLE OF CONTENTS

ACKNOWLEDGMENTS **5**

EXECUTIVE SUMMARY **6**

1. Introduction **12**

1.1 Study Purpose 12
1.2 Terminal Overviews 14
1.3 Sources 20
1.4 Inventory Boundary 21
1.5 Pollutants 22
1.6 Project Approach 23

2. Ocean-Going Vessels **24**

2.1 Emission Calculation Approach 25
2.2 Ship Call Data 26
2.3 Vessel Characteristics 29
2.4 Fuel Type 30
2.5 Time in Mode Calculations 31
2.6 Main Engine Load Factor 32
2.7 Auxiliary Engine Size & Load Factor 33
2.8 Boiler Load Factors 34
2.9 Emission Factors 34
2.10 Ocean-Going Tugs 36

3. Harbor Craft **37**

3.1 Ship Assist Events 37
3.2 Vessel Characteristics 38
3.3 Operating Hours 39
3.4 Load Factors 39
3.5 Emission Factors 39

4. Cargo Handling Equipment **40**

4.1 Equipment List 40
4.2 Hours of Operation 40
4.3 Load Factors 41
4.4 NONROAD Model Runs 41

5. Rail Locomotives **43**

5.1 Locomotive Hours 43
5.2 Locomotive Characteristics 43

5.3 Locomotive Emission Factors 43

6. Heavy Duty Vehicles 45

6.1 Truck Trips 45
6.2 Truck Trip Origin and Destination Distribution and Distances 46
6.3 On-Terminal Truck Time 47
6.4 Off-Terminal Truck Trip Time of Day and Segment Speeds 47
6.5 Emission Rates 47

7. Emission Results 49

7.1 All Sources 49
7.2 Ocean Going Vessels 51
7.3 Harbor Craft 55
7.4 Cargo Handling Equipment 56
7.5 Rail Locomotives 58
7.6 Heavy Duty Vehicles 60
7.7 Comparison with 2005 62

8. Study Limitations 72

REFERENCES 74

TABLE OF TABLES

Table ES-1: 2011 Emissions Inventory Summary, in tons 7
Table ES-2: Comparison of 2005 to 2011 Emissions 9
Table ES-3: Percent Change by Source Type from 2005 to 2011 9
Table 2-1: 2011 Ship Call Summary for All SCSPA Terminals 27
Table 2-2: Comparison of Ship Calls and Hotelling Time (2005 to 2011).....28
Table 2-3: Comparison of Ship Engine Sizes (2005 to 2011) 29
Table 2-4: OGV Transit Time in Mode 32
Table 2-5: Factors for Auxiliary Engine Size 33
Table 2-6: Auxiliary Engine Sizes & Load Factors 33
Table 2-7: Boiler Loads 34
Table 2-8: OGV Main Engine Emission Factors (g/kW-hr) 34
Table 2-9: OGV Maine Engine Low Load Adjustment Factors 35
Table 2-10: OGV Auxiliary Engine Emission Factors (g/kW-hr) 35
Table 2-11: OGV Boiler Emission Factors (g/kW-hr).....36
Table 2-12: Ocean-Going Tug Auxiliary Engine Emission Factors 36
Table 3-1: Harbor Craft Travel Distance and Speed Assumptions 37
Table 3-2: Harbor Craft Emission Factors (g/kw-hr).....39
Table 4-1: CHE Summary by Terminal 40
Table 5-1: Rail Assumptions Summary 44
Table 6-1: Count of Truck Visits by Terminal.....45
Table 6-2: Origin & Destination Splits for Trucks with Containers 46
Table 6-3: Average Travel Distances for Each Type of Truck Trip 46
Table 7-1: Summary Mass Emission Results for 2011 (tons).....49
Table 7-2: OGV Emissions Results by Terminal and Ship Type 52
Table 7-3: Harbor Craft Emissions Results 55
Table 7-4: CHE Emissions Results, All Terminals and All Fuels 56
Table 7-5: RL Emissions Results.....58
Table 7-6: Truck Emissions Results (tons) 60
Table 7-7: Truck Emissions Results (lbs/round trip) 61
Table 7-8: Container Throughput Comparison 62
Table 7-9: Bulk Throughput Comparison 62
Table 7-10: Mass Emissions Comparison (tons) 62
Table 7-11: Percent Change Over Time by Source Category 63
Table 7-12: CHE Emissions 2005 to 2011 Comparison by Terminal 68
Table 7-13: Rail Emissions 2005 to 2011 Comparison 70
Table 7-14: Comparison of Truck Counts, 2005 to 2011 71
Table 7-15: Comparison in Emissions Per Truck Trip 72

TABLE OF FIGURES

Figure ES-1: Percent Contribution by Each Source Category 8
Figure ES-2: Change in OGV Emissions Due to ECA Fuel Regulations 10
Figure 1-1: Locations of the SCSPA-Operated Terminals at the Port of Charleston 14
Figure 1-2: Aerial View of Columbus Street Terminal 15
Figure 1-3: Aerial View of North Charleston Terminal 16
Figure 1-4: Aerial View of Union Pier 17
Figure 1-5: Aerial View of Wando Welch Terminal 18
Figure 1-6: Aerial View of Veterans Terminal 19
Figure 1-7: Aerial Showing Boundary of the Charleston Tri-County Area 21
Figure 2-1: Navigational Chart of SCSPA Shipping Channels 24
Figure 3-1: Location of Tug Companies, Terminals, and Shutes Folley Island 38
Figure 7-1: Total Emissions by Source Category 50
Figure 7-2: NOx and PM Emissions by Source 51
Figure 7-3: OGV Emissions by Mode 53
Figure 7-4: OGV Emissions by Location 54
Figure 7-5: Harbor Craft Emissions by Terminal 56
Figure 7-6: NOx and PM10 Emissions by Equipment Type 57
Figure 7-7: Percent of Rail Emissions by Engine Type (Line Haul v. Switcher) 59
Figure 7-8: Comparison of OGV Emissions, 2005 to 2011 (all RO fuel) 64
Figure 7-9: Comparison of OGV Emissions, 2005 to 2015 (all 0.1% S MGO fuel) 65
Figure 7-10: Comparison of OGV Emissions as Fuel Improves Due to ECA 66
Figure 7-11: Comparison of Tug Emissions Over Time 67
Figure 7-12: Comparison of CHE NOx Emissions Over Time 69
Figure 7-13: Percent Reduction in Truck Emissions Over Time 71

ACKNOWLEDGMENTS

Moffatt & Nichol would like to thank the following South Carolina State Ports Authority Staff for their participation and critical assistance in providing comprehensive and detailed data on the equipment and activities at the Port of Charleston.

Jim Newsome – President and Chief Executive Officer of SCSPA
Barbara Melvin – Senior Vice President, External Affairs
Steve Kemp – Vice President, Terminal Operations
Patrick Moore – Environmental Stewardship Manager
Allison Skipper – Public Relations Manager
Mike Stresemann – Vice President, Crane and Equipment Maintenance
Rusty Mathews – Veterans Terminal Manager

Other participants we would like to thank:

Hugh Heine – U.S. Army Corps of Engineers, Wilmington District
Sean Fortener and Carly Remm – Crowley Marine
Steve Kicklighter – McAllister Fleet Manager
Jonathon Archer – Moran Fleet Manager

EXECUTIVE SUMMARY

The South Carolina State Ports Authority (SCSPA, or Port) is committed to environmental stewardship and has taken a leadership role in understanding and addressing the environmental impacts of air emissions associated with the Port's operation. The purpose of this study, the 2011 inventory update, is to estimate the level of air emissions coming from all significant internal combustion engines related to Port operations within the Charleston Tri-County area.

The SCSPA recognizes that a comprehensive emissions inventory, which includes all sources of Port-related air emissions, is needed to inform and facilitate the Port's role in maintaining clean air standards in the Charleston area. As a brief background, the SCSPA voluntarily conducted an air emissions inventory for all port-related activity occurring in calendar year 2005. That study, completed in September 2008, established their baseline emissions levels. The current study documented in this report is the 2011 update to the baseline inventory.

Moffatt & Nichol conducted both the 2005 baseline inventory and this 2011 update. The sources, boundaries, and methodologies were kept consistent between the two inventories as much as possible so that changes to emissions can be fairly compared between the two years.

The five emissions sources included in the study are:
1. Ocean-going vessels (OGV)
2. Harbor craft (HC), limited to vessel assist tug operations at SCSPA berths
3. Cargo handling equipment (CHE) operating on Port property
4. Rail locomotives (RL), including switchers at Port terminals and line haul engines
5. On-road trucks and heavy duty vehicles (HDV)

The results of the 2011 inventory form an update to the SCSPA's baseline inventory. The updated inventory can be used to:
- Analyze 2011 emission levels.
- Examine trends in emissions from 2005 levels.
- Evaluate the effectiveness of air emission reduction measures implemented since 2005.
- Help target emission reduction measures for the largest sources of specific pollutants of concern or in specific geographic areas of concern.
- Evaluate the cost effectiveness (i.e., dollars per ton reduction) of various reduction measures.
- Track emission reduction progress over time as technology and efficiency improvements are implemented.

Detailed data on ship calls, cargo throughputs, cargo handling equipment hours, truck trips, and switcher locomotive operations were provided by SCSPA. Tug activity and line haul locomotive activity were estimated based on vessel call data, throughput data, and modal split provided by SCSPA staff.

The methodology applied to prepare this emissions inventory was consistent with the U.S. Environmental Protection Agency (EPA) report titled "Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories," published in April 2009 by ICF International, referred to herein as the Current Methodologies Report (ICFI, 2009).

Emission levels were calculated for the following six pollutants:

1. oxides of nitrogen (NOx);
2. carbon monoxide (CO);
3. total hydrocarbons (HC);
4. particulate matter smaller than 10 microns (PM10);
5. particulate matter smaller than 2.5 microns (PM2.5); and
6. sulfur dioxide (SO2).

This is the familiar list of pollutants included in every U.S. port inventory. They are all criteria pollutants or precursors to criteria pollutants. (Criteria pollutants are pollutants for which the EPA has established standards called National Ambient Air Quality Standards, or NAAQS.) Every air quality district in every state must already meet, or have an implementation plan to meet, these air standards. The Charleston area is in attainment status for all NAAQS.

Over-the-road truck emission factors were estimated using MOVES 2010b, EPA's latest analysis software for over-the-road vehicles (it supersedes EPA's Mobile 6.2 program, which was used for the 2005 inventory). Cargo handling equipment emission factors were estimated using EPA's NONROAD 2008 model. Locomotive emission factors were based on the EPA Fact Sheet "EPA 420-F-09-025 Emission Factors for Locomotives," published in April 2009. OGV and harbor craft emission factors were taken from EPA's Current Methodologies Report (ICFI, 2009) and supplemented by the latest literature as needed.

The 2011 emission results are summarized below by source type.

Table ES-1: 2011 Emissions Inventory Summary, in tons

	NOx	CO	HC	PM10	PM2.5	SO2
OGV	1,560.4	174.0	94.2	187.7	170.4	1,493.2
Tugs	194.2	21.8	9.4	12.3	11.9	0.1
Trucks	540.8	128.7	21.9	22.2	21.6	0.6
Rail	42.2	6.3	2.4	1.6	1.5	0.0
CHE	114.4	62.4	9.6	7.8	7.6	0.2
Total	**2,451.9**	**393.1**	**137.5**	**231.6**	**213.0**	**1,494.1**

Figure ES-1 below displays the percentage each source (ships, tugs, trucks, locomotives, and CH) contributes to overall Port emissions.

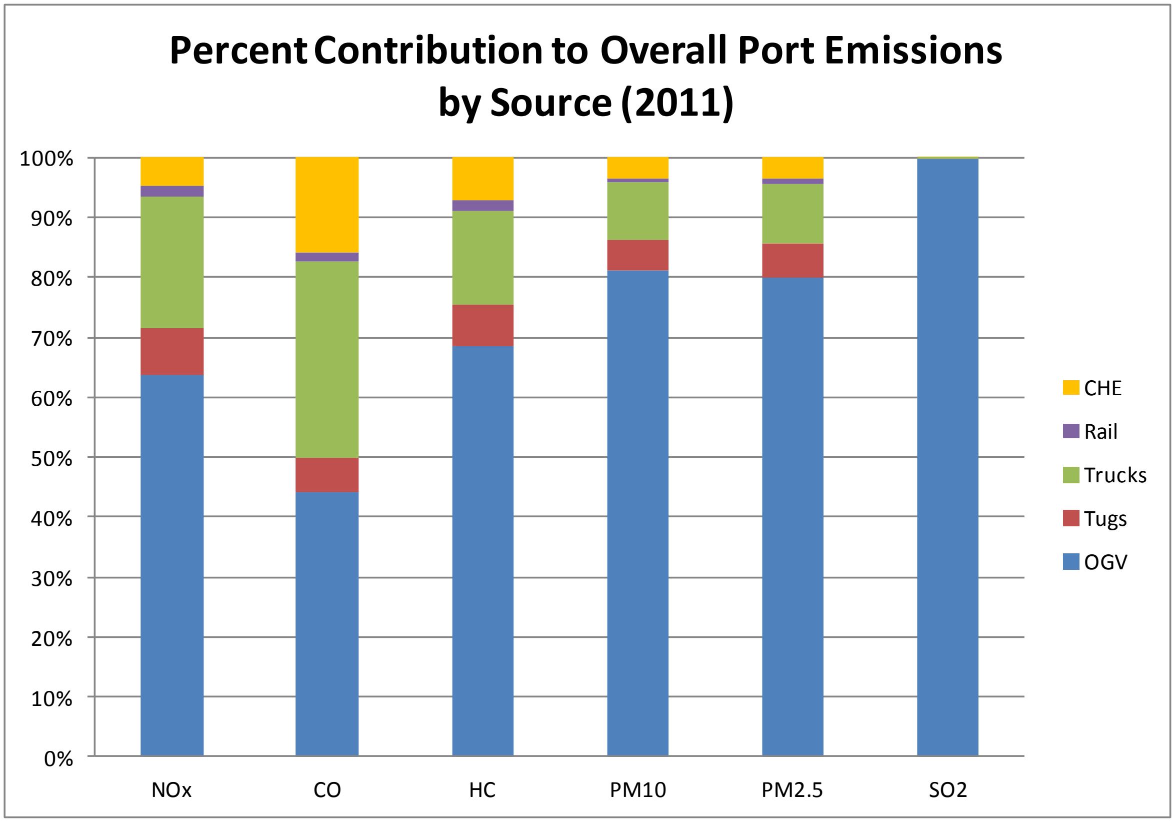


Figure ES-1: Percent Contribution by Each Source Category

The blue sections of these bars highlight the fact that ships are by far the biggest source of emissions at the Port. Trucks are the second biggest source, followed by tugs and CHE. Rail contributes less than 2% of the Port's emissions.

In 2005, the Port had 1,955 total ship calls (across all ship types – container, bulk, breakbulk, roll-on/roll-off, cruise, but not including tugs and barges). In 2011, the total number of ship calls was 1,666, a 15% decrease. Container throughput decreased 30% and bulk throughput increased 8% in that time period. The number of cruise ship calls almost doubled between 2005 and 2011.

Table ES-2 below shows how overall emissions have changed since 2005.

Table ES-2: Comparison of 2005 to 2011 Emissions

	NOx	CO	HC	PM10	PM2.5	SO2
2011	2,451.9	393.1	137.5	231.6	213.0	1,494.1
2005	3,476.8	807.7	185.0	192.8	175.7	1,157.9
Change	**-29%**	**-51%**	**-26%**	**20%**	**21%**	**29%**

This table shows that some pollutants have decreased over time, while others (PM and SOx) have actually increased over the last six years. To understand this, it is important to look at the percent change by source type, as shown in Table ES-3 below.

Table ES-3: Percent Change by Source Type from 2005 to 2011

	NOx	CO	HC	PM10	PM2.5	SO2
OGV	5%	20%	-3%	61%	67%	39%
Tugs	45%	-15%	238%	297%	297%	-98%
Trucks	-64%	-75%	-66%	-58%	-58%	-98%
Rail	-22%	-2%	27%	30%	26%	-99%
CHE	-60%	-48%	-52%	-57%	-57%	-100%
Total	**-29%**	**-51%**	**-26%**	**20%**	**21%**	**29%**

This table shows that truck and CHE emissions have decreased for every pollutant, which is a reflection of newer engines and better fuel combined with similar engine sizes and operations. Rail shows a mixture of increases and decreases, depending on the pollutant. Rail, however, represents only one to two percent of total Port emissions, so this source is not driving the overall changes. To understand the big picture, it is essential to look more closely at the two waterside sources.

Tugs show an increase in emissions over time, this despite improved fuel and better Tier level engines (Tier 0 in 2005 compared to Tier 1 in 2011). The higher tug emissions are driven by the fact that engine size increased over 50% in the last six years, and the total number of tug operating hours also increased about 25%. The increase in tug engine size corresponds with the increase in ship sizes, and is a trend that has been seen at other East Coast ports. It is also possible that the 2005 tug emissions were underestimated. For 2011, SCSPA was able to provide a better estimate of actual operating hours for the tug fleet.

Ships are by far the biggest emitters at the Port. Although the total number of ship calls decreased 15% since 2005, the average engine size of the ships increased 45%. This engine size increase, coupled with the fact that OGVs were still burning low quality bunker fuel in 2011, is the primary reason OGV emissions increased.

A recent development in the world of shipping is rapidly changing OGV emissions for the better, however. The EPA, working with the International Maritime Organization, has officially designated the entire North American coastline as an Emissions Control Area (ECA). This means that strict fuel regulations are being phased in for any ship transiting within 200 nautical miles of any U.S. coastline. 2011 was the last full year where bunker fuel was burned within 200 miles of shore. Starting in August 2012, ships were required to burn fuel with a maximum sulfur content of 1.0%. Starting in 2015, the maximum sulfur content will decrease to 0.1%. And starting in 2016, new ships will have to comply with stricter NOx standards as well.

Figure ES-2 shows how the new ECA fuel standards are expected to decrease OGV emissions over the next few years. This analysis uses the same ship activity as 2011 (meaning the same engine sizes and call counts) but changes the fuel type over time.

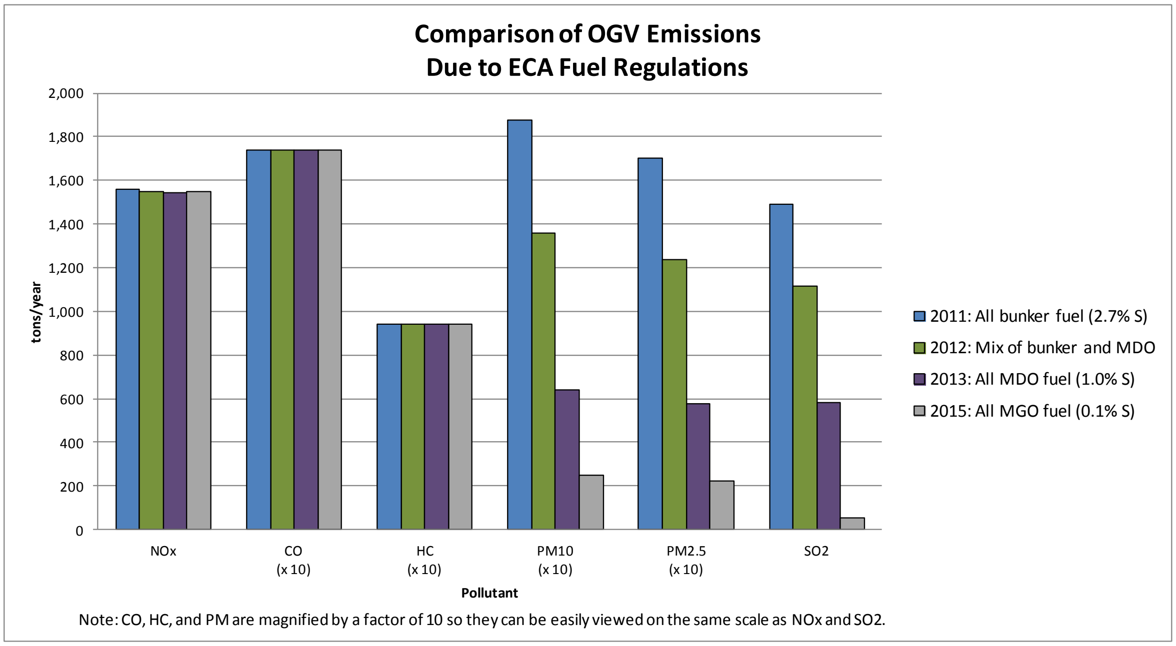


Figure ES-2: Change in OGV Emissions Due to ECA Fuel Regulations

The impact of the ECA requirements can be seen in the dramatic decrease in PM and SO2 emissions expected over the next few years.

In general, port emission reductions through 2011 are attributable to the use of low sulfur fuels and replacement of existing engines with cleaner engines. Additional mitigation measures to reduce air impacts implemented by the SCSPA since the 2005 baseline inventory are discussed below.

- Replaced diesel-fueled container cranes with electric cranes.
- Switched all on-terminal cargo handling equipment to ultra-low sulfur diesel (ULSD). In addition, seven on-terminal tenants have also switched to ULSD.
- Replaced engines in existing rubber-tired gantry cranes (RTGs) with cleaner EPA Tier 3 diesel engines.
- Increased productivity in cargo handling operations reducing truck turn times at port facilities.
- Created and implemented the Seaport Truck Air Cleanup Southeast (STACS) program, in cooperation with the South Carolina Department of Health and Environmental Control, to offer funding to port truck owners upgrade to cleaner running, more fuel efficient models.

1. Introduction

Nationally, air emissions from the many mobile sources associated with port operations have come under increased scrutiny. Regional challenges to achieve or maintain air quality standards within regulatory limits have led to increased focus on port-related emissions. The SCSPA has implemented emission reduction programs and initiatives at its five terminals to improve air quality and demonstrate sound environmental stewardship while continuing to expand port facilities and increase cargo throughput.

The SCSPA recognizes that a comprehensive emissions inventory that includes all sources of port-related air emissions is an essential part of understanding the impact on local air quality of international goods movement. In 2008, SCSPA prepared a baseline inventory of the emissions from cargo handling operations in 2005. This 2011 inventory provides an update to the baseline and reflects recent terminal activity levels, operational changes at the Port's five terminals, and changes to the EPA's software models for calculating emissions.

Since the baseline inventory for 2005, the SCSPA has made considerable strides in controlling the emissions from its cargo handling operations. The SCSPA has implemented programs to adopt the use of ultra-low sulfur diesel fuel, replace engines in its cargo handling equipment, replace older model trucks, and replace diesel equipment with electric equipment.

In the coming years, strict new regulations on the fuel sulfur content of ships transiting within 200 nautical miles of the U.S. will result in significant decreases in waterside emissions as well. These regulations became enforceable after the 2011 calendar year, so the benefits cannot be seen in this inventory. However this study includes an additional analysis to estimate the impact of the rule, see Section 2.4.

1.1 Study Purpose

Addressing air quality concerns in port operations starts with understanding current activity levels and their resulting emissions. Once the universe of emissions is understood and quantified, the appropriate sources can be identified and targeted for emission reductions. The purpose of the 2011 inventory update is to estimate current emissions and to monitor and document the changes that have occurred since the baseline inventory. In addition, the 2011 inventory results can be compared with the 2005 baseline levels to determine the effectiveness of various emissions reduction strategies.

The 2011 inventory update includes activities resulting from cargo handling operations from the five terminals the SCSPA owns and operates at the Port of Charleston. The terminals are: Columbus Street, North Charleston, Union Pier, Veterans Terminal, and

Wando Welch. The SCSPA facilities at the Port of Georgetown are outside of the Charleston Tri-County air boundary used for the 2005 baseline inventory and were therefore excluded from this update as well.

1.2 Terminal Overviews

The locations of the five Port of Charleston terminals are shown in red in Figure 1-1 below. Closer aerial images of each of the five terminals included in this inventory are given in this section along with a brief description of each terminal's 2011 operations.

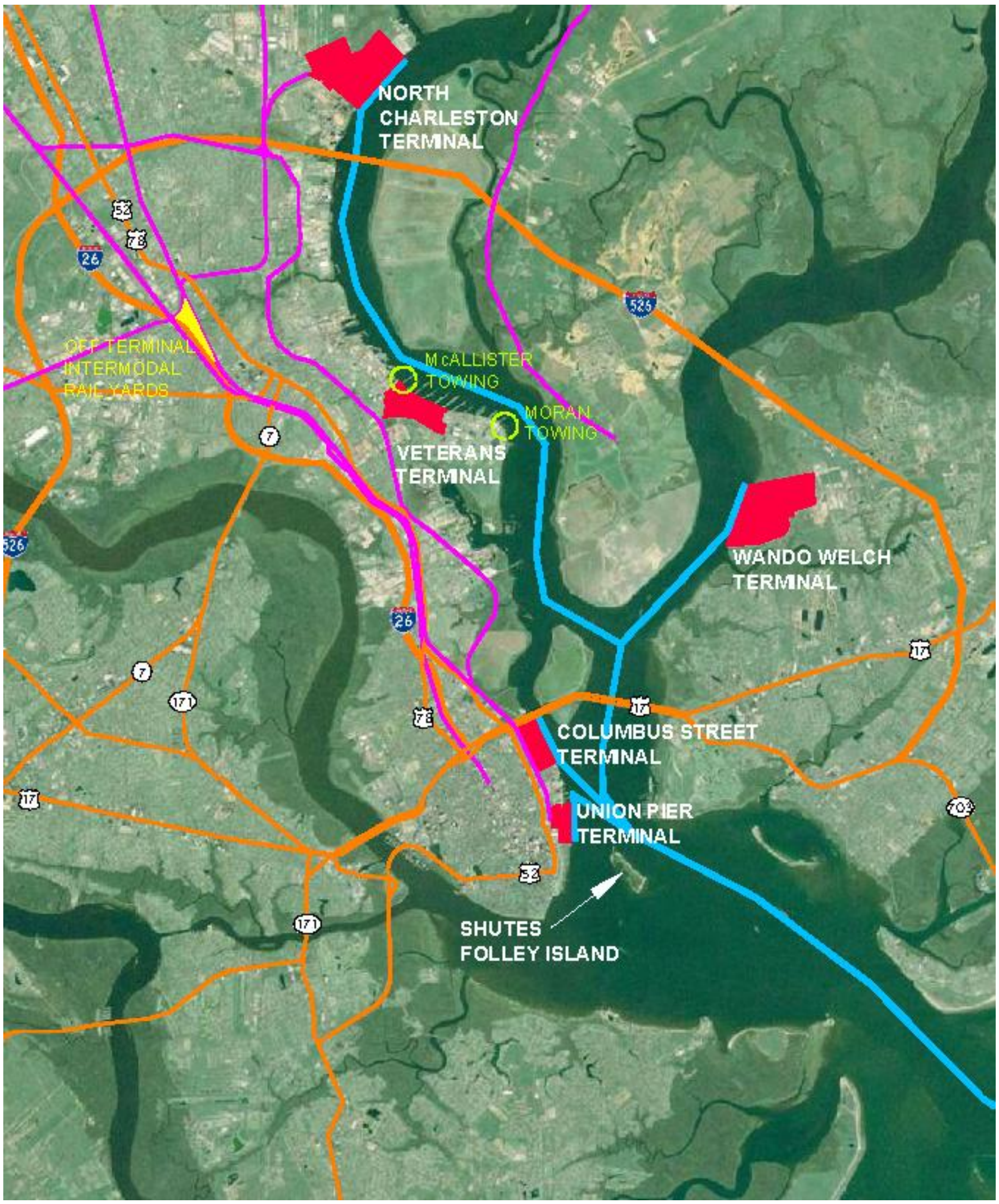


Figure 1-1: Locations of the SCSPA-Operated Terminals at the Port of Charleston
Source: SCSPA 2005 Baseline Inventory

Columbus Street Terminal

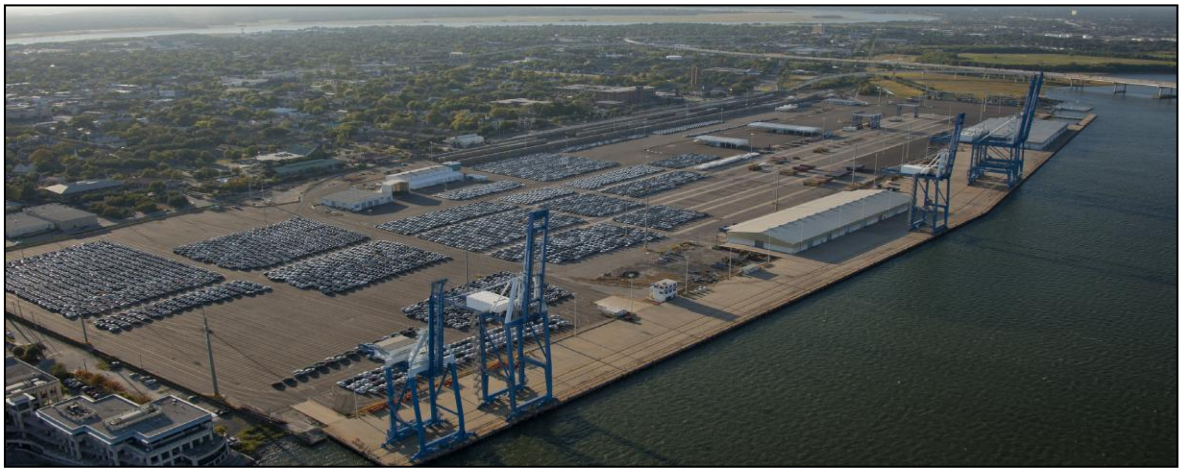


Figure 1-2: Aerial View of Columbus Street Terminal
Source: SCSPA website

The Columbus Street Terminal is located on the Cooper River side of the Charleston peninsula, downriver of the US Highway 17 bridge. The terminal is 14.4 nautical miles from the Charleston Harbor entrance.

The terminal covers a total of 155 acres and has 3,500 feet of berth. The berths at the terminal range are maintained to a depth of -45 feet MLW. The terminal is primarily used for heavy-lift cargo, roll-on/roll-off (ro-ro) and breakbulk operations. It no longer handles containers over the wharf, although it had a handful of containership calls in January of 2011. The breakbulk cargo is primarily paper that is transloaded from rail cars into containers which are then trucked from the terminal. The ro-ro operation includes BMWs that arrive on rail cars and driven onto car carrier ships. It also includes military vehicles and other equipment that can be driven.

The terminal currently has five container cranes on six berths. Two of the container cranes are super post-Panamax, meaning they can load and unload vessels that can pass through the future wider Panama Canal. The terminal includes 259,149 square feet of warehouses with covered rail access and an additional 100,000 square feet of warehouse with rail access. Access from the terminal to I-26 is via Morrison Avenue and East Bay Street.

Existing rail access to this terminal includes an on-terminal intermodal rail yard. Switching on the terminal is done by the Port Utilities Company (PUC). The Port Utilities Company is an operating subdivision of the State Carolina Public Railways (SCPR), which is in turn a division of the State of South Carolina's Department of Commerce. Both the CSX and Norfolk Southern Lines pick up and deliver at the terminal.

North Charleston Terminal

Figure 1-3: Aerial View of North Charleston Terminal
Source: SCSPA website

The North Charleston Terminal is located on the Cooper River north of I-526, between the Naval Weapons Station (immediately upriver) and the MeadWestvaco Paper Plant (immediately downriver). The terminal is 22 nm from the Charleston Harbor entrance. The terminal covers a total of 201 acres and has 2,500 feet of continuous berth. Berth depth at the terminal is -45 feet MLW at Berths 1 through 3. The berth depth is -35 feet MLW at the grain elevator berth.

There are six container cranes serving the berths. Four of the container cranes are sized to load and unload post-Panamax vessels, and two cranes are Super Post Panamax size. The primary use of the terminal is container operations and 132 acres are available for container processing and storage. A 1.5-million-bushel grain elevator is also located along the waterfront; however, it is not presently contracted and the waterfront area is being considered for demolition to develop additional berth and backland for container cargo.

Access between the terminal and I-526 is via Remount Road, Virginia Avenue and North Rhett Avenue. Access between the terminal and I-26 is via Remount Road.

The terminal has rail access and an on-terminal rail yard. Switching on the terminal is done by the Port Terminal Railroad (PTR). The Port Terminal Railroad is an operating subdivision of the State Carolina Public Railways. Both the CSX and Norfolk Southern Lines switch in to and out of the yard.

Union Pier

Figure 1-4: Aerial View of Union Pier
Source: SCSPA website

The Union Pier Terminal is located on the Cooper River side of the Charleston peninsula. The terminal is 14.2 nm from the Charleston Harbor entrance. The terminal covers a total of 70 acres and has 2,470 feet of berth. The maintained depth at the berth is -35 feet MLW.

Union Pier is primarily used as a cruise terminal, although it also handles a small amount of breakbulk (paper). Access between the terminal and I-26 is via Washington Street, Chapel Street, East Bay Street, Morrison Drive, and Mount Pleasant Street.

The terminal has existing rail access. This is operated by the Port Utilities Company and connects to the CSX and Norfolk Southern lines.

Wando Welch Terminal

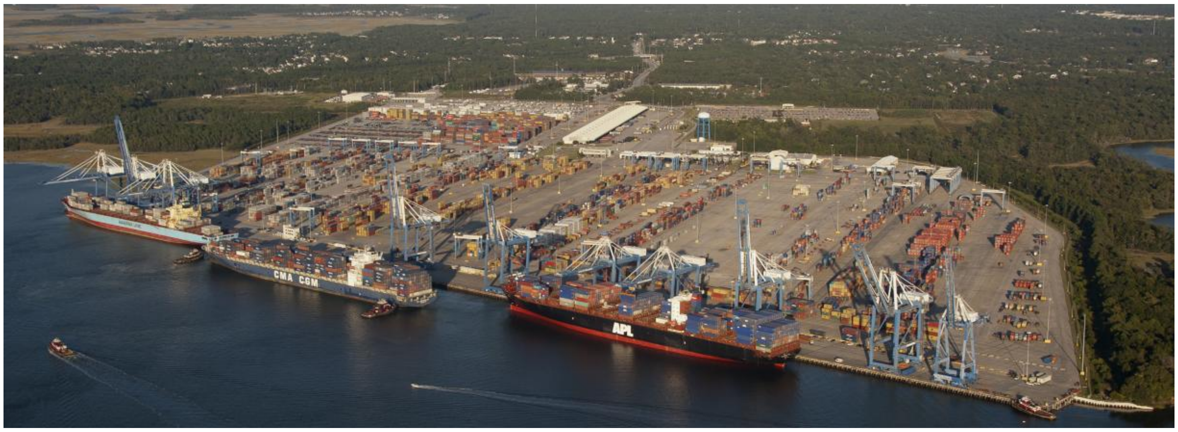


Figure 1-5: Aerial View of Wando Welch Terminal
Source: SCSPA website

The Wando Welch Terminal is located on the east side of the Wando River north of the Town of Mount Pleasant. The terminal is 16.6 nm from the Charleston Harbor entrance. The terminal covers a total of 689 acres and has 3,800 feet of continuous berth with a maintained depth of -45 feet MLW.

The terminal currently has ten container cranes on four container ship berths. Since the previous inventory was conducted, two cranes were dismantled and two cranes were moved over from the Columbus Street terminal. The terminal includes a 200,000 square foot container freight station for the stripping and stuffing of containers.

Access between the terminal and I-526 is provided by Long Point Road. There is no rail access to this terminal.

Veterans Terminal

Figure 1-6: Aerial View of Veterans Terminal
Source: SCSPA website

The Veteran's Terminal is located on the Cooper River south of I-526, on the northern end of the CNC. The terminal is a 110-acre facility dedicated to bulk, breakbulk, and ro-ro cargo. The terminal has four piers with a maintained depth of -35 feet MLW. The piers were originally constructed as part of the Charleston Naval Station. The terminal includes approximately 97,000 square feet of warehouse storage in two buildings. Interstate freeway (I-26) access is approximately 1.5 miles from Veteran's Terminal.

Veteran's Terminal did not have any ship calls in 2005, so it was not included in the baseline inventory. For 2011, however, it had 28 vessel calls as well as some layberthing of ocean-going tugs. The throughput consisted of some ro-ro traffic, mostly made up of military and construction type equipment. It also handled inbound bulk shipments of silica and crushed granite, and outbound shipments of steel by-products transloaded directly from barge to ship.

1.3 Sources

The following emissions sources were included:

- Ocean-Going Vessels (OGV) calling at a terminal owned by the SCSPA including the following vessel types:
    - Container ships
    - Cruise ships
    - Ocean-going tug & barges
    - Roll-on/roll-off (ro-ro) auto carriers
    - Breakbulk carriers
- Harbor Craft (HC) serving the terminals owned by the SCSPA:
    - Ship assist tugboats in direct service to the vessels docking at or sailing from SCSPA berths.
- Cargo Handling Equipment (CHE) in excess of 25 horsepower working on SCSPA property
- Railroad Locomotives (RL) at on-dock rail facilities within the Port
    - Switcher locomotives serving on-dock rail facilities
    - Line haul locomotives moving cargo into and out of on-dock rail facilities
- On-road Heavy Duty Vehicles (HDV),
    - Trucks operating within and transiting to and from SCSPA terminals
    - Passenger buses shuttling people to and from Union Pier cruise terminal

Emissions for activities that are not related to the operations of SCSPA terminals were not included as part of the inventory. Examples include on-road passenger vehicles, military vessels or equipment operations, pilot or crew boats, recreational boating, coastwise vessels not calling on SCSPA terminals, dredging or construction equipment. Trucks and buses delivering supplies and passengers to the cruise terminal were included in this inventory.

1.4 Inventory Boundary

In addition to emissions occurring directly on SCSPA property, the inventory also includes emissions from ships, locomotives, and trucks that occur outside the Port but within the Charleston Tri-County area. Figure 1-7 shows the boundary of the Tri-County area. Ship emissions were included from the sea buoy which is located approximately 12 nm from the Charleston harbor entrance, as shown below.

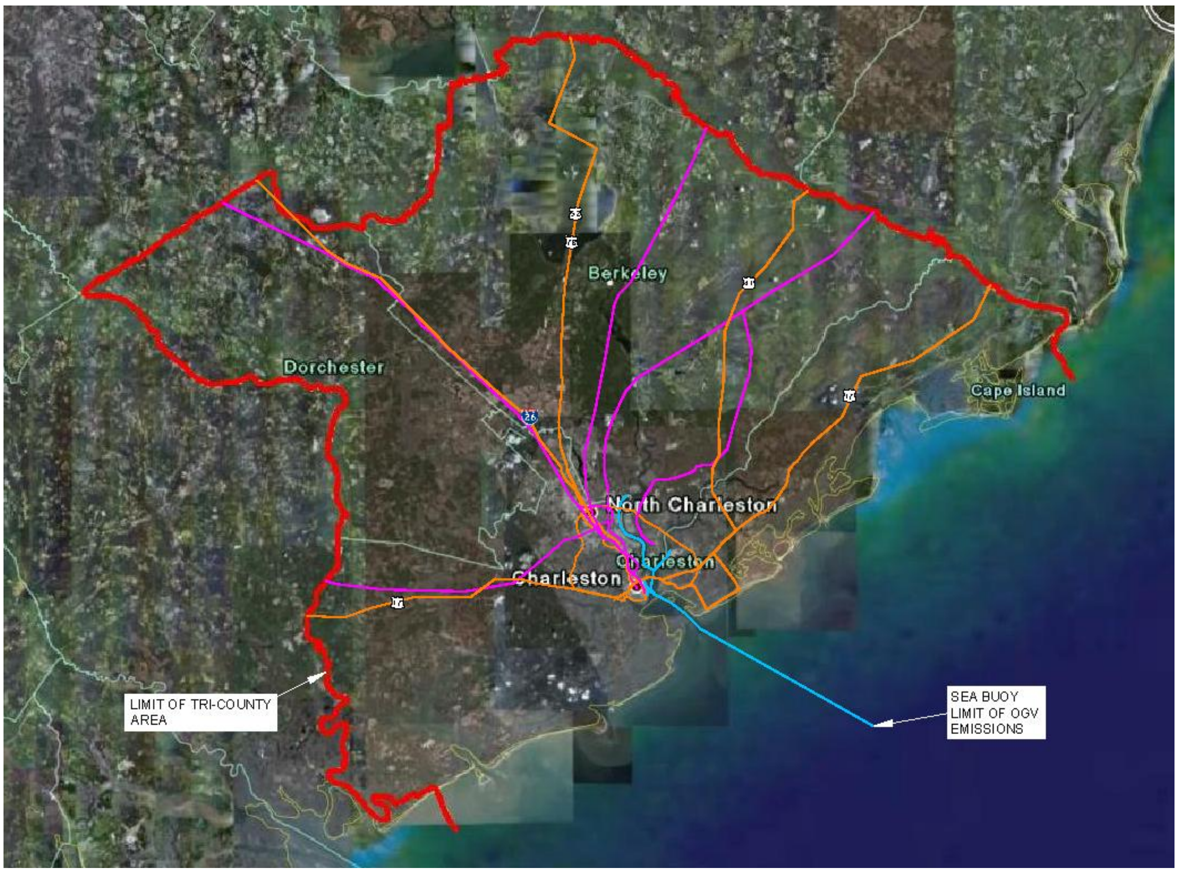


Figure 1-7: Aerial Showing Boundary of the Charleston Tri-County Area
Source: SCSPA 2005 Baseline Inventory

Emissions from truck trips are estimated to either the Charleston Tri-County boundary or the first point of destination (or origin) after leaving from (before arriving at) an SCSPA terminal, whichever is closer. Off terminal line haul emissions are based on the number of trains per year, as determined from container throughput, and the estimated average rail speed and distance to the air basin boundary.

1.5 Pollutants

Emissions were estimated for the following six pollutants:

Oxides of nitrogen (NOx): Oxides of nitrogen (or NOx, pronounced "knocks") are an important precursor to ozone. Ozone is a photochemical oxidant and the major component of smog. Ozone is not emitted directly but forms in the atmosphere in a reaction of oxides of nitrogen and volatile organic gases in presence of sunlight. These reactions are stimulated by sunlight and temperature so that peak ozone levels typically occur during the warmer times of the year. Ozone in the upper atmosphere is beneficial to life because it shields the earth from harmful ultraviolet radiation from the sun. However, high concentrations of ozone at ground level are a major health and environmental concern. Ozone and nitrogen dioxide (a common type of oxide of nitrogen) are criteria pollutants.

Carbon monoxide (CO): Carbon monoxide is a colorless, odorless, poisonous gas produced by incomplete burning of carbon in fuels. CO is a criteria pollutant.

Sulfur dioxide (SO2): High concentrations of sulfur dioxide affect breathing and may aggravate existing respiratory and cardiovascular disease. Sensitive populations include asthmatics, individuals with bronchitis or emphysema, children, and the elderly. SO2 is also a primary contributor to acid deposition, or acid rain, which causes acidification of lakes and streams and can damage trees, crops, historic buildings, and statues. In addition, sulfur compounds in the air contribute to visibility impairment in large parts of the country. This is especially noticeable in national parks. SO2 is a criteria pollutant. SO2 emissions are directly proportional to the sulfur content of in-use fuels.

Hydrocarbons (HC): Hydrocarbons are an important component in the formation of ozone. Ozone is formed through complex chemical reactions between precursor emissions of Volatile Organic Compounds (VOCs) and oxides of nitrogen (NOx) in the presence of sunlight. Hydrocarbon emissions are measured and reported in slightly different ways. Total hydrocarbons are the hydrocarbons measured by a specific test called Flame Ionization Detector.

Particulate matter 10 (PM10): Air pollutants called particulate matter include dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust. Particles formed in the atmosphere by condensation or the transformation of emitted gases such as SO2 and VOCs are also considered particulate matter. These are called secondary PM as they are not directly emitted but form in the atmosphere. PM10 is airborne particulates having an aerodynamic diameter 10 microns or less. PM10 is a criteria pollutant.

Particulate matter 2.5 (PM2.5): A subset of PM10, PM2.5 is airborne particulate of aerodynamic diameter 2.5 microns or less and is often referred to as "fine PM". Standards for PM2.5 are relatively new. A further subset of particulate matter is the subject of on-going study and is referred to as "ultrafine PM." Ultrafine particles have an aerodynamic diameter of 0.1 micron. No standards for ultrafine particles currently exist. Fine particles are especially concerning because their small size allows them to travel more deeply into the lungs, increasing the potential for health problems.

The EPA has established National Ambient Air Quality Standards (NAAQS) for six "criteria" pollutants. The pollutants listed above and included in this inventory are either criteria pollutants or precursors to those pollutants.

The NAAQS have been updated since the 2005 inventory was completed. The Charleston area is in attainment for every standard. More information on the EPA's air quality standards can be found at this website: http://www.epa.gov/air/criteria.html.

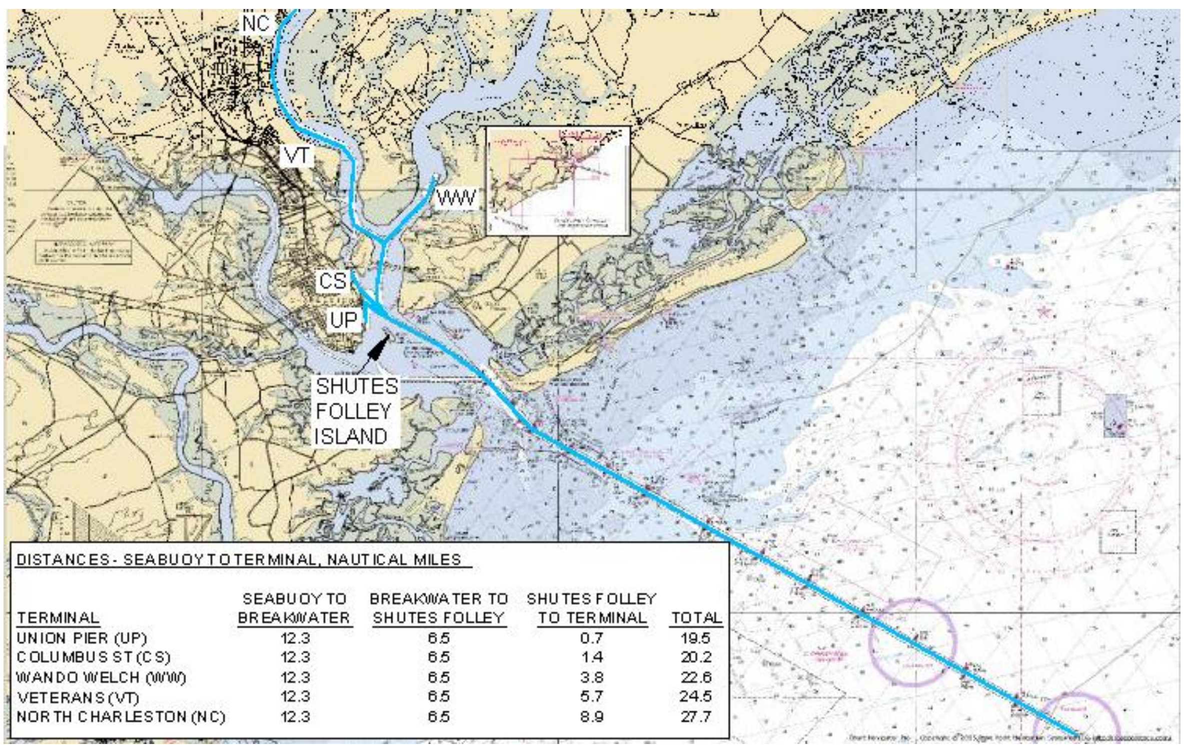
1.6 Project Approach

The emissions inventory was developed using actual 2011 terminal activity data provided by SCSPA, supplemented with cargo based projections of activity as needed. The methods applied were consistent with the EPA Current Methodologies Report (ICFI, 2009). The scope, data sources and calculation methodology for each of the five source categories are discussed in the following sections.

2. Ocean-Going Vessels

Ocean-going vessels are by far the largest contributor to emissions. Depending on the pollutant, OGV emissions account for 45% to 99.9% of total port emissions (see Figure ES-1).

The inventory boundary for vessel emissions is the sea buoy, just over twelve nautical miles outside the tip of the entrance jetties. Figure 2-1 displays a navigational chart showing the channels used by ships approaching the SCSPA terminals. Each terminal is labeled with its initials. Shutes Folley Island is called out because it is the assumed meet up and drop off location for assist tugs. The inset table lists the estimated travel distances for various legs of the journey to each of the five terminals. Emissions were calculated for vessels to and from each terminal to the sea buoy as well as the at-berth emissions of auxiliary generators and boilers.



DISTANCES - SEABUOY TO TERMINAL, NAUTICAL MILES

TERMINAL	SEABUOY TO BREAKWATER	BREAKWATER TO SHUTES FOLLEY	SHUTES FOLLEY TO TERMINAL	TOTAL
UNION PIER (UP)	12.3	6.5	0.7	19.5
COLUMBUS ST (CS)	12.3	6.5	1.4	20.2
WANDO WELCH (WW)	12.3	6.5	3.8	22.6
VETERANS (VT)	12.3	6.5	5.7	24.5
NORTH CHARLESTON (NC)	12.3	6.5	8.9	27.7

Figure 2-1: Navigational Chart of SCSPA Shipping Channels
Source: SCSPA 2005 Inventory

2.1 Emission Calculation Approach

OGVs have three sources of emissions onboard: the main propulsion engines, the auxiliary engines, and boilers. OGV emissions are calculated for each of these sources using energy based emission factors (published by the EPA) together with activity profiles for each vessel call. Each activity is described as a mode of operation.

OGVs operate in one of four different modes:

1. Cruising mode. This occurs in the open ocean where vessel movement is not constrained to channels. Typical cruising speed for container ships is anywhere from 19 to 23 knots.
2. Reduced speed zone (RSZ). This is when the vessel is operating at less than cruising speed, typically within defined channels
3. Maneuvering. This occurs when the vessel is close to the dock maneuvering into or out of berth, typically with assist tugs.
4. Hotelling mode. This is when the vessel is tied up at berth and its main engines are turned off.

Each of the three sources (main engines, auxiliary engines, boilers) operates at different loads during each of the modes listed above. Main engines are on any time the ship is in motion (transiting at any speed and maneuvering). Auxiliary engines are on all the time. At sea, the auxiliary engines are used to provide power for ship needs (lights, pumps, radios, air conditioning, etc.). At berth, the auxiliary engines are used to provide the same power and also to keep any refrigerated containers cold while the ship is being worked. The boilers are assumed to be on any time the main engine is operating at less than 20% of installed power. The boilers provide steam and hot water for the vessels.

The bulk of the inventory work involves looking up the engine power for each vessel and developing the activity profiles for all the ship calls to each facility. Using this information, emissions per ship call and mode can be determined using the equation below:

$$E = P \times LF \times A \times EF$$

Where E = Emissions (grams, g)

P = Maximum Continuous Rated Power (this is the installed engine size, expressed in kilowatts, kW)

LF = Load Factor (percent of vessel's total power in use for each mode)

A = Activity (this is the time in mode, expressed in hours)

EF = Emission Factor (this is the rate of emissions, expressed in grams per kilowatt-hour, g/kW-hr)

The emission factors are published by the U.S. EPA Current Methodologies Report (ICFI, 2009) and are expressed in terms of emissions per unit of energy from the engine.

2.2 Ship Call Data

Detailed ship call data for all vessel calls in calendar year 2011 was provided by SCSPA. The data included ship name, shipping line, arrival date and time, departure date and time, terminal, and previous and next ports of call.

A total of 476 unique vessels made a total of 1,704 vessel calls at the Port of Charleston in 2011. Table 2-1 below shows the distribution of call types for each terminal.

Table 2-1: 2011 Ship Call Summary for All SCSPA Terminals

	Vessel Type	Number of Calls	Avg Vessel Length (ft)	Avg. Duration at Berth (hrs)
Columbus Street	Container	6	779	46.9
	Tug & Barge			
	Cruise			
	Bulk/Breakbulk/Ro-ro/Other	225	608	20.6
North Charleston	Container	392	856	14.0
	Tug & Barge			
	Cruise			
	Bulk/Breakbulk/Ro-ro/Other	2	572	22.4
Union Pier	Container			
	Tug & Barge			
	Cruise	88	811	12.3
	Bulk/Breakbulk/Ro-ro/Other	35	612	15.8
Wando Welch	Container	890	938	12.8
	Tug & Barge			
	Cruise			
	Bulk/Breakbulk/Ro-ro/Other			
Veterans	Container			
	Tug & Barge (layberthing)	38		
	Cruise			
	Bulk/Breakbulk/Ro-ro/Other	28	557	73.7
All SCSPA	Container	1,288	912	13.3
	Tug & Barge (layberthing)	38		
	Cruise	88	811	12.3
	Bulk/Breakbulk/Ro-ro/Other	290	603	25.2
	2011 Total	1,704	853	
	2005 Total (for comparison)	2,014	751	

Source: SCSPA data

This table shows that overall, ship counts decreased about 15% over the six year period since the baseline inventory was conducted. In that same time period, however, ship length increased about 14%. This means that, in general, SCSPA is seeing fewer calls overall but the calls are being made by larger ships.

Table 2-2 shows a more detailed comparison of call counts and hotelling durations, by terminal and ship type.

Table 2-2: Comparison of Ship Calls and Hotelling Time (2005 to 2011)

		Num. Calls			Avg Hotel Time per Call (hr)		
Terminal	Ship Type	2005	2011	% Change	2005	2011	% Change
Wando Welch	Container	1,082	890	-18%	14.2	12.8	-10%
Columbus St	Container	251	6	-98%	17.8	46.9	163%
	Bulk/Other	42	225	436%	27.3	20.6	-25%
N. Charleston	Container	350	392	12%	15.3	14.0	-8%
	Bulk/Other	5	2	-60%	24.9	22.4	-10%
Union Pier	Passenger	46	88	91%	21.4	12.3	-43%
	Bulk/Other	179	35	-80%	15.5	15.8	2%
Veterans	Bulk/Other	-	28	n/a	-	73.7	n/a
		1,955	1,666	-15%			
		Total number of calls has decreased.			Hoteling times per call have mostly decreased.		

This table shows that hotelling times have decreased around 8-10% for container ships over the last six years. (The unusual increase seen for container ship hotelling time at Columbus Street Terminal is based on only six calls in 2011 – container operations ceased in January of that year. The long at-berth time is skewed by a single outlier call that stayed almost a week in September, possibly a bad data point.) Cruise ship hotelling at Union Pier decreased by 43% (down from 21 hours to 12 hours per call). Dwell times for bulk/breakbulk/ro-ro ships either decreased 10-25% or stayed about the same. Shorter at-berth times are generally indicative of more efficient operations. Reducing at-berth time is beneficial to emissions.

Total hotelling time in 2005 was 30,217 hours. Total hotelling time in 2011 was 25,516 hours. Overall hotelling time decreased 16% since 2005.

2.3 Vessel Characteristics

A total of 476 individual vessels called on SCSPA terminals in 2011, making a total of 1,704 calls. The characteristics of each of the 474 vessels were researched using the Clarkson Register as well as Lloyd's Register of Ships and other internet sources. Details for the vessels including dimensions, build year, carrying capacity, main and auxiliary engine rated power, engine type and speed (rpm), and service speed were used to calculate emissions for each call. Where specific vessel characteristics were not available, such as auxiliary engine and boiler power, recent literature on vessels of similar size and type were used.

The following table, Table 2-3, shows how engine sizes have increased since the baseline inventory was conducted. The larger engine size is consistent with the increase in vessel length shown in Table 2-2 above.

Table 2-3: Comparison of Ship Engine Sizes (2005 to 2011)

		Avg Main Eng. Size (kW)			Avg Aux Eng. Size (kW)		
Terminal	Ship Type	2005	2011	% Change	2005	2011	% Change
Wando Welch	Container	25,432	41,996	65%	6,586	9,239	40%
Columbus St	Container	20,994	29,513	41%	5,857	6,493	11%
	Bulk/Other	10,346	13,012	26%	2,850	2,889	1%
N. Charleston	Container	29,255	33,097	13%	6,297	7,281	16%
	Bulk/Other	16,630	10,332	-38%	2,850	2,294	-20%
Union Pier	Passenger	20,255	38,120	88%	2,026*	7,000*	246%
	Bulk/Other	12,404	14,010	13%	2,834	3,110	10%
Veterans	Bulk/Other	-	9,100	n/a	-	2,020	n/a

** for cruise ships these numbers are **loads** on the engine, not installed power*

Most ocean-going vessels are either slow speed diesels or medium speed diesels. (There are also steam and gas turbine ships, but these are uncommon. Neither of these ships types called at Charleston in 2011, so they are not discussed further in this inventory.)

SSD = slow speed diesel (max engine rpm of less than 130)
MSD = medium speed diesel (max engine rpm of over 130, typically over 400)

Almost all of the ships in this inventory were SSD. The only exception was some of the bulk ships calling at Veterans Terminal and most of the cruise ships are MSD. Almost all of the bulk carriers and 100% of the container calls were SSD ships.

2.4 Fuel Type

For 2011, it was assumed that all the OGVs burned residual oil (RO), or bunker, in their main and auxiliary engines. However, there is a critical development in the world of shipping that is rapidly changing the type of fuel burned by ocean-going vessels. This will have significant impact on emissions, especially SOx and PM in the near term.

In March of 2010 the U.S. EPA and the International Maritime Organization (or IMO, the agency with jurisdiction over international shipping) officially designated the entire coastline of the United States and Canada (both the Pacific and Atlantic coasts as well as the Gulf of Mexico) as an Emissions Control Area (ECA). The ECA designation means that strict rules for sulfur and NOx emissions from ships will be phased in over time. Specifically, any vessel transiting within 200 miles of the U.S. shoreline will have to comply with strict fuel requirements as follows:

Year	Fuel Sulfur Content
2010	10,000 ppm (1.0% S)
2015	1,000 ppm (0.1% S)

The fuel rule will greatly reduce SOx and PM emissions. Additionally, starting in 2016, new build ships will also have to comply with Tier III engine standards, which require aftertreatment on the exhaust to reduce NOx emissions.

More information about the ECA can be found here:
http://epa.gov/oms/regs/nonroad/marine/ci/420f10015.pdf
and here:
http://epa.gov/oms/oceanvessels.htm#emissioncontrol

It is important to note that although the ECA was officially adopted in 2010, enforcement of the ECA did not begin until August of 2012. Due in part to the higher cost of better quality fuel, it was assumed that no ships calling at Charleston in 2011 were complying with the ECA.

SCSPA requested that this inventory study include additional analyses to capture the benefit of the new ECA. For this reason, three additional cases were studied. All three cases use the 2011 data set for ship call data and vessel characteristics (e.g., activity levels and engine sizes stay the same) but change the assumed fuel type. The first case represents 2012, with a mixture of RO and marine diesel oil (MDO) fuels. The first 7 months use

RO, and the second 5 months use MDO, reflecting enforcement starting in August 2012. The second case assumes all MDO fuel, representative of years 2013-2015. The third case assumes all marine gas oil (MGO) fuel with 0.1% sulfur content, representative of years 2015 and beyond. This allows the SCSPA to estimate the emission reductions due to eventual compliance with the ECA.

For all 2011 summary tables in this report, the 100% residual oil case is used for OGV emissions. Although some portion of ships may be in early compliance with the ECA, it was assumed that it would be minimal because the higher quality fuels are more expensive.

2.5 Time in Mode Calculations

Load factors for ship engines vary depending on the mode the ship is in; modes include traveling at cruising speed, transiting in channels at reduced speed, maneuvering in and out of the berth and hotelling at berth. The variation in load for each engine category in each of these modes requires a separate emission calculation. The times in each mode for the ocean-going vessels transit legs (except for hotelling) were calculated by dividing the channel distances by assumed vessel speeds. Because the boundary for OGV emissions is the entrance to the channel (marked by the outer seabuoy, approximately twelve nautical miles from the breakwater), no cruising speed emissions are included in this inventory.

Reduced speed zone (RSZ) is the portion of the trip where the ship is transiting in the channels at less than cruising speed. Maneuvering is the leg of the journey in close proximity to the terminals where the vessels are slowing or accelerating and maneuvering into the berths.

Transit times within the boundary of the emissions inventory vary from roughly two to three hours depending on the terminal and type of vessel. On average, vessel transit times per trip were approximately two hours. Main engine load factors ranged from 60% to 2%, depending on the leg and vessel type. Main engine load factors were determined by using the propeller law (the cube of vessel speed in mode ÷ vessel maximum speed), see Section 2.6. Loads within the bay were typically in the 20-30% range.

This analysis does not account for any time vessels spend at anchor.

Table 2-4 summarizes the OGV travel distances, speeds, and times in mode for each terminal in the study. The letters BW stand for breakwater.

Table 2-4: OGV Transit Time in Mode

		Distance (nm)				Speed (knots)				Time in Mode (hrs) per Round Trip			
		Cruise	Reduced Speed Zone		Maneuver		Reduced Speed Zone				Reduced Speed Zone		
		Cruise	Outside BW	Inside BW	Maneuver	Cruise	Outside BW	Inside BW	Maneuver	Cruise	Outside BW	Inside BW	Maneuver
Union Pier	Container Ships	0	12.3	7.2	2	21.5	15	8	4	0.00	1.64	1.80	1.00
	Barges					9.4	9	6	4	0.00	2.73	2.40	1.00
	Ro-Ro					19.0	12	8	4	0.00	2.05	1.80	1.00
	Cruise					18.7	12	8	4	0.00	2.05	1.80	1.00
	Breakbulk					16.5	12	8	4	0.00	2.05	1.80	1.00
Columbus Street	Container Ships	0	12.3	7.9	2	21.5	15	8	4	0.00	1.64	1.98	1.00
	Barges					9.4	9	6	4	0.00	2.73	2.63	1.00
	Ro-Ro					19.0	12	8	4	0.00	2.05	1.98	1.00
	Cruise					18.7	12	8	4	0.00	2.05	1.98	1.00
	Breakbulk					16.5	12	8	4	0.00	2.05	1.98	1.00
Wando Welch	Container Ships	0	12.3	10.3	2	21.5	15	8	4	0.00	1.64	2.58	1.00
	Barges					9.4	9	6	4	0.00	2.73	3.43	1.00
	Ro-Ro					19.0	12	8	4	0.00	2.05	2.58	1.00
	Cruise					18.7	12	8	4	0.00	2.05	2.58	1.00
	Breakbulk					16.5	12	8	4	0.00	2.05	2.58	1.00
North Charleston	Container Ships	0	12.3	15.4	2	21.5	15	8	4	0.00	1.64	3.85	1.00
	Barges					9.4	9	6	4	0.00	2.73	5.13	1.00
	Ro-Ro					19.0	12	8	4	0.00	2.05	3.85	1.00
	Cruise					18.7	12	8	4	0.00	2.05	3.85	1.00
	Breakbulk					16.5	12	8	4	0.00	2.05	3.85	1.00
Veterans	Container Ships	0	12.3	12.2	2	21.5	15	8	4	0.00	1.64	3.05	1.00
	Barges					9.4	9	6	4	0.00	2.73	4.07	1.00
	Ro-Ro					19.0	12	8	4	0.00	2.05	3.05	1.00
	Cruise					18.7	12	8	4	0.00	2.05	3.05	1.00
	Breakbulk					16.5	12	8	4	0.00	2.05	3.05	1.00

Source: SCSPA 2005 Inventory, updated to include Veterans Terminal

Hotelling times were calculated using the actual arrival and departure times for each vessel call, as provided by SCSPA.

2.6 Main Engine Load Factor

Load factors for a ship's main engine are expressed as a percentage of the engine's total installed power. At service or cruise speeds, engine load is assumed to be 83%. At lower speeds, the propeller law is used to estimate the ship's propulsion load, based on the theory that the propulsion load varies by the cube of the ratio between actual and maximum speeds.

$$LF = (AS/MS)^3$$

Where LF = Load Factor (percent)
AS = Actual Speed (knots)
MS = Maximum Speed (knots)

Maximum speed for each vessel is taken from the Clarkson Register. The assumed actual speeds for various legs are given in Table 2-4 above, the time in mode table. Below a 20% load factor, a correction factor is applied to account for increased rate of emission per kW used at low load (see Table 2-9 in Section 2.9). This is done to account for the fact that propulsion engines do not operate efficiently at low loads and therefore create emissions at a higher rate during low load operation.

2.7 Auxiliary Engine Size & Load Factor

Ocean-going vessels have auxiliary engines which are used to generate electricity and run equipment such as lights, pumps, electronics, bow thrusters, etc. Auxiliary engine sizes are typically not available in the Clarkson Register. Therefore, auxiliary engine sizes were calculated using the average ratio of auxiliary engine to main engine size, as reported in the EPA Current Methodologies Report (ICFI, 2009). These ratios are given in Table 2-5 below.

Table 2-5: Factors for Auxiliary Engine Size

Ship Type	Ratio of Auxiliary to Main Engine Power
Container	0.22
Bulk	0.222
Cruise	0.278

Source: ICFI, 2009

Auxiliary engine load factors for the different ship types in different modes of operation are show in Table 2-6 below.

Table 2-6: Auxiliary Engine Sizes & Load Factors

Ship Type	RSZ	Maneuver	Hotel
Container	25%	48%	19%
Bulk	27%	45%	22%
Cruise	80%	80%	64%

Source: ICF, 2009

2.8 Boiler Load Factors

Boilers are used to generate hot water and to keep bunker fuel warm (required to maintain pumpable viscosity). While at sea, most vessels use exhaust gas heat recovery systems for these heating functions, but they must run the auxiliary boilers to generate the required heat when the main engines are running slowly (in channels) or are turned off (at berth). Auxiliary boiler data are not typically available in the Clarkson Register. Therefore, auxiliary boiler load data were taken from the Port of Los Angeles 2011 emissions inventory (Starcrest, 2012) as shown in Table 2-7 below.

Table 2-7: Boiler Loads

Ship Type	All Modes (kW)
Container	492
Bulk	132
Cruise	1,393

Source: Port of LA 2011 Emissions Inventory

2.9 Emission Factors

Emission factors for ocean-going vessels were taken from the EPA Current Methodologies Report (ICFI, 2009) and are given in Table 2-8 below. These emission factors are largely based on a July 2002 Entec study prepared for the European Commission. In this study, propulsion engines are assumed to burn residual fuel oil. Propulsion emission factors vary by engine speed and fuel type.

The fuel types included are bunker (RO) and marine diesel oil (MDO).

Table 2-8: OGV Main Engine Emission Factors (g/kW-hr)

Ship Speed	Fuel Type	Fuel Sulfur Content	NOx	CO	HC	PM10	PM2.5	SO2
SSD	RO	2.7%	18.10	1.40	0.60	1.42	1.31	10.29
MSD	RO	2.7%	14.00	1.10	0.50	1.43	1.32	11.24
SSD	MDO	1.0%	17.00	1.40	0.60	0.45	0.42	3.62
MSD	MDO	1.0%	13.20	1.10	0.50	0.47	0.43	3.97

Source: ICFI, 2009

Propulsion emissions at low loads are adjusted per the low load correction factors given in Table 2-9.

Table 2-9: OGV Maine Engine Low Load Adjustment Factors

Load	NOx	CO	HC	PM10	PM2.5	SO2
1%	11.47	19.32	59.28	19.17	19.17	5.99
2%	4.63	9.68	21.18	7.29	7.29	3.36
3%	2.92	6.46	11.68	4.33	4.33	2.49
4%	2.21	4.86	7.71	3.09	3.09	2.05
5%	1.83	3.89	5.61	2.44	2.44	1.79
6%	1.60	3.25	4.35	2.04	2.04	1.61
7%	1.45	2.79	3.52	1.79	1.79	1.49
8%	1.35	2.45	2.95	1.61	1.61	1.39
9%	1.27	2.18	2.52	1.48	1.48	1.32
10%	1.22	1.96	2.20	1.38	1.38	1.26
11%	1.17	1.79	1.96	1.30	1.30	1.21
12%	1.14	1.64	1.76	1.24	1.24	1.18
13%	1.11	1.52	1.60	1.19	1.19	1.14
14%	1.08	1.41	1.47	1.15	1.15	1.11
15%	1.06	1.32	1.36	1.11	1.11	1.09
16%	1.05	1.24	1.26	1.08	1.08	1.07
17%	1.03	1.17	1.18	1.06	1.06	1.05
18%	1.02	1.11	1.11	1.04	1.04	1.03
19%	1.01	1.05	1.05	1.02	1.02	1.01
20%	1.00	1.00	1.00	1.00	1.00	1.00

Source: ICFI, 2009

Auxiliary engines are all assumed to be medium speed diesels. Emission factors vary by fuel type and are given in Table 2-10. The fuel types included are bunker (RO) and marine diesel oil (MDO).

Table 2-10: OGV Auxiliary Engine Emission Factors (g/kW-hr)

Fuel Type	Fuel Sulfur Content	NOx	CO	HC	PM10	PM2.5	SO2
RO	2.7%	14.70	1.10	0.40	1.44	1.32	11.98
MDO	1.0%	13.90	1.10	0.40	0.49	0.45	4.24

Source: ICFI, 2009

Auxiliary boiler emission factors are summarized in Table 2-11.

Table 2-11: OGV Boiler Emission Factors (g/kW-hr)

Fuel Type	Fuel Sulfur Content	NOx	CO	HC	PM10	PM2.5	SO2
RO	2.7%	2.10	0.20	0.10	0.80	0.60	16.50
MDO	1.0%	1.89	0.20	0.10	0.38	0.28	9.16

Source: Port of Los Angeles 2011 Inventory (Starcrest, 2012)

2.10 Ocean-Going Tugs

Two ocean-going tugs, the *Resolve* and the *Integrity* (both operated by Crowley Marine) layberthed at Veterans Terminal in 2011. Layberthing is when a tug ties up at a berth while it is either between jobs or waiting for its next assignment. The tug's auxiliary engines are running while it is tied up, although the main engines are not running.

There were 38 instances of layberthing recorded in the ship call logs. The layberthing durations were recorded only in full day increments (likely a reflection of the billing procedure) however the tugs were probably tied up for less than 24 hours at a time. In this respect, this portion of the inventory is conservative in that it overestimates the layberthing emissions for these tugs.

Aside from layberthing at Veterans Terminal, there were no other instances of ocean-going tugs and barges calling at SCSPA in 2011.

Both of these tugs have two 454 hp (339 kW) Tier 2 auxiliary engines, although only one of the engines is running when they are tied up. The tugs burned ULSD fuel in 2011. This information was provided to SCSPA by the tug operator.

The assumed load factor during hotelling is 22% (ICF, 2009). The emission factors used are summarized in Table 2-12 below, and have been adjusted for ULSD fuel.

Table 2-12: Ocean-Going Tug Auxiliary Engine Emission Factors

Fuel Type	Fuel Sulfur Content	NOx	CO	HC	PM10	PM2.5	SO2
ULSD	15 ppm	6.80	1.50	0.27	0.26	0.25	0.01

Source: ICFI, 2009

3. Harbor Craft

Harbor craft emissions were estimated only for the harbor tugs involved in ship assist work for vessels calling on SCSPA's Charleston terminals. The tugs that layberth at Veterans Terminal were included with ocean going vessels because they are ocean-going tugs, not normal harbor tugs.

There are two main tug companies operating in the Charleston vicinity, McAllister Towing and Transportation and Moran Towing Corporation. SCSPA interviewed the tug operators and determined that all tugs were burning ultra low-sulfur diesel fuel (ULSD) in 2011.

3.1 Ship Assist Events

Assumptions for the harbor craft emissions are shown in Table 3-1 below. The calculation of tug time per vessel call assumes the tugs start and end each assist event at their home yard in the vicinity of Veterans Terminal and they meet and drop off vessels in the area of Shutes Folley Island.

Table 3-1: Harbor Craft Travel Distance and Speed Assumptions

						Tug Yard to Shutes Folley Is.		Shutes Folley Island to Terminal		Terminal to Tug Yard					
Terminal	Vessel Type	Number of calls	Avg # Sailing Tugs	Avg # Docking Tugs	Avg Tug Power (Kw)	Dist (nmi)	Speed (knts)	Dist (nmi)	Speed (knts)	Dist (nmi)	Speed (knts)	Manuevering Time At Berth (hrs)	Total Time per Tug per Vessel Trip (hrs)	Total Sailing Tug Hours	Total Docking Tug Hours
Columbus Sttreet	Container	6	1.7	1.8	3,357	5.00	8	1.40	8	4.50	8	0.50	1.86	19	20
	Barge	0	2.0	2.0	3,357	5.00	6	1.40	8	4.50	6	0.50	2.26	0	0
	Cruise	0	2.0	2.0	3,357	5.00	8	1.40	8	4.50	8	0.50	1.86	0	0
	Ro-Ro	0			3,357	5.00	8	1.40	8	4.50	8	0.50	1.86	0	0
	Breakbulk	225	2.0	2.0	3,357	5.00	8	1.40	8	4.50	8	0.50	1.86	838	838
North Charleston	Container	392	1.85	1.85	3,357	5.00	8	8.90	8	3.75	8	0.50	2.71	1,963	1,963
	Barge	0	2.0	1.9	3,357	5.00	6	8.90	8	3.75	6	0.50	3.07	0	0
	Cruise	0	0.0	0.0	3,357	5.00	8	8.90	8	3.75	8	0.50	2.71	0	0
	Ro-Ro	0	1.0	1.0	3,357	5.00	8	8.90	8	3.75	8	0.50	2.71	0	0
	Breakbulk	2	2.0	2.3	3,357	5.00	8	8.90	8	3.75	8	0.50	2.71	11	12
Union Pier	Container	0	0.0	0.0	3,357	5.00	8	0.70	8	5.25	8	0.50	1.87	0	0
	Barge	0	0.0	0.0	3,357	5.00	6	0.70	8	5.25	6	0.50	2.30	0	0
	Cruise	88	0.0	0.0	3,357	5.00	8	0.70	8	5.25	8	0.50	1.87	0	0
	Ro-Ro	0	1.5	1.6	3,357	5.00	8	0.70	8	5.25	8	0.50	1.87	0	0
	Breakbulk	35	1.8	1.8	3,357	5.00	8	0.70	8	5.25	8	0.50	1.87	118	118
Wando Welch	Container	890	2.0	2.0	3,357	5.00	8	3.8	8	5.25	8	0.50	2.26	4,016	4,016
	Barge	0	1.7	1.7	3,357	5.00	6	3.8	8	5.25	6	0.50	2.68	0	0
	Cruise	0	0.0	0.0	3,357	5.00	8	3.8	8	5.25	8	0.50	2.26	0	0
	Ro-Ro	0	0.0	0.0	3,357	5.00	8	3.8	8	5.25	8	0.50	2.26	0	0
	Breakbulk	0	0.0	0.0	3,357	5.00	8	3.8	8	5.25	8	0.50	2.26	0	0
Veterans	Container	0			3,357	5.00	8	3.8	8	5.25	8	0.50	2.26	0	0
	Barge	0			3,357	5.00	6	3.8	8	5.25	6	0.50	2.68	0	0
	Cruise	0	0.0	0.0	3,357	5.00	8	3.8	8	5.25	8	0.50	2.26	0	0
	Ro-Ro	0	0.0	0.0	3,357	5.00	8	3.8	8	5.25	8	0.50	2.26	0	0
	Breakbulk	28	2.0	2.0	3,357	5.00	8	3.8	8	5.25	8	0.50	2.26	126	126

Source: SCSPA 2005 Inventory, updated

Figure 3-1 shows the location of the tug operators (circled in yellow), the marine terminals (highlighted in red), and Shutes Folley Island.

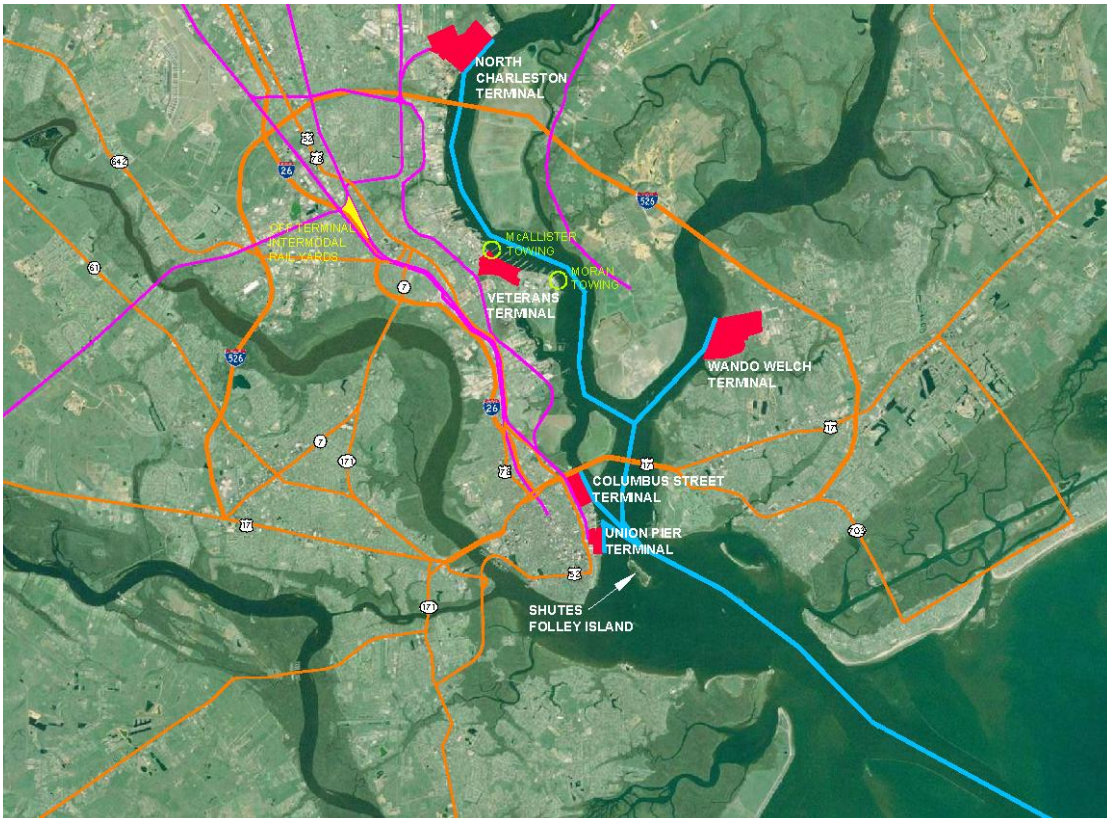


Figure 3-1: Location of Tug Companies, Terminals, and Shutes Folley Island
Source: SCSPA 2005 Inventory

3.2 Vessel Characteristics

Tug engine sizes specific to the Charleston fleet were looked up on the McAllister and Moran websites. Using this information, it was determined that a reasonable representative harbor tug has a Tier 1 engine with 4,500 hp.

The representative tug from the 2005 baseline inventory was assumed to be Tier 0 and 3,000 hp. That means the average tug engine size has increased over 50% over the last six years. This observation is consistent with the trend seen at other Atlantic coast ports and is a reflection of the larger vessels coming to the harbor.

Tug auxiliary engines were not included in this inventory, to be consistent with the 2005 baseline inventory.

3.3 Operating Hours

The total number of tug operating hours was calculated based on the speed, distance, and tug assignment assumptions shown in Table 3-1.

The number of assist tugs used by each vessel type is not necessarily the same for every single call. For example, sometimes containerships calling at North Charleston Terminal use two tugs, and sometimes just one. For 2011, it was discovered that cruise ships never use assist tugs (the baseline inventory assumed two tugs per cruise call).

The SCSPA, through interviews with the U.S. Army Corps of Engineers and tug fleet operators, was able to provide an estimate for the total annual working hours for the actual fleet of tug boats serving the Port of Charleston in 2011. M&N adjusted the number of tugs assigned to each vessel type in an effort to keep the overall methodology consistent with 2005 while at the same time using the available information on actual operating hours. The numbers of tugs per call were adjusted until the total operating hours predicted by the model matched the total operating hours reported by the tug operators.

Using this methodology, the total number of tug operating hours for 2011 was estimated to be approximately 17,300 hours.

3.4 Load Factors

The load factor for the tugs was assumed to be 31%, from the EPA Current Methodologies Report (ICFI, 2009). This load factor takes into account all the different modes of operation that a tug uses in one call (transiting to the meet up location, escorting the ship, actively berthing the ship, etc.). Accordingly, the single load factor is applied to the entire operating hours of the tugs.

3.5 Emission Factors

Emission factors for harbor craft were taken from the EPA Current Methodologies Report (ICFI, 2009) and are shown in Table 3-2 below. All tugs burned ULSD fuel in 2011.

Table 3-2: Harbor Craft Emission Factors (g/kw-hr)

Fuel Type	Fuel Sulfur Content	NOx	CO	HC	PM10	PM2.5	SO2
ULSD	15 ppm	9.8	1.10	0.475	0.619	0.601	0.007

Source: ICFI, 2009

4. Cargo Handling Equipment

4.1 Equipment List

Cargo handling equipment emissions were calculated for equipment exceeding 25 hp using EPA's NONROAD 2008 emissions model and the equipment list and 2011 operating hours provided by SCSPA. A summary of the equipment list and operating hours is given in Table 4-1 below. Emissions calculations were performed for each piece of equipment. Fuel types included diesel and liquid propane gas (LPG).

Table 4-1: CHE Summary by Terminal

Equipment Type	Number	Avg hp	Avg hrs	Total hrs	Avg Model Year	Avg Age
Columbus Street Terminal						
Container Handler, Full	6	271	72	433	1997	14
Crane, RTG	3	558	148	443	1999	12
Backhoe/Tractor	6	90	258	1,550	1997	14
Forklift	48	112	176	8,426	1998	13
North Charleston Terminal						
Container Handler, Full	24	293	1,069	25,653	1999	12
Crane, RTG	10	558	1,852	18,522	1996	15
Container Handler, Empty	5	231	1,497	7,486	2004	7
Forklift	20	89	637	12,737	1997	14
Assumed Avg Hostler	19	164	2,800	53,508	2009	3
Union Pier Terminal						
Forklift	19	76	312	5,924	1999	12
Wando Welch Terminal						
Container Handler, Full	18	279	2,026	36,467	1998	13
Crane, RTG	30	535	1,254	37,628	2004	7
Container Handler, Empty	12	218	1,544	18,528	2001	10
Forklift	35	101	305	10,679	1993	18
Assumed Avg Hostler	9	173	2,800	24,730	2011	0
Veterans Terminal						
Backhoe/Tractor	1	262	604	604	1994	17
Forklift	8	130	410	3,279	1994	17

Source: SCSPA data

4.2 Hours of Operation

For the 2011 inventory, the SCSPA provided hours of operation for all equipment types except yard tractors based on maintenance records.

The yard tractors, or hostlers, are not operated by SCSPA. The annual hours for the entire fleet of hostlers were provided by SCSPA for each terminal where hostlers were used. The number of hostlers was calculated by dividing the estimated annual operating hours for the hostler fleet by the average annual hours per hostler from other ports.

The hostler horsepower was determined from manufacturer specifications based on the equipment descriptions provided by SCSPA. The hostler equipment age was also based on the information provided by SCSPA. Where the hostler age was not available, the age was based on a similar age as the baseline inventory in 2005 and assumes turnover of the fleet towards newer equipment.

4.3 Load Factors

Default load factors from the EPA's NONROAD 2008 model were used for CHE based on the applied EPA source classification code (SCC). Professional judgment and experience were used to apply the EPA SCC's to various types of cargo handling equipment to be consistent with previous inventories.

Load factors are an area where there is likely to be room for refinement in port inventories as the NONROAD default load factors may not represent actual operating conditions for CHE. For recent Port of Long Beach and Port of Los Angeles emission inventories, a joint study was conducted to determine the load factors for yard tractors (hostlers) and RTG Cranes under normal operating cycles. Based on the results of this study, the load factors for yard tractors and RTG cranes were reduced in consultation with the California Air Resources Board. However, given the established practice of using default NONROAD load factors in previous port inventories, it was decided to maintain that practice for consistency sake and leave the refinement of load factors for future application if/when it is found to be an acceptable practice by the appropriate regional resource agencies.

4.4 NONROAD Model Runs

The NONROAD model runs were accomplished through the use of detailed spreadsheets using the EPA NONROAD 2008 model input files and various lookup functions to:

- Assign the proper Tier for an engine based on its model year and engine size (hp).
- Assign the proper brake specific fuel consumption and zero hour emission factors based on the engines' SCC, horsepower range and Tier. These emission factors have the transient adjustment factors built into them based on the SCC to take into account the transient nature of various engine applications.
- Assign the proper NONROAD load factor based on the SCC.
- Calculate the proper deterioration factor based on assumed hours on the engine (age multiplied by NONROAD's median annual hours for that SCC), the median life hours at full load for that SCC and the appropriate shape factor. Deterioration factors account

for the fact that engines generally emit more as they get older up to a certain point, at which time it is assumed the engine is rebuilt with fresh rings, etc.

- Calculate SO2 emission factors based on the brake specific fuel consumption and assumed fuel sulfur content as given by NONROAD depending on the year of analysis. Note that all CHE at the Port of Charleston is fueled by ultra-low sulfur (15 ppm) diesel fuel so the NONROAD inputs were revised to reflect this.
- Adjust the PM emission factors based on the variance between the sulfur content in the fuel and the assumed sulfur content upon which the NONROAD emission factor is based.

The end result is a calculation of emissions for each piece of equipment. The general equation for the emissions calculation is:

Emissions = (Installed hp) x (Annual hours of operation) x (Load factor) x (Adjusted emission factor)

The above emissions equation is applied for each individual pollutant included in the inventory.

5. Rail Locomotives

5.1 Locomotive Hours

Locomotive hours for both switcher and line-haul locomotives associated with work at the Port of Charleston terminals were included in this analysis. Locomotive hours and engine information for switchers operating at the Port's terminals were provided to the SCSPA by SCPR. Line haul locomotive hours were estimated for the percentage of containerized port cargo or other project cargo that entered or left the Port through the nearby NS or CSX intermodal rail yards. Line haul locomotive activity was developed based on the number of trains of a given length needed to accommodate the estimated rail cargo throughput. Line haul emissions are split between off-terminal operations and on-terminal operations. Line haul emissions are based on the estimated number of trains per year, assumed average rail speed and distance to the Tri-County boundary.

None of the locomotive activities (idling, switching or cargo handling) within the local NS or CSX intermodal terminals were included in this inventory.

5.2 Locomotive Characteristics

Switcher locomotive horsepower is based on the engine information provided to the SCSPA by the SCPR. Line haul locomotive characteristics are based on typical line-haul locomotives currently in use by NS and CSX to move freight into/out of their local Charleston intermodal yards.

5.3 Locomotive Emission Factors

Locomotive emission factors are based on a detailed analysis of the 1998 Locomotive Emission Standards Regulatory Support Document in combination with the updated emission factors included in the EPA Fact Sheet "Emission Factors for Locomotives," published in April 2009. The procedure for determining load factors for locomotives is different from that used for other sources. The current practice in the literature is to calculate a load factor for each of ten engine settings (dynamic braking, idling, and eight notch positions). Composite load factors are developed based on a percentage of time in each notch for typical switching and line haul activity. All SCPR switcher engines and NS or CSX line-haul engines operating at their local yards or at the Port's terminals in 2011 used ultra-low sulfur diesel.

Rail assumptions used in the locomotive emissions estimates are shown in Table 5-1 below.

Table 5-1: Rail Assumptions Summary

SOUTH CAROLINA STATE PORT AUTHORITY (SCSPA) 2011 Rail Emissions														
				2011										
Line Haul		**Tier 0**							**Emission Factors (g/hp-hr)**					
	Train Arrival/Departure		No. of Trains	No. Locomotives	Speed (mph)	Avg Dist To Tri-County Border (mi)	HP per Locomotive	Annual Locomotive Hours	NOx	PM10	PM2.5	HC	CO	SO2
	Line-Haul Locomotive (Off-Terminal)		**691**	4	40.0	35	4,000	2,419	8.60	0.32	0.31	0.48	1.28	0.005
	Line-Haul Locomotive (On-Terminal)		**691**	4			4,000	1,382	8.60	0.32	0.31	0.48	1.28	0.005
	Total Line Haul													
Switcher		**Tier 0**							**Emission Factors (g/hp-hr)**					
	Train Arrival/Departure						HP per Locomotive	Annual Locomotive Hours	NOx	PM10	PM2.5	HC	CO	SO2
	Locomotive Switch Engine (PUC to CST & UPT)						1,000	1,455.0	12.60	0.44	0.43	1.01	1.83	0.006
	Locomotive Switch Engine (PTR to NCT & VT)						1,750	45.0	12.60	0.44	0.43	1.01	1.83	0.006
	Total Switching							1,500						
	Switcher engine hours - operating hours and fuel usage provided by SCSPA													
	Line-Haul Op:	Norfolk Southern; CSX												
	Number of train trips to/from Charleston are based on TEU assumption of 18% average boxes to rail													
		Total Annual TEU	Annual Rail TEU Estimate	TEU per Train	No. of Trains									
	2011	1,382,061	248,771	360	691									

Source: SCSPA 2005 Inventory, updated for 2011

6. Heavy Duty Vehicles

Emissions were calculated for a total of nearly 1.7 million truck trips and forty-three million vehicle miles including the number of truck trips associated with the movement of containerized cargo as well as the reported number of breakbulk truck trips at each terminal. Truck and rail trips associated with ro-ro cargo that were not included in the reported breakbulk truck trips are not included in this inventory. The containerized cargo truck trips are by far the dominant component of truck trips and truck emissions, representing over 98% of the estimated vehicle miles traveled. Given the relative throughput volumes of container to ro-ro cargo, excluding ro-ro truck and rail trips is not expected to have a significant impact on total emissions estimates.

6.1 Truck Trips

The number of truck trips for 2011 was provided by SCSPA for each terminal, as shown in Table 6-1 below.

Table 6-1: Count of Truck Visits by Terminal

Terminal	Number of Truck Visits
Columbus Street	202
North Charleston	317,524
Wando Welch	511,779
Union Pier – trucks	6,787
Union Pier – buses	10,200
Veterans	4,145

In the previous inventory, the number of truck trips was estimated using one of M&N's proprietary spreadsheet models. For 2011, the number of truck trips was based on recorded data.

The Union Pier cruise terminal had passenger bus trips in addition to trucks. The buses made shuttle runs between the parking lot and the terminal, a distance of one mile. According to SCSPA, there were 10 buses, each making 15 round trips per call of the *Carnival Fantasy*. In 2011 the *Carnival Fantas*y called 68 times (of the 88 total cruise ship calls).

6.2 Truck Trip Origin and Destination Distribution and Distances

The destination of trucks with containers was divided among local rail yards, destinations within the local Charleston area, and outside the Tri-County area using the 18% local rail factor provided by SCSPA and data from the 2002 Wilbur Smith study to apportion the remaining containers. The resulting distribution is shown in Table 6-2 below.

Table 6-2: Origin & Destination Splits for Trucks with Containers

Taken from Exhibit 2-6 of Wilbur Smith & Associates (March 2002)				
Origin/Destination Summary	Local Rail Yards	Charleston	Other South Carolina	Out of state
Record Search	27.8%	18.1%	15.1%	39.0%
Telephone	12.0%	15.9%	17.5%	54.6%
Weighted Average	22.9%	17.5%	15.8%	43.8%
Split removing rail yards (in order to use updated rail %)				
		22.7%	20.5%	56.8%
			77.3%	
	Given Rail Split	Local Charleston	Out of Tri-County	
	18.0%	18.6%	63.4%	

Source: SCSPA 2005 Inventory

South Carolina destinations outside of Charleston were added to out of state destinations for a total split of 18% local rail yards, 18.6% within local Charleston, and 63.4% outside the Tri-County area.

Table 6-3 summarizes the average travel distances between each terminal and each origin or destination for each type of truck trip.

Table 6-3: Average Travel Distances for Each Type of Truck Trip

Travel Distances Applied to Trucktrips				Distance (miles) to/from Terminal			
	Truck Type	% Split	Origin/Destination	Union Pier	Columbus Street	North Charleston	Wando Welch
Containerized	Loads & Empties	18.0%	Offsite Railyards	7.00	6.00	5.50	12.75
		18.6%	Local Charleston	15.30	14.30	9.75	16.50
		63.4%	Out of Tri-County	51.00	50.00	40.00	52.00
	Bobtails	100.0%	Ashley P west of 26	12.30	11.30	6.75	13.50
	Chasis	100.0%	Offsite Railyards	7.00	6.00	5.50	12.75

Source: SCSPA 2005 Inventory

The number of each type of truck trip was calculated for each terminal based on the 2011 throughput at each terminal. The appropriate distances were applied for each truck trip type at each terminal. The results indicate that 1.659 million truck trips generated slightly under 43 million vehicle miles traveled.

For Union Pier, the percentages and travel distances are different from those shown in Table 6-3 because the terminal is being used differently from 2005. Most of the truck trips in 2011, 6,423 trips, were to a terminal located 10 miles away. The remaining 364 truck trips were cruise ship supply trucks coming from warehouses approximately 15 miles away. As previously stated, buses at Union Pier were making shuttle trips to/from a parking lot one mile away.

For Veterans Terminal, which did not have any truck trips in 2005 and is therefore not shown in Table 6-3, about 56% of trips were going out of the Tri-County area (45 mile travel distance), 41% were carrying gravel to the airport for an expansion project (5 mile travel distance), and the remaining 3% of trips were to various local markets (assumed 25 mile travel distance).

6.3 On-Terminal Truck Time

The on-terminal time for trucks consists of the time spent idling at the gate and idling while being serviced inside the terminal. On-terminal truck idling time was estimated to be 0.2 hours (12 minutes) per trip and did not include creep idle or transit within the terminal.

The passenger buses at Union Pier were assumed to idle on the terminal for 10 minutes per round trip, according to SCSPA guidance.

6.4 Off-Terminal Truck Trip Time of Day and Segment Speeds

Truck paths and speeds were developed from a detailed analysis of cargo destinations for the 1.659 million truck trips in 2011. For this inventory, trips were not broken down by time of day (weekday AM rush hour, weekday PM rush hour, weekday non-rush hour, and weekend) or by segments at different speeds as they were in the 2005 inventory. This is because the previous inventory used a different model (MOBILE 6.2) which provided different emission rates for different driving speeds and conditions.

For this inventory, the MOVES model produces emission rates (lbs/mile) that represent average rates over a typical range of driving speeds and conditions. These rates are applied to the entire travel distance, not broken up by segments.

6.5 Emission Rates

Emission rates for over the road trucks were developed using EPA's MOVES 2010b modeling software. They were calculated in pounds per mile for diesel fuel combination short-haul trucks and are based on selected road types. Emission factors for trucks vary widely by model year. MOVES 2010b provides a default distribution of model years based on the year of analysis. The default model year distribution was used since no better data were available. For 2011, the vehicle model years ranged from 1981 to 2011.

7. Emission Results

Summary results for the 2011 emissions inventory are presented in this section. Results of the emission calculations can be broken out by source, mode, pollutant, terminal, and location (on-terminal vs. off-terminal) in a variety of different ways.

7.1 All Sources

Table 7-1 summarizes the total 2011 emission results, listing tons of emissions of the six pollutants by the five different source categories.

Table 7-1: Summary Mass Emission Results for 2011 (tons)

	NOx	CO	HC	PM10	PM2.5	SO2
OGV	1,560.4	174.0	94.2	187.7	170.4	1,493.2
Tugs	194.2	21.8	9.4	12.3	11.9	0.1
Trucks	540.8	128.7	21.9	22.2	21.6	0.6
Rail	42.2	6.3	2.4	1.6	1.5	0.0
CHE	114.4	62.4	9.6	7.8	7.6	0.2
Total	**2,451.9**	**393.1**	**137.5**	**231.6**	**213.0**	**1,494.1**

Any small discrepancies in the totals are due to rounding.

Figure 7-1 shows the percent each source contributes to overall Port emissions. This chart clearly illustrates that OGV are the primary source of emissions at the Port. The second biggest source is trucks, followed by CHE and tugs. Rail is the smallest source.

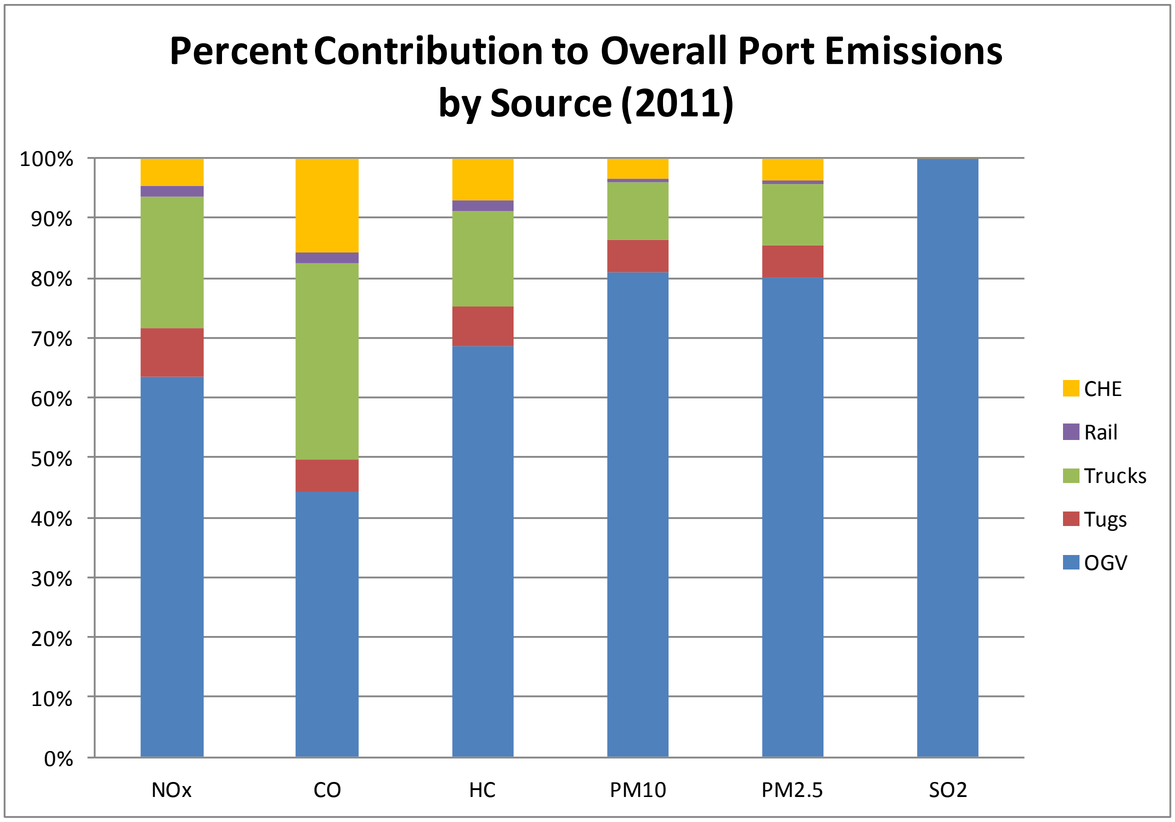


Figure 7-1: Total Emissions by Source Category

Figure 7-2 is similar to the bar chart above, but focuses on NOx and PM which are typically the pollutants of most concern. Again, these highlight that OGV are the biggest source of emissions, and rail is the smallest.

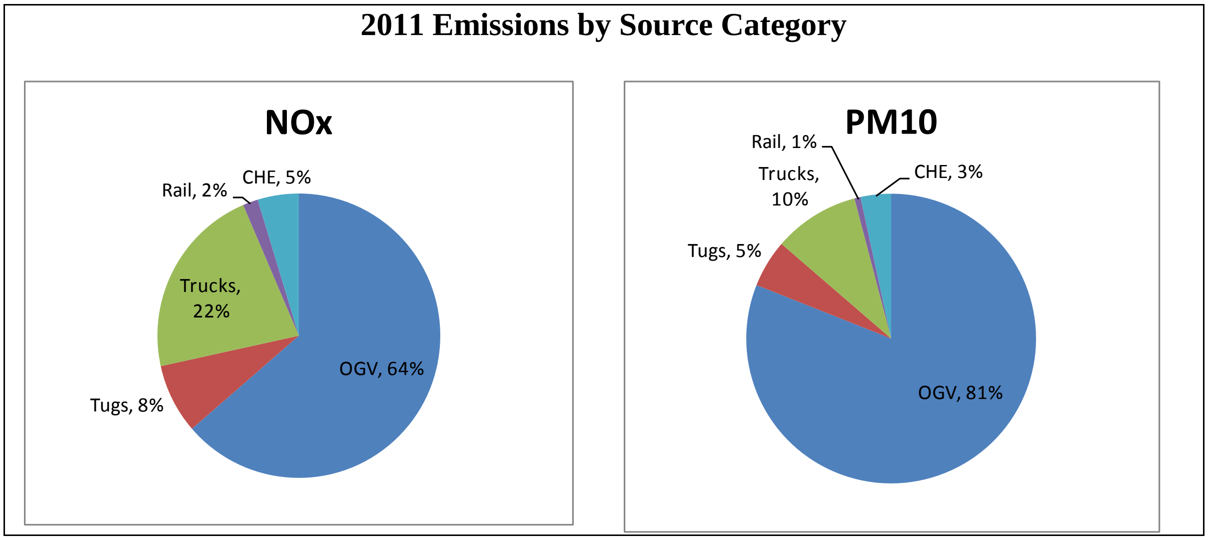


Figure 7-2: NOx and PM Emissions by Source

7.2 Ocean Going Vessels

The 2011 ocean-going vessel emissions are shown in Table 7-2. This table divides the emissions by terminal and ship type. It also summarizes emissions by on- and off-terminal. Hotelling is considered on-terminal and transit and maneuvering are considered off-terminal.

Table 7-2: OGV Emissions Results by Terminal and Ship Type

		Columbus Street	North Charleston	Union Pier	Wando Welch	Veterans	**Off-Terminal**			**On-Terminal**	**Total**
		Total	Total	Total	Total	Total	Transit	Maneuv.	Subtotal Offsite	Hotel	
Container Ships	NOx	9.46	358.98	0.00	871.39	0.00	703.73	154.01	857.74	382.08	**1239.82**
	CO	0.86	42.49	0.00	101.24	0.00	86.86	21.71	108.56	36.03	**144.59**
	HC	0.39	24.05	0.00	56.71	0.00	51.22	16.58	67.80	13.35	**81.15**
	PM10	1.09	43.99	0.00	106.43	0.00	78.78	20.56	99.34	52.16	**151.50**
	PM2.5	0.98	39.88	0.00	96.71	0.00	72.17	18.82	90.99	46.58	**137.57**
	SO2	10.08	344.36	0.00	823.06	0.00	531.48	120.50	651.98	525.51	**1177.49**
Cruise	NOx	0.00	0.00	201.66	0.00	0.00	78.39	15.23	93.62	108.04	**201.66**
	CO	0.00	0.00	16.87	0.00	0.00	6.45	1.57	8.02	8.85	**16.87**
	HC	0.00	0.00	7.19	0.00	0.00	2.85	1.07	3.93	3.26	**7.19**
	PM10	0.00	0.00	22.16	0.00	0.00	7.82	1.86	9.68	12.48	**22.16**
	PM2.5	0.00	0.00	20.07	0.00	0.00	7.16	1.69	8.85	11.22	**20.07**
	SO2	0.00	0.00	197.53	0.00	0.00	64.20	13.15	77.35	120.18	**197.53**
Breakbulk/Vehicle Carriers/Ro-Ro/Other	NOx	86.22	0.71	13.15	0.00	17.96	55.59	11.00	66.60	51.43	**118.03**
	CO	9.09	0.08	1.41	0.00	1.77	6.04	1.54	7.58	4.78	**12.36**
	HC	4.35	0.04	0.68	0.00	0.75	2.87	1.19	4.06	1.77	**5.82**
	PM10	10.12	0.09	1.53	0.00	2.27	5.73	1.46	7.20	6.83	**14.02**
	PM2.5	9.19	0.08	1.39	0.00	2.05	5.26	1.34	6.60	6.12	**12.72**
	SO2	83.79	0.77	12.39	0.00	21.21	42.52	8.41	50.93	67.24	**118.16**
Ocean Going Tug	NOx	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.00	0.91	**0.91**
	CO	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.20	**0.20**
	HC	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	**0.04**
	PM10	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03	**0.03**
	PM2.5	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03	**0.03**
	SO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Total	NOx	95.7	359.7	214.8	871.4	18.9	837.7	180.2	1,018.0	542.5	**1,560.4**
	CO	10.0	42.6	18.3	101.2	2.0	99.3	24.8	124.2	49.9	**174.0**
	HC	4.7	24.1	7.9	56.7	0.8	56.9	18.8	75.8	18.4	**94.2**
	PM10	11.2	44.1	23.7	106.4	2.3	92.3	23.9	116.2	71.5	**187.7**
	PM2.5	10.2	40.0	21.5	96.7	2.1	84.6	21.8	106.4	63.9	**170.4**
	SO2	93.9	345.1	209.9	823.1	21.2	638.2	142.1	780.3	712.9	**1,493.2**

Figure 7-3 shows the relative contribution of the various modes of operation of the OGVs including transiting through the channels (RSZ), maneuvering, and hotelling while at berth.

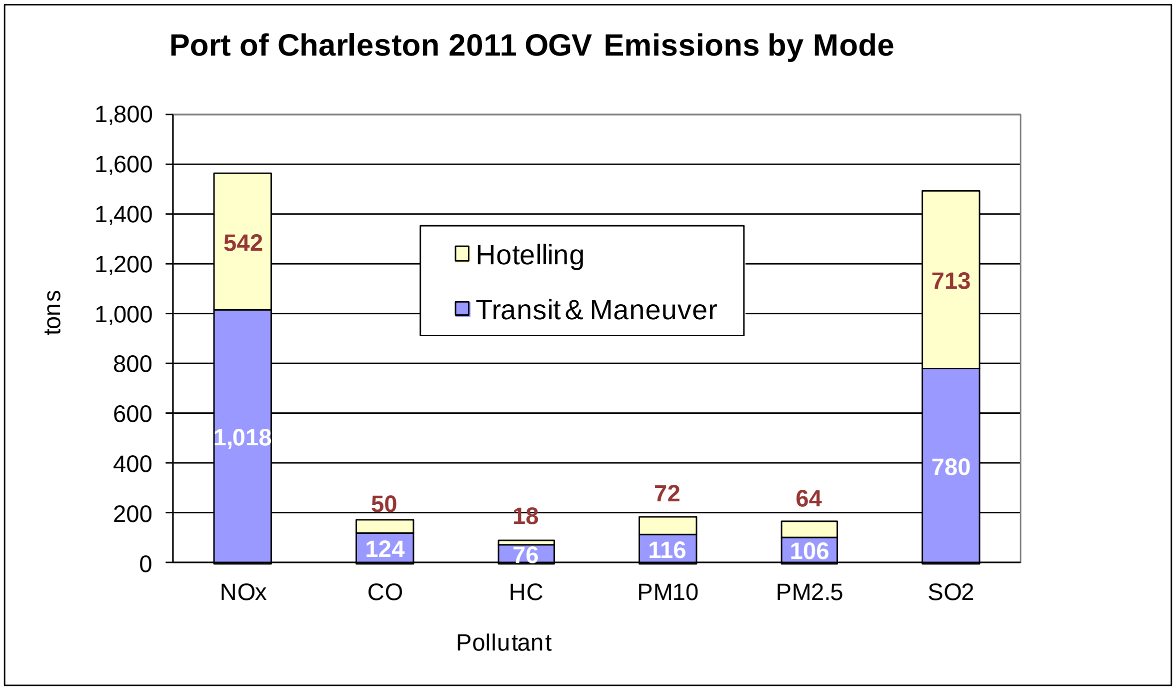


Figure 7-3: OGV Emissions by Mode

Figure 7-4 shows the location of OGV emissions, as either on- or off-terminal. This graph shows that hotelling accounts for between 20% and 48% of ship emissions, depending on the pollutant. Almost half of SO2 emissions occur at berth.

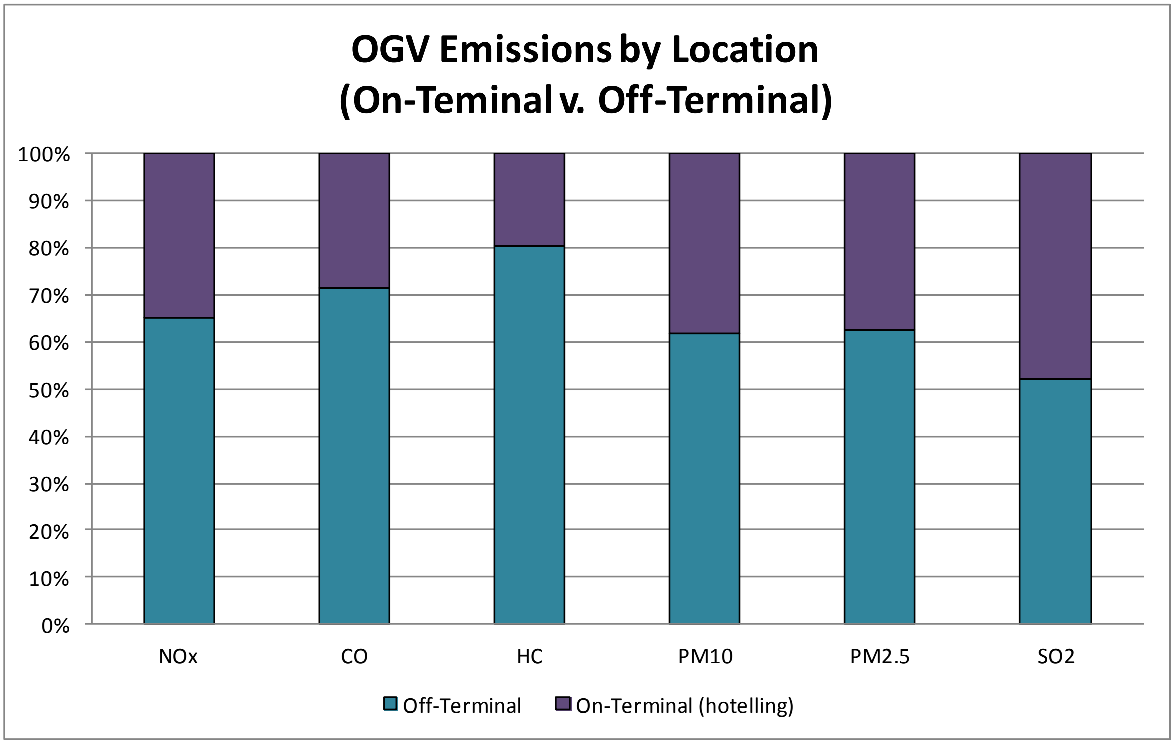


Figure 7-4: OGV Emissions by Location

All OGV hotelling emissions are caused by the ships' auxiliary engines. If the engines could be shut down while at berth, this source would go down to almost zero.

7.3 Harbor Craft

Total harbor craft emissions are summarized in Table 7-3 below by terminal and call type.

Table 7-3: Harbor Craft Emissions Results

		2011 Emissions (tons per year)					
Terminal	Vessel Type	NOx	CO	HC	PM10	PM2.5	SO2
Columbus Street	Container	0.56	0.06	0.03	0.04	0.03	0.00
	Barge	0.00	0.00	0.00	0.00	0.00	0.00
	Cruise	0.00	0.00	0.00	0.00	0.00	0.00
	Ro-Ro	0.00	0.00	0.00	0.00	0.00	0.00
	Breakbulk & Other	23.90	2.68	1.16	1.51	1.46	0.02
		24.46	**2.75**	**1.19**	**1.55**	**1.50**	**0.02**
North Charleston	Container	52.28	5.87	2.53	3.30	3.20	0.03
	Barge	0.00	0.00	0.00	0.00	0.00	0.00
	Cruise	0.00	0.00	0.00	0.00	0.00	0.00
	Ro-Ro	0.00	0.00	0.00	0.00	0.00	0.00
	Breakbulk & Other	0.31	0.03	0.02	0.02	0.02	0.00
		52.59	**5.90**	**2.55**	**3.32**	**3.22**	**0.03**
Union Pier	Container	0.00	0.00	0.00	0.00	0.00	0.00
	Barge	0.00	0.00	0.00	0.00	0.00	0.00
	Cruise	0.00	0.00	0.00	0.00	0.00	0.00
	Ro-Ro	0.00	0.00	0.00	0.00	0.00	0.00
	Breakbulk & Other	3.36	0.38	0.16	0.21	0.21	0.00
		3.36	**0.38**	**0.16**	**0.21**	**0.21**	**0.00**
Wando Welch	Container	110.31	12.38	5.34	6.97	6.76	0.07
	Barge	0.00	0.00	0.00	0.00	0.00	0.00
	Cruise	0.00	0.00	0.00	0.00	0.00	0.00
	Ro-Ro	0.00	0.00	0.00	0.00	0.00	0.00
	Breakbulk & Other	0.00	0.00	0.00	0.00	0.00	0.00
		110.31	**12.38**	**5.34**	**6.97**	**6.76**	**0.07**
Veterans	Container	0.00	0.00	0.00	0.00	0.00	0.00
	Barge	0.00	0.00	0.00	0.00	0.00	0.00
	Cruise	0.00	0.00	0.00	0.00	0.00	0.00
	Ro-Ro	0.00	0.00	0.00	0.00	0.00	0.00
	Breakbulk & Other	3.47	0.39	0.17	0.22	0.21	0.00
		3.47	**0.39**	**0.17**	**0.22**	**0.21**	**0.00**
Total	Container	163.15	18.31	7.90	10.31	10.00	0.11
	Tug & Barge	0.00	0.00	0.00	0.00	0.00	0.00
	Cruise	0.00	0.00	0.00	0.00	0.00	0.00
	Ro-Ro	0.00	0.00	0.00	0.00	0.00	0.00
	Breakbulk & Other	31.04	3.48	1.50	1.96	1.90	0.02
	Total	**194.19**	**21.80**	**9.41**	**12.27**	**11.90**	**0.13**

Figure 7-5 shows the contribution each terminal makes toward total harbor craft emissions
.

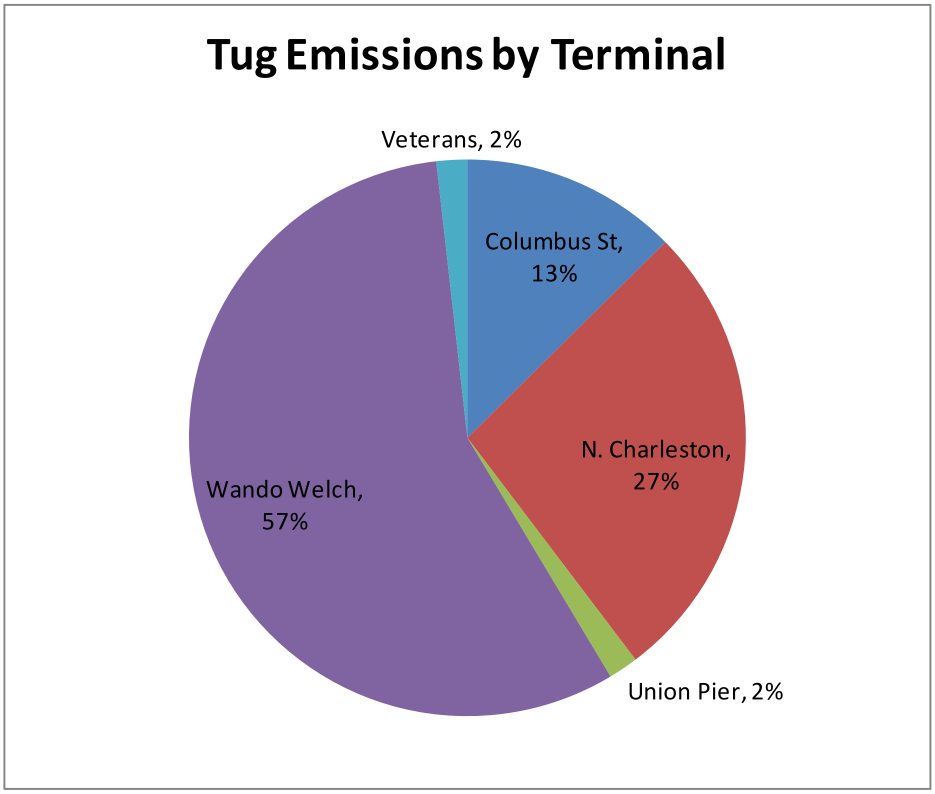


Figure 7-5: Harbor Craft Emissions by Terminal

7.4 Cargo Handling Equipment

Table 7-4 summarizes the CHE emissions results by pollutant and type of equipment.

Table 7-4: CHE Emissions Results, All Terminals and All Fuels

	Num.	Avg. hp	Total hrs	NOx	CO	HC	PM10	PM2.5	SO2
Container Handler, Full	48	285	62,554	24.1	7.3	1.5	1.3	1.2	0.0
Crane, RTG	43	542	56,593	28.9	15.5	2.7	1.8	1.8	0.0
Container Handler, Empty	17	222	26,014	14.0	2.5	0.9	0.7	0.7	0.0
Backhoe/Tractor	7	115	2,154	0.6	0.6	0.1	0.1	0.1	0.0
Forklift	182	94	54,867	20.8	24.8	2.3	1.7	1.7	0.0
Yard Tractor (Hostler)	28	167	78,238	26.0	11.6	2.1	2.2	2.2	0.0
Total	**346**		**280,420**	**114.4**	**62.4**	**9.6**	**7.8**	**7.6**	**0.2**

It is important to note that all the container cranes were electric in 2011. They are not included in the list above because without diesel engines they create no emissions at the Port.

Figure 7-6 below shows how the different types of equipment contribute to total CHE NOx and PM emissions (the two pollutants typically of most concern).

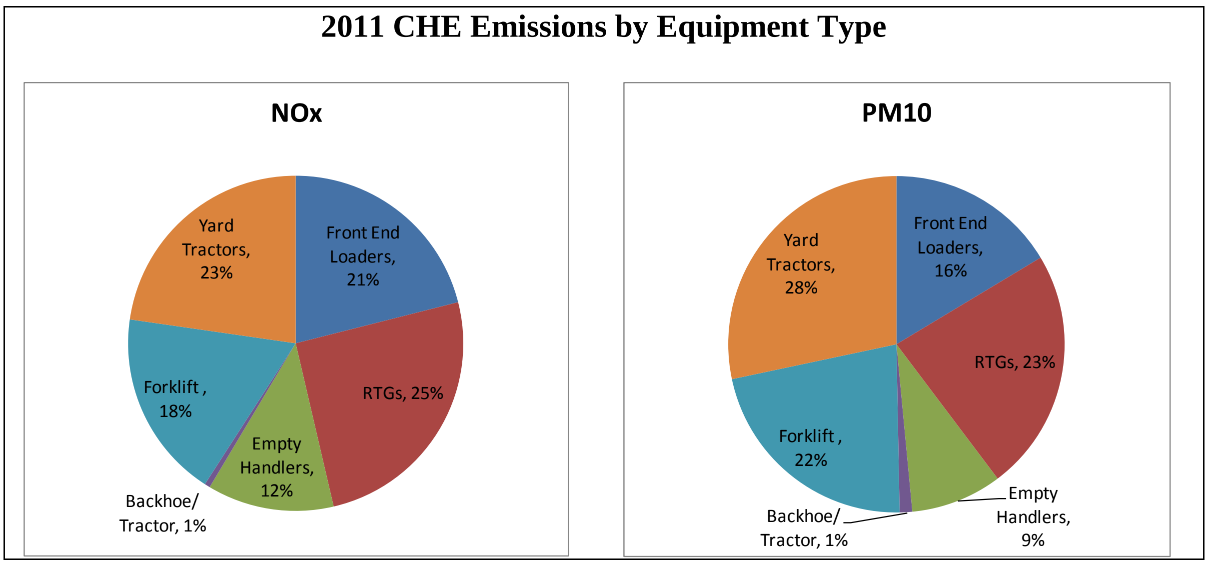


Figure 7-6: NOx and PM10 Emissions by Equipment Type

7.5 Rail Locomotives

Table 7-5 summarizes the rail emissions for 2011.

Table 7-5: RL Emissions Results

SOUTH CAROLINA STATE PORT AUTHORITY (SCSPA) 2011 Baseline Rail Emissions													
			2011										
Line Haul	Tier 0							Line Haul Emissions (tons)					
Train Arrival/Departure		No. of Trains	No. Locomotives	Speed (mph)	Avg Dist To Tri-County Border (mi)	HP per Locomotive	Annual Locomotive Hours	NOx	PM10	PM2.5	HC	CO	SO2
Line-Haul Locomotive (Off-Terminal)		691	4	40.0	35	4,000	2,419	25.46	0.95	0.92	1.42	3.79	0.01
								25.46	0.95	0.92	1.42	3.79	0.01
Line-Haul Locomotive (On-Terminal)		691	4			4,000	1,382	14.55	0.54	0.53	0.81	2.17	0.01
								14.55	0.54	0.53	0.81	2.17	0.01
Total Line Haul								40.02	1.49	1.44	2.23	5.96	0.02
Switcher	Tier 0							Switcher Emissions (tons)					
Train Arrival/Departure						HP per Locomotive	Annual Locomotive Hours	NOx	PM10	PM2.5	HC	CO	SO2
Locomotive Switch Engine (PUC to CST & UPT)						1,000	1,455.0	2.04	0.07	0.07	0.16	0.30	0.00
Locomotive Switch Engine (PTR to NCT & VT)						1,750	45.0	0.11	0.00	0.00	0.01	0.02	0.00
Total Switching							1,500	2.15	0.08	0.07	0.17	0.31	0.001
							Totals	**42.17**	**1.56**	**1.52**	**2.41**	**6.27**	**0.02**
Switcher engine hours - operating hours and fuel usage provided by SCSPA													
Line-Haul Op:	Norfolk Southern; CSX												
Number of train trips to/from Charleston are based on TEU assumption of 18% average boxes to rail													
	Total Annual TEU	Annual Rail TEU Estimate	TEU per Train	No. of Trains									
2011	1,382,061	248,771	360	691									

The emissions results for each pollutant are presented by locomotive type (switcher or line haul) in Figure 7-7 below. All switcher emissions are created on-terminal. Line haul engines are assumed to work on-terminal for a half hour per trip. The rest of their emissions are created off-terminal.

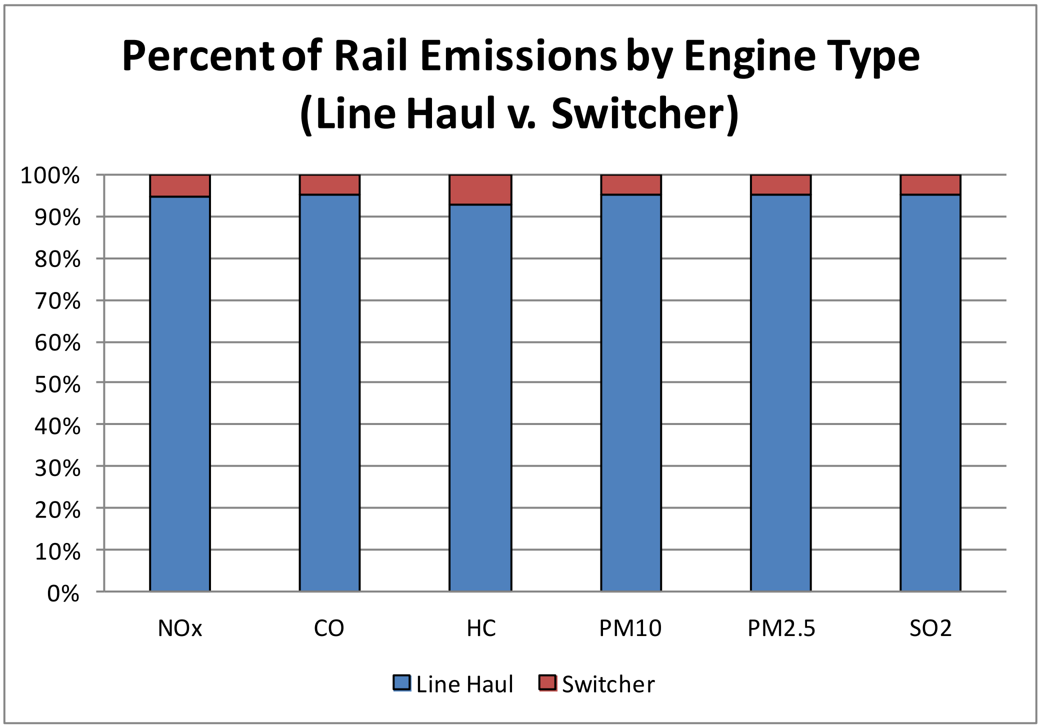


Figure 7-7: Percent of Rail Emissions by Engine Type (Line Haul v. Switcher)

7.6 Heavy Duty Vehicles

Table 7-6 lists the truck emissions for 2011 by terminal and location (either on- or off-terminal). On-terminal emissions refer to the idling time spent at the gate and waiting for service once on the terminal.

Table 7-6: Truck Emissions Results (tons)

Terminal	NOx	PM10	PM2.5	HC	SO2	CO
CS on terminal	0.003	0.000	0.000	0.000	0.000	0.001
CS off terminal	0.137	0.006	0.005	0.006	0.000	0.033
Total	**0.140**	**0.006**	**0.006**	**0.006**	**0.000**	**0.033**
NC on terminal	4.625	0.154	0.148	0.143	0.002	1.139
NC off terminal	168.227	6.944	6.736	6.844	0.203	39.992
Total	**172.852**	**7.098**	**6.884**	**6.987**	**0.205**	**41.132**
WT on terminal	7.454	0.247	0.239	0.231	0.004	1.836
WT off terminal	355.419	14.671	14.231	14.460	0.429	84.493
Total	**362.873**	**14.918**	**14.470**	**14.691**	**0.433**	**86.329**
VT on terminal	0.060	0.002	0.002	0.002	0.000	0.015
VT off terminal	2.800	0.116	0.112	0.114	0.003	0.666
Total	**2.860**	**0.118**	**0.114**	**0.116**	**0.003**	**0.680**
UP on terminal	0.099	0.003	0.003	0.003	0.000	0.024
UP off terminal	1.708	0.071	0.068	0.069	0.002	0.406
UP off terminal - BUSES	0.227	0.014	0.014	0.013	0.000	0.062
Total	**2.034**	**0.088**	**0.085**	**0.085**	**0.002**	**0.492**
Total on terminal	12.241	0.406	0.393	0.379	0.006	3.015
Total off terminal	528.291	21.807	21.153	21.493	0.638	125.590
Total	**540.759**	**22.227**	**21.559**	**21.885**	**0.644**	**128.667**

Table 7-7 shows the same emissions results, normalized to truck visits. The numbers here give the average amount of emissions (in lbs) produced by each round trip visit to each SCSPA terminal.

For Union Pier, the numbers shown below are for trucks only, not for buses

Table 7-7: Truck Emissions Results (lbs/round trip)

Terminal	NOx	PM10	PM2.5	HC	SO2	CO
CS on-terminal	0.029	0.001	0.001	0.001	0.000	0.007
CS off-terminal	1.356	0.056	0.054	0.055	0.002	0.322
Total	**1.386**	**0.057**	**0.055**	**0.056**	**0.002**	**0.330**
NC on-terminal	0.029	0.001	0.001	0.001	0.000	0.007
NC off-terminal	1.060	0.044	0.042	0.043	0.001	0.252
Total	**1.089**	**0.045**	**0.043**	**0.044**	**0.001**	**0.259**
WT on-terminal	0.029	0.001	0.001	0.001	0.000	0.007
WT off-terminal	1.389	0.057	0.056	0.057	0.002	0.330
Total	**1.418**	**0.058**	**0.057**	**0.057**	**0.002**	**0.337**
UP on-terminal	0.018	0.001	0.001	0.001	0.000	0.004
UP off-terminal	0.839	0.035	0.034	0.034	0.001	0.199
Total	**0.857**	**0.035**	**0.034**	**0.035**	**0.001**	**0.204**
VT on-terminal	0.824	0.034	0.033	0.034	0.001	0.196
VT off-terminal	0.110	0.007	0.007	0.006	0.000	0.030
Total	**0.981**	**0.042**	**0.041**	**0.041**	**0.001**	**0.238**
Total on-terminal	0.029	0.001	0.001	0.001	0.000	0.007
Total off-terminal	1.242	0.051	0.050	0.051	0.001	0.295
Total	**1.272**	**0.052**	**0.051**	**0.051**	**0.002**	**0.303**

7.7 Comparison with 2005

This section shows how the results of the 2011 inventory update compare with the Port's 2005 baseline emissions.

The first two tables, Table 7-8 and Table 7-9 summarize how the Port's throughput has changed since the baseline inventory was conducted. This helps put changes in emissions into context. The tables show that container throughput has decreased overall by 30% in that time period, while bulk throughput has increased 8%.

Table 7-8: Container Throughput Comparison

	2005 Containers	2011 Containers	% Change
N. Charleston	252,977	272,052	8%
Columbus St.	154,541	1,551	-99%
Wando Welch	727,674	525,276	-28%
	1,135,192	**798,879**	**-30%**

Columbus Street Terminal stopped handling containers in January of 2011. The small number of containers for this terminal came from the five containership calls that occurred in January, before container operations were completely phased out.

Table 7-9: Bulk Throughput Comparison

	2005 Bulk (tons)	2011 Bulk (tons)	% Change
Veterans	132,850	194,648	47%
N. Charleston	3,918	12,570	221%
Columbus St.	146,478	506,050	245%
Wando Welch	3,417	2,512	-26%
Union Pier	441,017	72,508	-84%
	727,680	**788,288**	**8%**

Table 7-10 shows how overall emissions changed over the last six years. It shows that NOx, CO, and HC have all decreased considerably. It also shows that PM and SO2 have increased in that time period. This is mostly due to ship emissions, as will be seen in the next few tables and graphs.

Table 7-10: Mass Emissions Comparison (tons)

	NOx	CO	HC	PM10	PM2.5	SO2
2011	2,451.9	393.1	137.5	231.6	213.0	1,494.1
2005	3,476.8	807.7	185.0	192.8	175.7	1,157.9
Change	**-29%**	**-51%**	**-26%**	**20%**	**21%**	**29%**

Table 7-11 summarizes how much each source category has increased or decreased emissions since the baseline inventory. Tugs and ships both show significant increases in emissions, especially PM. For both sources, this is primarily due to sizeable increases in engine size over the last six years.

Table 7-11: Percent Change Over Time by Source Category

	NOx	CO	HC	PM10	PM2.5	SO2
OGV	5%	20%	-3%	61%	67%	39%
Tugs	45%	-15%	238%	297%	297%	-98%
Trucks	-64%	-75%	-66%	-58%	-58%	-98%
Rail	-22%	-2%	27%	30%	26%	-99%
CHE	-60%	-48%	-52%	-57%	-57%	-100%
Total	**-29%**	**-51%**	**-26%**	**20%**	**21%**	**29%**

Figure 7-8 compares OGV emissions for each source over time. It can be seen that emissions rise for almost every pollutant, despite the 15% drop in number of ship calls and the general trend towards shorter hotelling times. As stated previously, the increase in emissions is caused by the large increase in engine size (both propulsion and auxiliary engines).

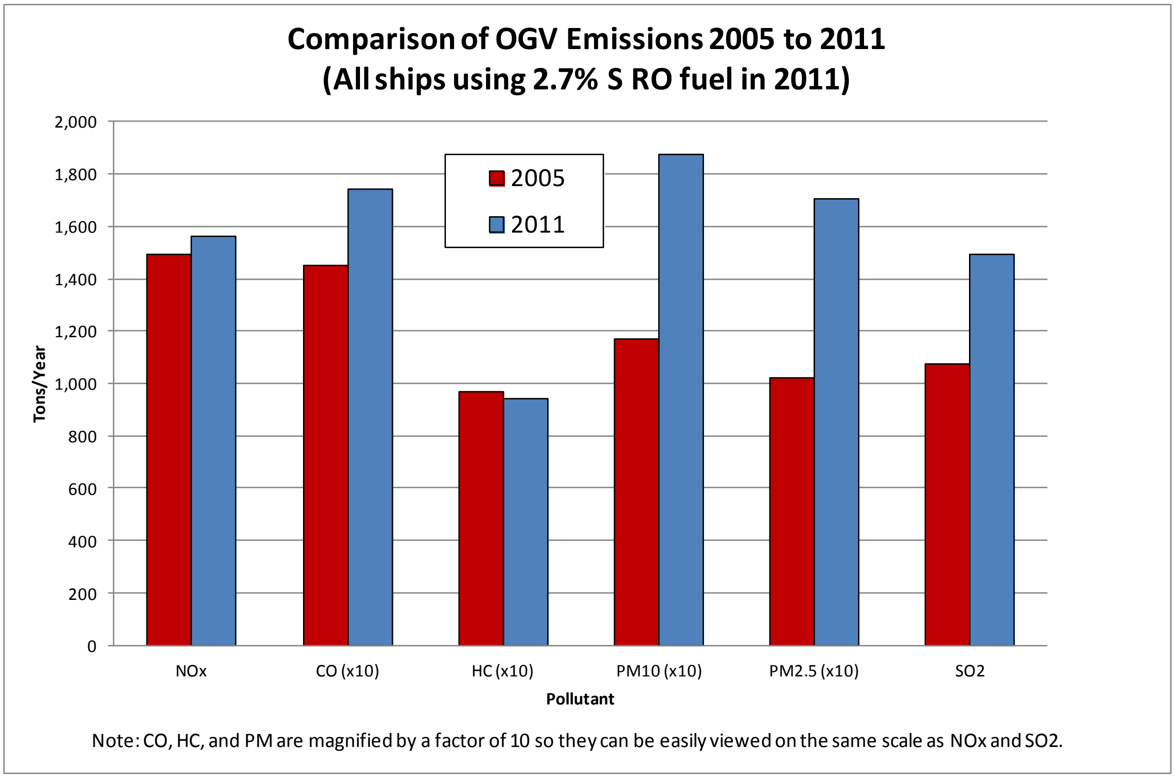


Figure 7-8: Comparison of OGV Emissions, 2005 to 2011 (all RO fuel)

In both 2005 and 2011, ships predominantly were burning bunker fuel. However, due to the recent designation of the North American Emissions Control Area (ECA), cleaner fuel is rapidly becoming mandatory.

Starting mid-year in 2012, ships operating within 200 nm of the U.S. coastline had to burn fuel with a sulfur content of 1.0% or less. Starting in 2015, the fuel sulfur content must be 0.1% or less. Figure 7-9 shows how this will impact OGV emissions in 2015. This analysis uses the same ship activity and characteristics as 2011 (meaning no growth forecast or changes to ship size, call frequency, or hotelling times) but substitutes the better fuel. The impact on PM and SO2 emissions is enormous.

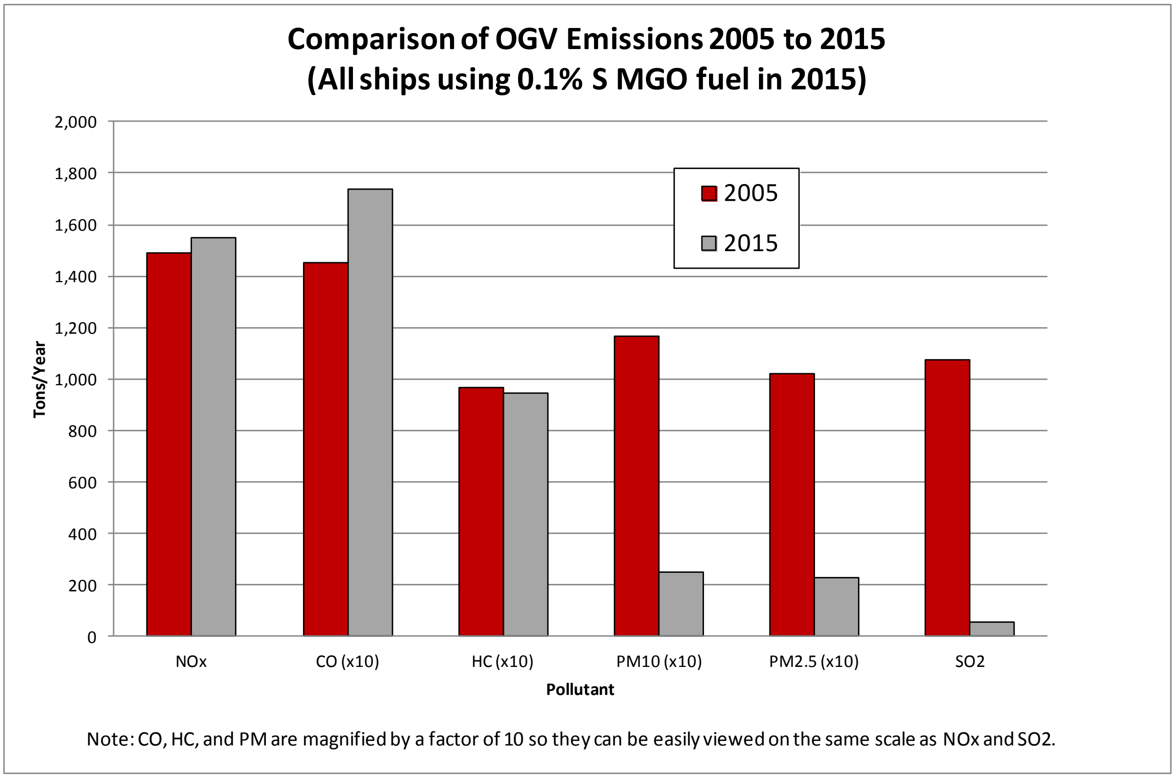


Figure 7-9: Comparison of OGV Emissions, 2005 to 2015 (all 0.1% S MGO fuel)

The next graph, Figure 7-10, shows how OGV emissions are expected to change over the next few years as a direct result of the ECA regulations. See Section 2.4 for more information.

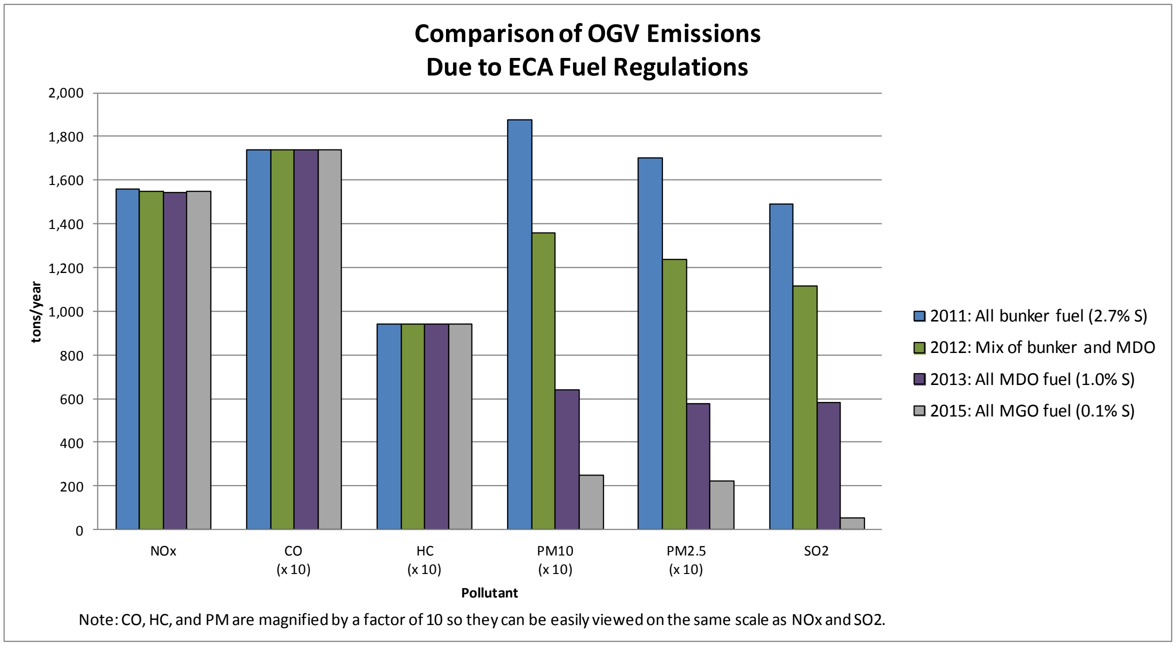


Figure 7-10: Comparison of OGV Emissions as Fuel Improves Due to ECA

Figure 7-11 shows how tug emissions have changed since the baseline. The drop in SO2 emissions is directly attributable to the use of ULSD fuel. The large increase seen for some of the other pollutants is due to the 53% increase in engine size.

NOx and CO did not go up as much as the other pollutants for tugs because of improved engine tier levels. In 2011, the representative tug used in the emission calculations had Tier 1 engines instead of Tier 0 in the baseline inventory.

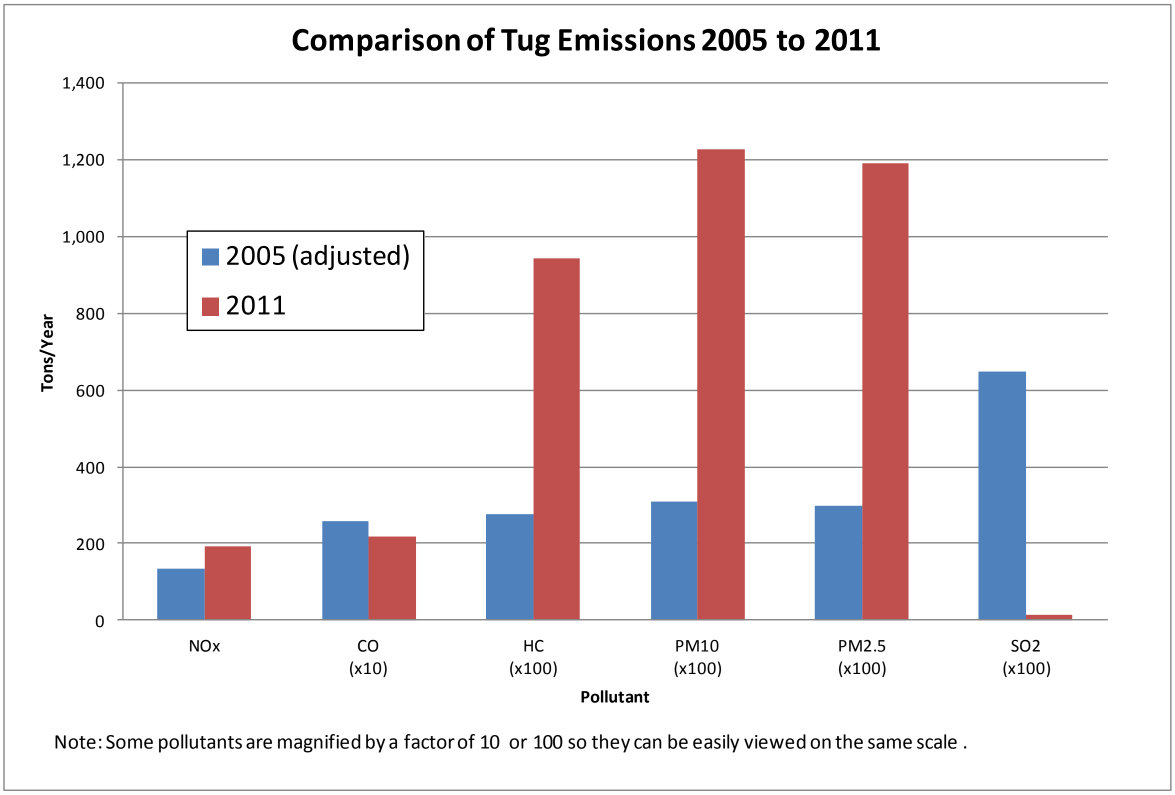


Figure 7-11: Comparison of Tug Emissions Over Time

It is important to note that, for this graph only, the 2005 results were adjusted to use Category 2 engine emission factors. The original 2005 analysis assumed Category 1 engines. The 2005 results were updated for this graph because the PM emission factors for Category 1 engines are much lower (more than half) than for Category 2 engines. Comparing Category 1 and 2 results was making the PM results look unreasonable.

According to the EPA Current Methodologies Report (ICFI, 2009), approximately 90% of tug and tow boats are Category 1. However, after consulting with fleet operators from Moran and McAllister, SCSPA determined that the local tugs meet Category 2 standards. Figure 7-11 above shows the tug comparison *as though Category 2 tugs were assumed in the baseline* as well as the update. For future updates, more research should be done on the tug fleet.

All other 2005 tug results presented in this report use the actual (not adjusted) results from the actual baseline report.

Table 7-12 summarizes the CHE results comparison. The blue text indicates increases over time (for example, in the number of equipment pieces at Columbus St and North

Charleston, and in some instances of total operating hours). The red text indicates decreases over time

Table 7-12: CHE Emissions 2005 to 2011 Comparison by Terminal

	# of Equipt.	Total hrs	HC tons	CO tons	NOx tons	PM10 tons	PM2.5 tons	SO2 tons	Total Installed hp-hrs	Total hp-hrs	TEUs	BB Tons
Columbus St. 2005	57	57,325	3.13	27.92	40.94	2.34	2.27	4.86	15,431,703	6,045,371	278,103	146,478
Columbus St. 2011	103	16,527	0.81	10.33	5.75	0.43	0.42	0.01	1,922,800	838,066	2,683	
% Diff. 2005-2011	*79.44%*	*-71.17%*	*-74.16%*	*-63.01%*	*-85.95%*	*-81.49%*	*-81.48%*	*-99.81%*	*-87.54%*	*-86.14%*	*-99.04%*	*-100.00%*
N. Charleston 2005	57	85,799	5.80	30.21	72.76	4.94	4.79	8.90	27,386,217	10,504,304	428,621	3,918
N. Charleston 2011	86	117,928	3.65	19.57	44.48	3.31	3.21	0.07	29,722,566	12,119,748	470,650	
% Diff. 2005-2011	*49.70%*	*37.45%*	*-36.96%*	*-35.22%*	*-38.87%*	*-32.98%*	*-32.98%*	*-99.24%*	*8.53%*	*15.38%*	*9.81%*	*-100.00%*
Wando Welch 2005	103	205,097	10.85	54.17	168.38	10.90	10.57	22.35	69,996,724	26,027,523	1,278,163	3,417
Wando Welch 2011	126	135,844	4.76	29.74	59.76	3.65	3.54	0.08	40,070,834	13,698,011	908,727	
% Diff. 2005-2011	*21.93%*	*-33.77%*	*-56.13%*	*-45.09%*	*-64.51%*	*-66.56%*	*-66.56%*	*-99.63%*	*-42.75%*	*-47.37%*	*-28.90%*	*-100.00%*
Union Pier 2005	16	5,426	0.40	7.15	2.38	0.06	0.06	0.10	545,561	240,033		441,017
Union Pier 2011	20	6,075	0.17	1.44	1.63	0.22	0.21	0.00	482,397	282,644		
% Diff. 2005-2011	*25.00%*	*11.96%*	*-57.41%*	*-79.90%*	*-31.73%*	*259.77%*	*258.31%*	*-98.20%*	*-11.58%*	*17.75%*		*-100.00%*
Veterans 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		
Veterans 2011	11	4,046	0.24	1.29	2.79	0.24	0.23	0.00	734,245	368,545		
% Diff. 2005-2011	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		

The PM emissions at Union Pier increased considerably in spite of the fact that total operating hours only grew 12%. This is because in 2005, 14 of the 16 pieces of equipment (mostly forklifts) at Union Pier ran on LPG fuel. In 2011, 19 of the 20 forklifts burned diesel.

The notable decrease in SO2 emissions, over 99%, is directly attributable to the use of ULSD fuel.

Figure 7-12 shows how NOx emissions from cargo handling equipment have changed since the baseline at each of the terminals.

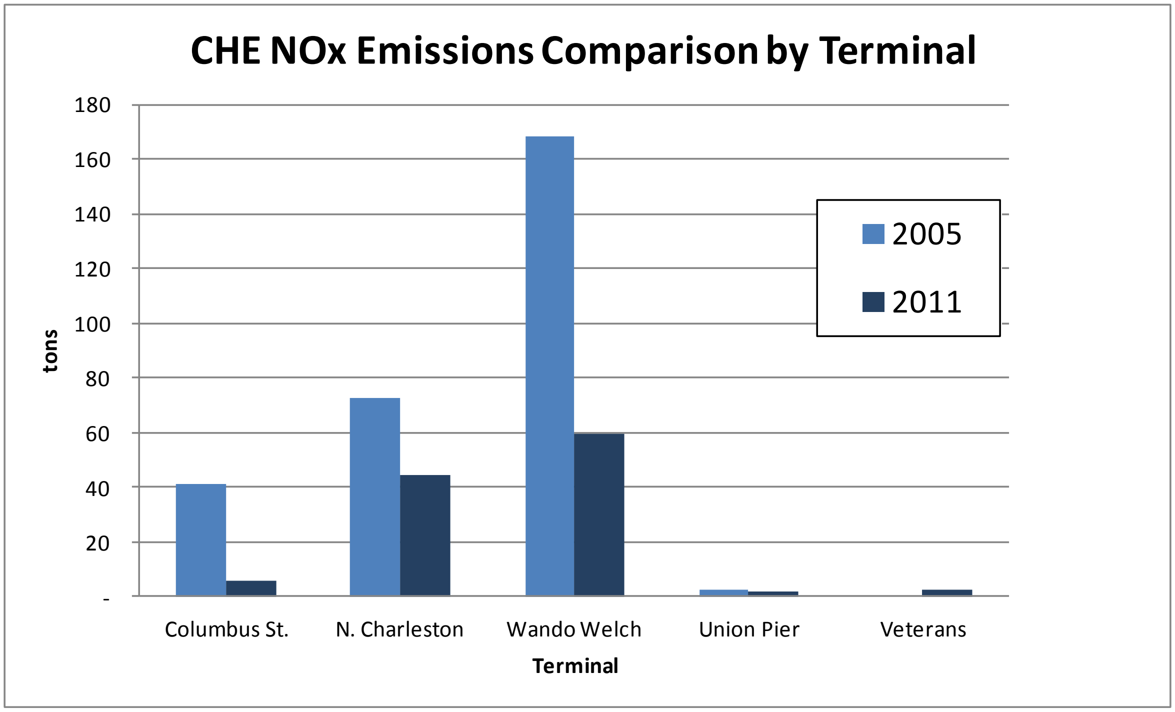


Figure 7-12: Comparison of CHE NOx Emissions Over Time

The comparison for the other pollutants looks very similar to the chart above, with the exception of PM at Union Pier. In that case PM increased, due to the switch from LPG to diesel fuel.

Table 7-13 shows how locomotive emissions have changed since the baseline period. This table shows that the number of trains decreased almost 30%.

Locomotive emissions are the least understood of all the sources included in this inventory. The EPA methodology for how to calculate emissions keeps evolving. For the 2005 inventory, an EPA notch and power analysis was used. For the 2011 inventory, the published emission factors for different tier level engines were used.

It was assumed that the line haul locomotives were all Tier 0 engines in 2011 because no real data were available. This assumes that all of the line haul engines were built or rebuilt between 1973 and 2001. The switcher engines were also assumed to be Tier 0. This was based on the manufacture year of the engines (provided by SCSPA).

Table 7-13: Rail Emissions 2005 to 2011 Comparison

		No. of Trains	Total hrs	NOx tons	PM10 tons	PM2.5 tons	HC tons	CO tons	SO2 tons	TEUs
2005	Line-Haul Off-Terminal	969	3,391	44.96	1.02	0.99	1.51	5.50	2.53	
	Line-Haul On-Terminal		0	0.00	0.00	0.00	0.00	0.00	0.00	
	Switcher On-Terminal		3,900	9.18	0.20	0.19	0.39	0.91	0.37	
	Total Off-Terminal	969	3,391	44.96	1.02	0.99	1.51	5.50	2.53	
	Total On-Terminal		3,900	9.18	0.20	0.19	0.39	0.91	0.37	
	Total Emissions	969	7,291	54.14	1.22	1.18	1.90	6.41	2.90	348,746
2011	Line-Haul Off-Terminal	691	2,419	25.46	0.95	0.92	1.42	3.79	0.01	
	Line-Haul On-Terminal		1,382	14.55	0.54	0.53	0.81	2.17	0.01	
	Switcher On-Terminal		1,500	2.15	0.08	0.07	0.17	0.31	0.00	
	Total Off-Terminal	691	2,419	25.46	0.95	0.92	1.42	3.79	0.01	
	Total On-Terminal		2,882	16.71	0.62	0.60	0.98	2.48	0.01	
	Total Emissions	691	5,301	42.17	1.56	1.52	2.41	6.27	0.02	248,771
	% Diff. 2005-2011	*-28.69%*	*-27.29%*	*-22.10%*	*28.40%*	*28.40%*	*26.68%*	*-2.16%*	*-99.22%*	*-28.67%*

The PM and HC emissions for locomotives increased over time. This is because the published emission factors in the EPA document 420-F-09-025 "*Emission Factors for Locomotives*," April 2009, are higher than when using the notch and power analysis from the older EPA Regulatory Support Document, April 1998. The drop in sulfur is due to the switch to ULSD fuel.

When looking at the locomotive results, it is important to keep in mind that rail contributes only 1 to 2% of overall Port emissions.

Table 7-14 below shows how the number of truck trips to each terminal has changed since the baseline period. As stated before, Columbus Street Terminal stopped handling containers in January 2011, so the number of truck trips dropped accordingly. Also, in 2011, Union Pier did not report any truck trips. Overall, there were 15% less truck trips in 2011 than in 2005.

Table 7-14: Comparison of Truck Counts, 2005 to 2011

Terminal	Number of Visits		Change
	2005	2011	
Columbus St.	141,451	202	-100%
N. Charleston	218,926	317,524	45%
Wando Welch	609,990	511,779	-16%
Union Pier - Trucks	8,299	6,787	-18%
Union Pier - Buses	n/a	10,200	n/a
Veterans	n/a	4,145	n/a
Total	**978,666**	**850,637**	**-13%**

Figure 7-13 shows how much truck emissions have dropped since the baseline period. Truck emissions are down approximately 60% to 98%, depending on the pollutant. These reductions are attributable to decrease in the number of truck trips as well as the natural fleet turnover towards newer model engine years.

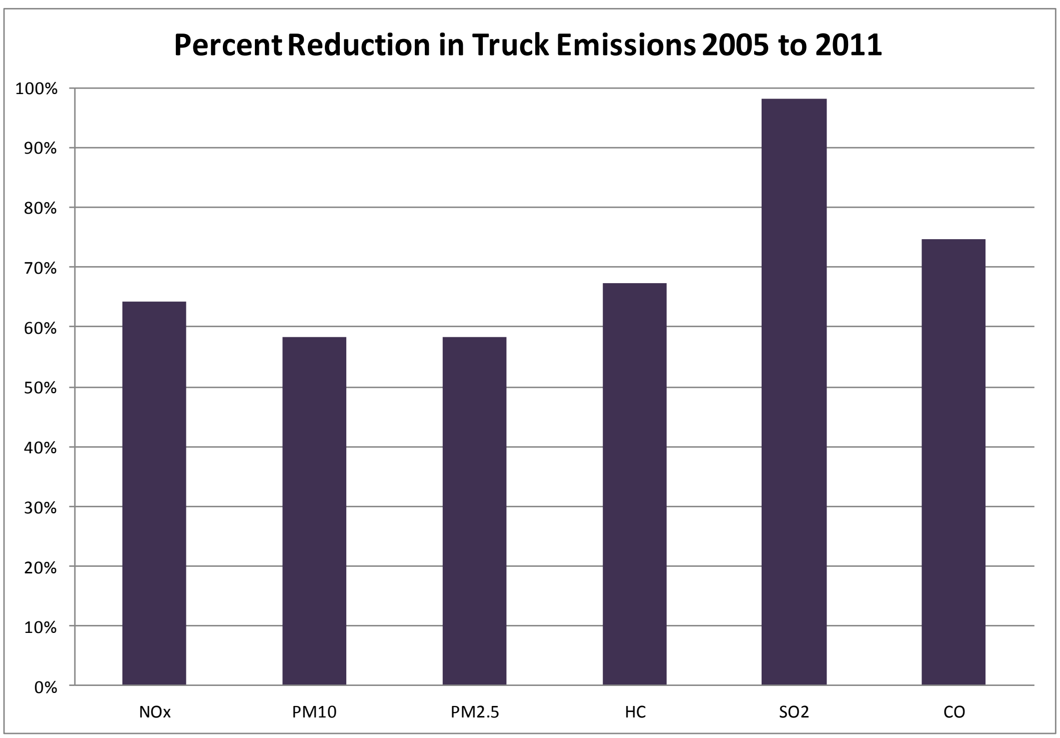


Figure 7-13: Percent Reduction in Truck Emissions Over Time

Table 7-15 shows how the amount of emissions created for each truck visit have decreased since the baseline period for each of the terminals that reported truck trips in both analysis years.

Table 7-15: Comparison in Emissions Per Truck Trip

Reduction in "per trip" Emissions, 2005 to 2011						
	NOx	PM10	PM2.5	HC	SO2	CO
Columbus St.	-54.2%	-46.6%	-46.6%	-58.1%	-97.7%	-67.8%
N. Charleston	-56.1%	-48.5%	-48.5%	-61.9%	-97.8%	-71.1%
Wando Welch	-57.4%	-50.6%	-50.6%	-60.4%	-97.9%	-69.4%
Union Pier	-68.9%	-64.1%	-63.3%	-72.2%	-98.5%	-78.5%

The Union Pier "per trip" emissions decreased more than the other terminals because the travel distances decreased. In 2011, Union Pier truck trips were almost all only 10 miles away instead of up to 50 miles away (see Table 6-3).

8. Study Limitations

This inventory study provides a detailed baseline inventory of air emissions resulting from international goods movement through the Port of Charleston. Methods used to calculate emissions from each source carefully follow EPA guidance and are consistent with recent literature and other port air emissions inventories in the nation. The results are based on data of sufficient detail to serve the purposes of the study; however, the limitations of this study are worth noting.

1. Ocean-going vessel emissions are based on published main engine data for each vessel calling in 2011. However, auxiliary engine power and boiler loads are based on surveys from other studies. OGV emissions could be refined by surveying shipping lines to obtain more specific information on the auxiliary engines and boilers of vessels calling at the Port of Charleston.

2. Times at berth for OGVs are based on actual data for each ship call. However, transit times are based on assumed speeds and the layout of the channels. Transit emissions could be refined by surveying vessel operators and using AIS tracking data to define transit times in greater detail. Emission calculations are also very sensitive to engine load factors. This inventory could be refined in the future by using a ship boarding program similar to that used by POLA to determine actual engine loads during different phases of transit to and from each terminal.

3. The tug characteristics for the Charleston fleet should be analyzed further. In 2005, it was assumed that the representative tug had a Tier 0 Category 1 engine. In 2011, according to SCSPA (relying on interviews conducted by the U.S. Army Corps of

Engineers), the representative tug had a Tier 1 Category 2 engine. This makes results of the two inventories difficult to compare (Category 1 and 2 engines use different emission factors). SCSPA may also want to consider the tug auxiliary engines for future inventory updates, as well as more careful analysis of the average number of tugs used to assist different types of vessels into and out of berth.

4. Locomotive emissions are limited to switcher activity as reported by SCPR and an estimate of the line haul emissions from containerized cargo that leaves or enters the area through near-dock private rail yards. Non-containerized cargo arriving or leaving the Tri-County area on rail is not included.

5. Heavy duty vehicle emissions are dominated by containerized truck trips. Truck trips for this study are estimated in a way that does not account for the stripping or stuffing of containers into and out of domestic sized containers. Although this is not expected to make a significant difference, HDV emissions could be refined with field surveys of gate traffic at each terminal.

6. The age profile of the truck fleet serving SCSPA terminals is an important factor in HDV emissions. License plate surveys used to identify truck age in other port inventories have shown the average age of port trucks to be older than the industry average. This study uses EPA default age distributions for the heavy duty vehicle fleet for the year 2011. The inventory could be refined in the future by looking up license plates for trucks serving Charleston in the Department of Motor Vehicles database to obtain their actual age distribution.

7. This study includes rail switcher activity for all types of cargo but line haul rail activity (from local railyards to Tri-County boundary) is estimated for containerized cargo only. Any breakbulk or ro-ro cargo that leaves the Charleston area by rail would not be included in the line haul rail estimates. This is not expected to be significant.

REFERENCES

California Air Resources Board, *2005 Oceangoing Ship Survey, Summary of Results*, September 2005. Available online at http://www.arb.ca.gov/regact/marine2005/appc.pdf

EPA, *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*. AP 42, Fifth Edition. Available online at: http://www.epa.gov/ttn/chief/ap42/index.html

EPA, *Emission Factors for Locomotives*, EPA Fact Sheet EPA-420-F-09-025, April 2009. Available online at http://www.epa.gov/nonroad/locomotv/420f09025.pdf

EPA, *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, NR-009D*, EPA-420-R-10-018, July 2010. Available online at http://www.epa.gov/oms/models/nonrdmdl/nonrdmdl2010/420r10018.pdf

EPA, *Locomotive Emission Standards*, EPA Regulatory Support Document EPA-420-R-98-101, April 1998. Available online at http://www.epa.gov/otaq/documents/420r98101.pdf

Entec UK Limited, *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community*, prepared for the European Commission, July 2002. Available online at http://www.europa.eu.int/comm/environment/air/background.htm

ICF International, *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories*, prepared for the U.S. EPA, April 2009. Available online at http://epa.gov/cleandiesel/documents/ports-emission-inv-april09.pdf

Starcrest Consulting Group LLC, *Port of Los Angeles Inventory of Air Emissions - 2011*, prepared for the Port of Los Angeles, July 2012. Available online at http://www.portoflosangeles.org/pdf/2011_Air_Emissions_Inventory.pdf

Starcrest Consulting Group LLC, *Port of Long Beach Air Emissions Inventory - 2011*, prepared for the Port of Long Beach, July 2012. Available online at http://www.polb.com/environment/air/emissions.asp