Barnes

South Carolina Ports

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EXECUTIVE SUMMARY

Nationally, the air emissions from the many mobile sources associated with Port operations has come under increasing scrutiny in recent years. This is due to a combination of strong growth in the movement of goods and the application of improved controls on sources that have historically been more regulated than marine sources such as on-road vehicles and stationary sources.

The South Carolina State Ports Authority (SCSPA, or SPA) is committed to environmental stewardship and has taken on a leadership role in understanding and addressing the environmental impacts of air emissions associated with the Port's operation. The SCSPA has recognized that a comprehensive emissions inventory that includes all sources of Port-related air emissions is needed to proactively take up the Port's role in maintaining clean air standards in the Charleston area.

Effectively addressing air quality concerns in the Port business starts with an understanding of current activity levels and resulting air emissions. Once the universe of emissions is understood and quantified, the appropriate sources can be identified for reduction and various reduction strategies considered in the context of the total emissions.

Moffatt & Nichol, on behalf of the South Carolina State Ports Authority, prepared a comprehensive, activity-based baseline inventory of air emissions from SCSPA operations at the Port of Charleston in 2005. Port-related emissions sources included in this inventory are:

- Ocean-going vessels (OGV)
- Harbor craft (HC), limited to vessel assist tug operations at SPA berths
- Cargo handling equipment (CHE)
- Rail locomotives (RL), limited to South Carolina Public Railways (SCPR) operated switchers and line haul engines for international containers to/from off-terminal intermodal yards.
- On-road trucks and heavy duty vehicles (HDV)

The purpose of the study is to estimate the level of air emissions coming from all significant internal combustion sources related to Port operations within the Charleston tri-county area. The results of the study will form the SCSPA's baseline inventory. The baseline inventory can be used to:

- ➢ evaluate the relative contribution of international goods movement to overall regional emission inventories prepared by the Department of Health and Environmental Control.
- ➢ 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 reduced and percent reduction) of various potential reduction measures

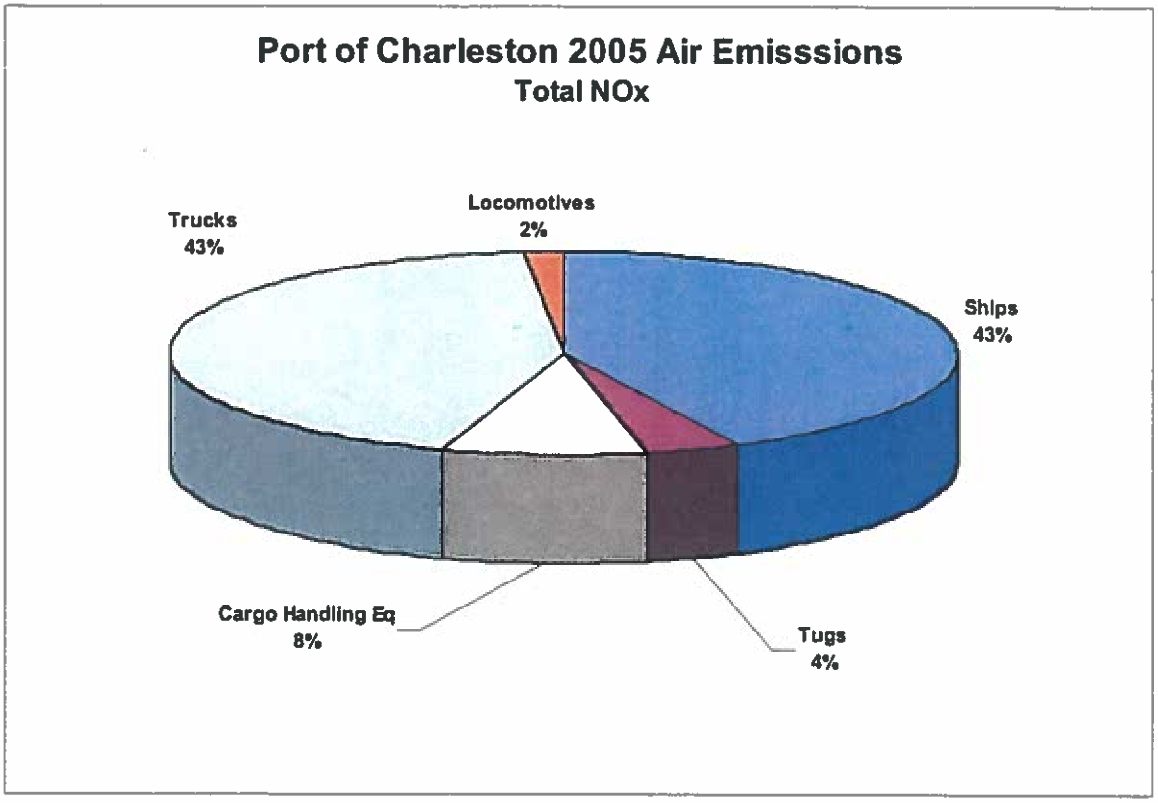


Figure ES-1: Percent Contribution to NOx Emissions by Source

The graph above shows the contribution of each source to the total NOx emissions. However, the relative contribution of each source category to the total emissions of a given pollutant depends on the pollutant in question. This can be an important consideration as the pollutant of concern depends on local air quality and conditions and therefore the sources of concern may differ from port to port. The percentage contribution of each source category to each pollutant total is given below in Figure ES-2.

- track progress over time as technology and efficiency improvements are implemented and throughput grows.

Detailed data on ship calls, cargo throughputs, cargo handling equipment hours, and switcher locomotive operations were provided by SCSPA and SCPR staff. Truck trips, harbor craft activity and line haul locomotive activity were estimated based on vessel call data, throughput data and modal split provided by SPA staff. The methodology used to prepare this emissions inventory was consistent with the EPA guidance for best practices (ICF Consulting, 2006).

Emission levels were calculated for the following six pollutants; oxides of nitrogen (NOx), carbon monoxide (CO), total organic gases (TOG), particulate matter smaller than 10 microns (PM10), particulate matter smaller than 2.5 microns (PM2.5), and sulfur dioxide (SO2). Over the road truck emission factors were estimated using the EPA's Mobile 6.2 model. Cargo handling equipment emission factors were estimated using the EPA's NONROAD model. Locomotive emission factors were derived from EPA test data. OGV and harbor craft emission factors were taken from the EPA guidance for best practices (ICF Consulting, 2006) supplemented by the latest literature for vessel auxiliary boiler emissions. The results of the mass emission estimates by pollutant and source are summarized below in Table ES-1 .

Table ES-1: Emission Results by Pollutant and Source

Port of Charleston 2005 Air Emissions (tons)						
Pollutant	Source					
	OGV	HC	CHE	HDV	RL	**Total**
NOx	1,492.0	133.9	284.5	1,512.3	54.1	**3,476.8**
CO	145.3	25.7	119.4	510.8	6.4	**807.7**
SO2	1,076.0	6.5	36.2	36.3	2.9	**1,157.9**
TOG	103.4	3.0	21.6	67.9	2.0	**197.9**
PM10	116.8	3.1	18.2	53.5	1.2	**192.8**
PM2.5	101.9	3.0	17.7	51.9	1.2	**175.6**

The contribution of each source category to the total NOx emissions is shown graphically below in Figure ES-1

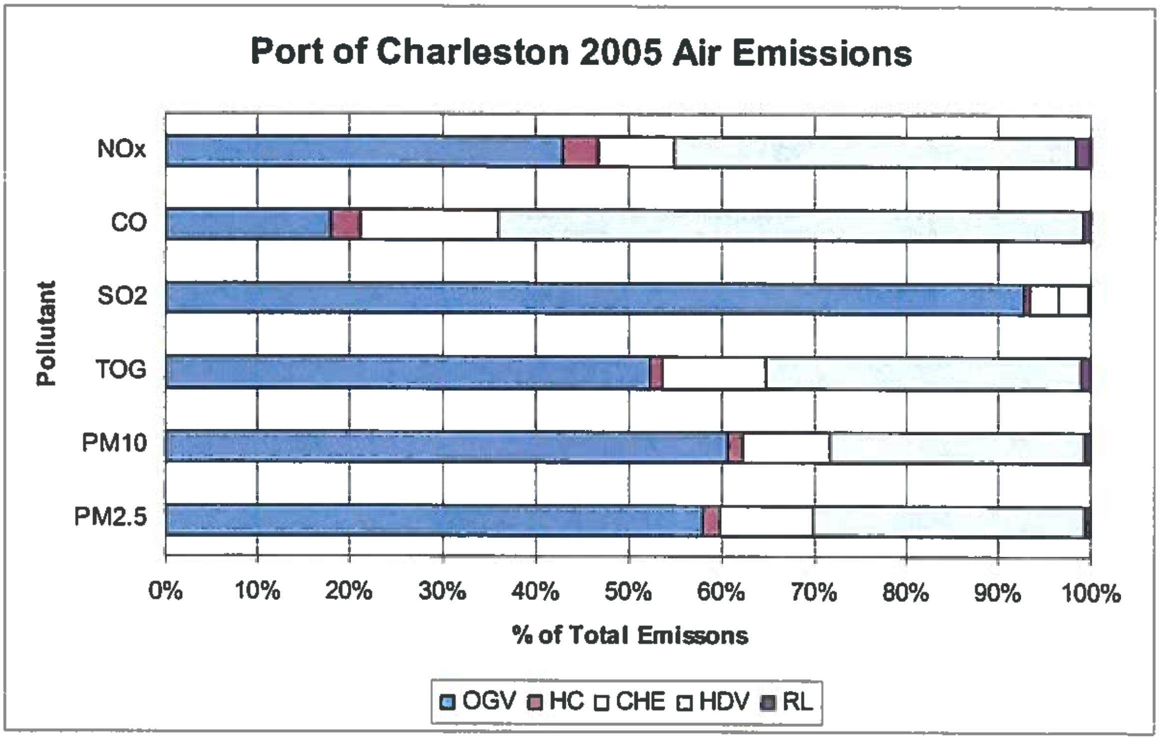


Figure ES-2: Percent Contribution to Emissions by Pollutant and Source

Port Authorities have varying levels of control over emissions depending on the source and the location of its activity. For this reason, it is valuable to separate the source emissions into on-terminal and off-terminal emissions. Tables ES-2 and ES-3 below show the emissions totals for 2005 broken up by location (on-terminal vs. off-terminal). For the purposes of this analysis, SCPR switcher locomotive emissions are counted as "on-terminal," as are hoteling emissions of ships at berth, cargo handling equipment emissions and onroad truck emissions while on-terminal.

Table ES-2: On-Terminal Emissions Results

Port of Charleston 2005 On-Terminal Air Emissions (tons)						
Pollutant	Source					
	OGV	HC	CHE	HDV	RL	**Total**
NOx	591.7	0.0	284.5	224.0	9.2	**1,109.3**
CO	45.4	0.0	119.4	161.4	0.9	**327.2**
SO2	596.4	0.0	36.2	4.0	0.4	**637.0**
TOG	17.3	0.0	21.6	18.1	0.4	**57.4**
PM10	49.2	0.0	18.2	6.6	0.2	**74.2**
PM2.5	41.1	0.0	17.7	6.4	0.2	**65.4**

Table ES-3: Off-Terminal Emissions Results

Port of Charleston 2005 Off-Terminal Air Emissions (tons)						
Pollutant	Source					
	OGV	HC	CHE	HDV	RL	**Total**
NOx	900.4	133.9	0.0	1,288.3	45.0	**2,367.6**
CO	99.9	25.7	0.0	349.4	5.5	**480.5**
SO2	479.5	6.5	0.0	32.3	2.5	**520.8**
TOG	86.1	3.0	0.0	49.8	1.6	**140.5**
PM10	67.6	3.1	0.0	46.9	1.0	**118.6**
PM2.5	60.8	3.0	0.0	45.5	1.0	**110.3**

The contributions of each source to on- and off-terminal total NOx emissions are shown next in Figures ES-3 and ES-4.

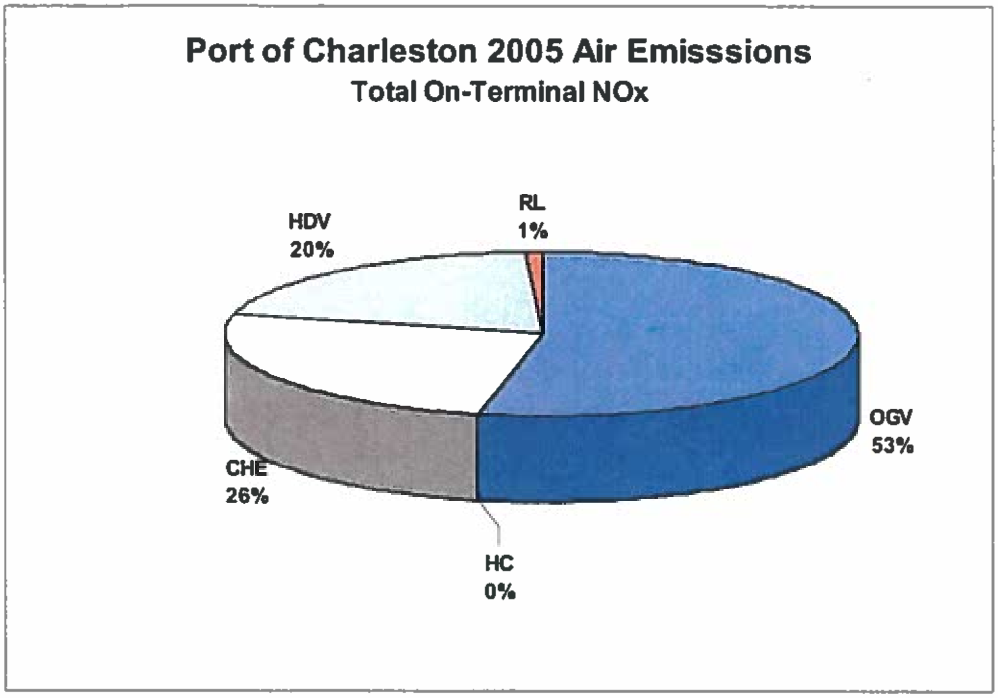


Figure ES-3: Percent Contribution by Source to On-Terminal NOx Emissions

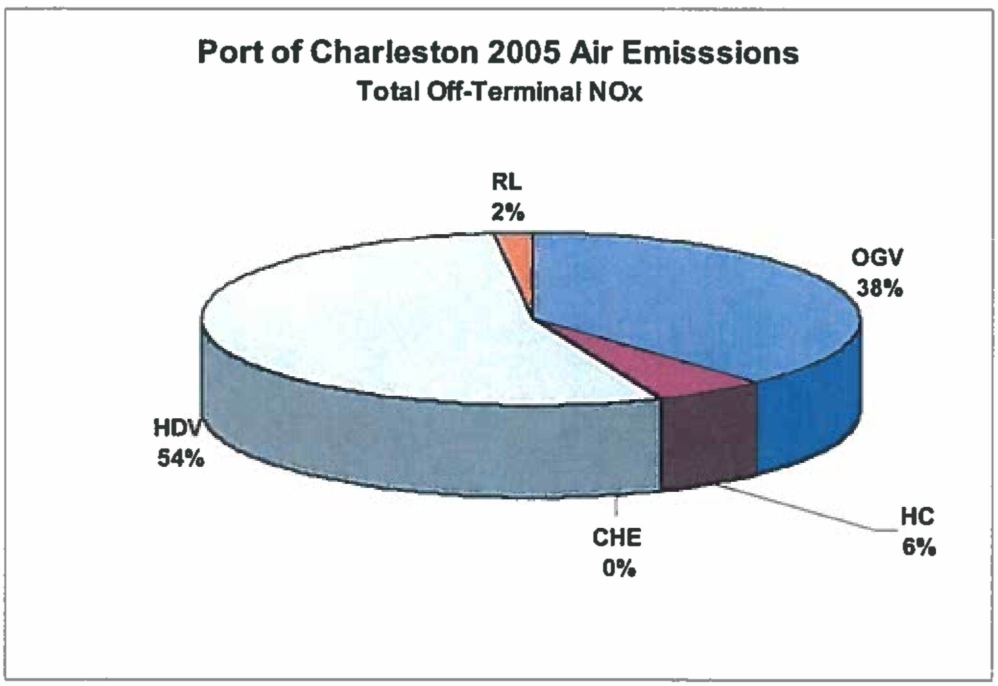


Figure ES-4: Percent Contribution by Source to Off-Terminal NOx Emissions

It is difficult to compare total annual emissions with those of other ports because emissions depend heavily on throughput, the specific geography of the port surroundings and the geographical extents of the inventory. The main value of an inventory is to understand, track, and target emission sources for a given port over time. However, because this is the baseline inventory for the Port of Charleston, there are no previous inventories with which to compare it.

For the sake of comparison, the 2005 mass emissions for the Ports of Los Angeles and Long Beach (as reported in their emissions inventories) were divided by total throughput to yield an emissions estimate normalized to TEU of throughput which can be compared with the Port of Charleston. The Port of Charleston's total TEU in 2005 was 1,984,887 as compared to 7,454,625 and 6,709,818 for the Port of Los Angeles and Port of Long Beach respectively. The results for NOx are shown below in Figure ES-5.

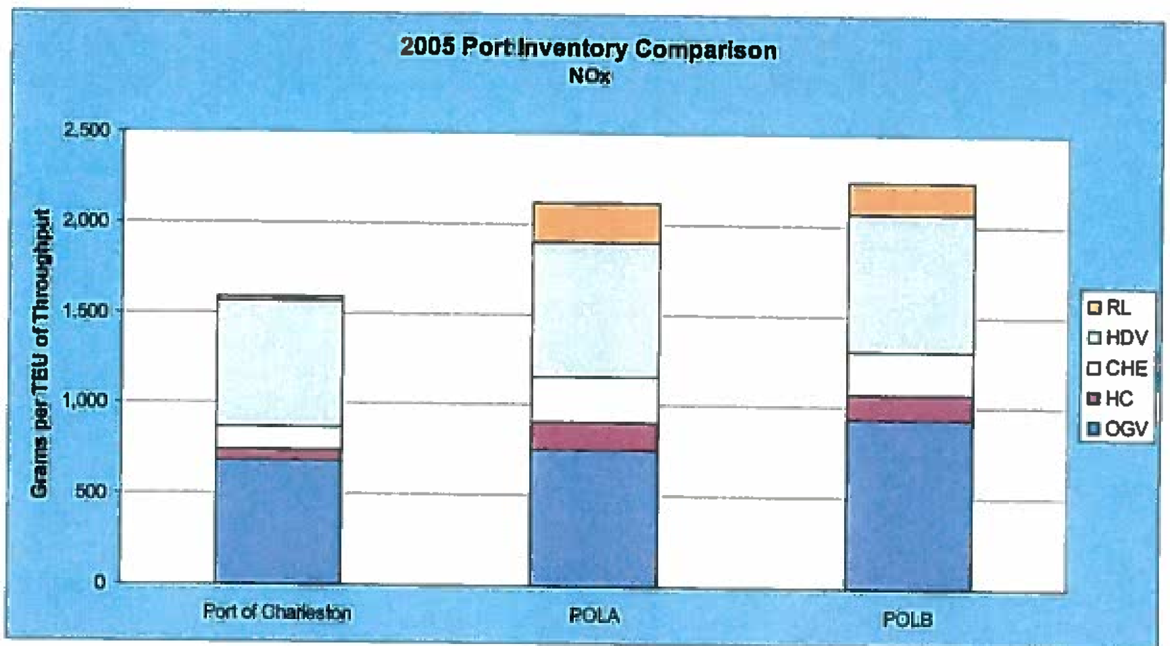


Figure ES-5: NOx Comparison to Other Port Inventories

In general, this comparison shows the total NOx emissions at the Port of Charleston are slightly over 1,500 grams/TEU as compared with roughly 2,000 grams/TEU at the Port of Los Angeles and the Port of Long Beach. It should be understood that differences in the scope of the inventory, the affect of non-container operations, and most importantly the geographic extents of each inventory make this a comparison of limited value. However, it does show that the relative contribution of each source category is similar. The exception is rail locomotives, which are used more extensively and were covered in greater detail in the POLA and POLB inventories.

1. Introduction

Nationally, air emissions from the many mobile sources associated with port operations have come under increasing scrutiny in recent years. This is due to a combination of strong growth in the movement of goods and the application of improved controls on sources that have historically been more regulated than marine sources such as on-road vehicles and stationary sources.

The SCSPA 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 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 through the Port. For this reason, SCSPA has retained Moffatt & Nichol to perform a detailed activity based emissions inventory.

1.1 Study Purpose

Addressing air quality concerns in port operations starts with an understanding of current activity levels and their resulting emissions. Once the universe of emissions is understood and quantified, the appropriate sources can be identified for reduction and various emission reduction strategies can be considered and compared. The purpose of this study is to estimate the air emissions coming from all significant internal combustion sources related to Port operations within the Charleston tri-county area.

The SCSPA owns and operates five terminals at the Port of Charleston. The terminals are: Columbus Street, North Charleston, Union Pier, Veterans Terminal, and Wando Welch.

The year 2005 was chosen in cooperation with the South Carolina Department of Health and Environmental Control (DHEC). There were no reported ship calls at Veterans Terminal in 2005 so the inventory includes only the four remaining terminals owned by the SCSPA.

1.2 Terminal Overviews

The locations of the five Port of Charleston terminals are shown in red in the Figure below. Closer aerial images of each of the four terminals included in this study (recall that Veterans Terminal is not included because it had no ship calls in 2005) are also given in this section along with a brief description of their operations.

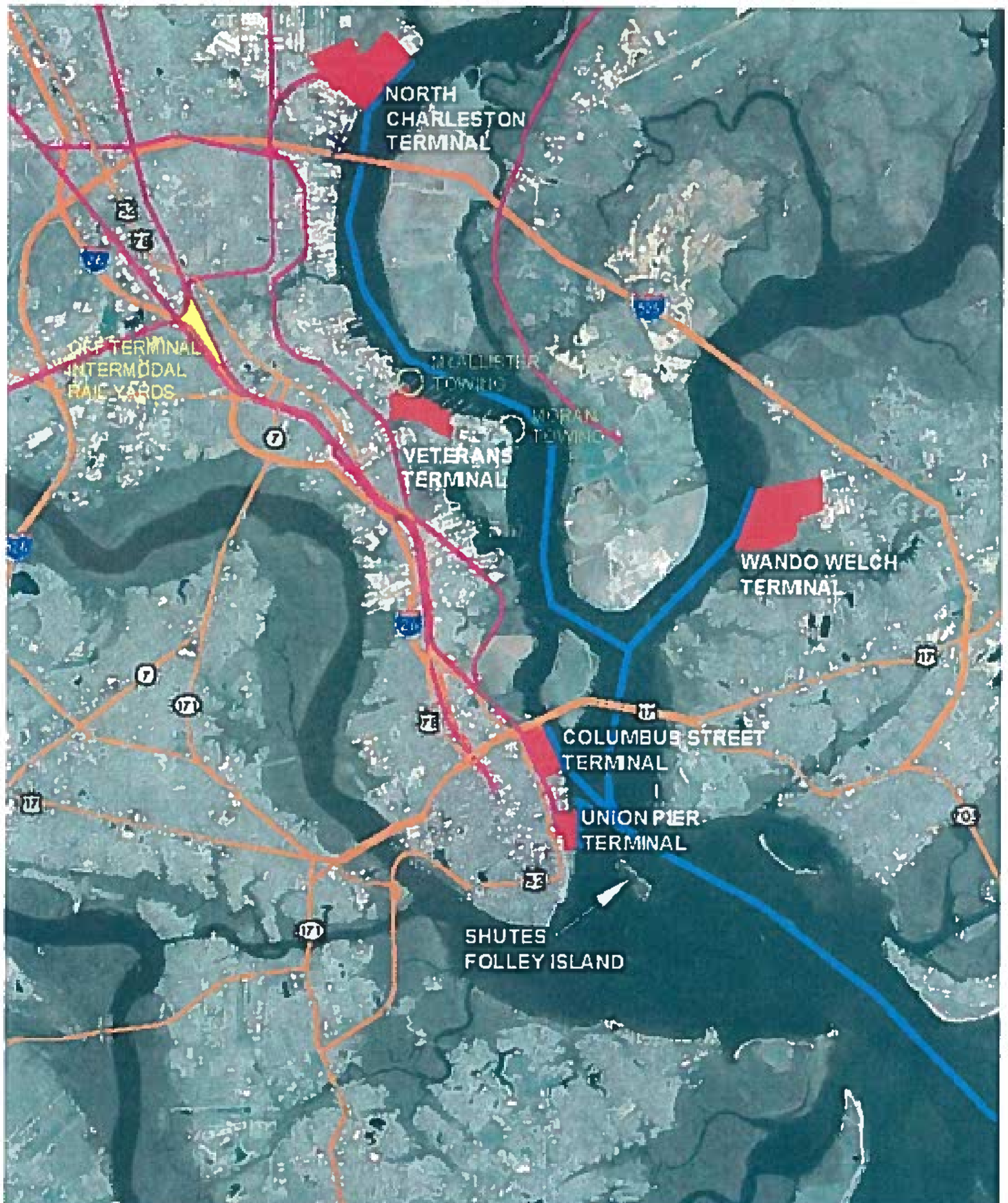


Figure 1-1: Locations of the SCSPA-Operated Terminals at the Port of Charleston

Columbus Street Terminal

Figure 1-2: Aerial View of Columbus Street Terminal

The Columbus Street Terminal is located on the Cooper River side of the Charleston peninsula, downriver of the new US Highway 17 bridge.

The terminal has 3,875 feet of berth. The berths at the terminal range in maintained depth from -38 feet MLW (Berths 4 and 5) to -45 feet MLW (Berths 1-3). The terminal is primarily used for container and breakbulk operations. The terminal includes five container cranes on two container berths and four breakbulk 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. 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

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). This terminal has 2,480 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 could load and unload post-Panamax vessels. The primary use of the terminal is container operations. 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 another operating subdivision of the State Carolina Public Railways. Both the CSX and Norfolk Southern Lines switch in to and out of the yard.

<u>Union Pier</u>

Figure 1-4: Aerial View of Union Pier

The Union Pier Terminal is located on the Cooper River side of the Charleston peninsula. The terminal has 2,470 feet of berth. The maintained depth at the berth is -32 feet MLW. The terminal includes 680,938 square feet of transit shed and is primarily used for automobile and breakbulk shipments. The terminal includes a cruise passenger facility adjacent to Berth 1. 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

The Wando Welch Terminal is located on the east side of the Wando River north of the Town of Mount Pleasant. The terminal has 3,800 feet of continuous berth with a maintained depth of -45 feet MLW. The terminal has ten container cranes on four container ship berths. Four of the container cranes were super post-Panamax size, four were post-Panamax and two were Panamax.

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

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 or sailing from SCSPA berths.
- Cargo Handling Equipment (CHE) including
  - Top picks
  - Side picks
  - Forklifts
  - Rubber tired gantry (RTG) cranes
  - Yard tractors (hostlers)
- Railroad Locomotives at rail facilities within the Port (RL)
  - Switcher locomotives serving the terminals (operated by PUC and PTR).
  - Line haul locomotive moving containerized port cargo to and from local rail yards
- On-road Heavy Duty Vehicles (HDV) driving to, from, and in SCSPA terminals

Emissions for activities that are not related to the operations of SCSPA terminals were not included. Examples include government naval activities, recreational boating, and other vessels transiting Cooper River bound for non-SCSPA terminals.

Other sources were excluded because their contribution to total emissions is negligible and because they are not typically included in port emission inventories. These include terminal equipment of less than 25 hp and on-road passenger vehicles.

1.4 Inventory Boundary

In addition to emissions occurring directly on SCSPA property, emissions from OGV, HC, RL, and HDV that occur outside the Port but within the Charleston tri-county area were included. Figure 1-6 shows the boundary of the tri-county area. Ship emissions were counted from the seabouy as shown below.

Figure 1-6: Aerial Showing Boundary of the Charleston Tri-County Area

1.5 Pollutants

Emissions were estimated for the following pollutants emitted by the internal combustion engines associated with the sources included in the inventory:

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, meaning there are standards set by EPA on the acceptable concentration level of CO in the air.

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; this 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. Sulfur dioxide is a criteria pollutant. Sulfur dioxide emissions are directly proportional to the sulfur content of in-use fuels.

Hydrocarbons or Total Organic Gases (TOG) – Hydrocarbons are an important component in the formation of ozone which 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, or THC, is the hydrocarbons measured by a specific test called FID. This test does not properly detect some alcohols and aldehydes. Separate tests detect these compounds and when the results are added to the THC, the sum is known as Total Organic Gases (TOG). Methane is orders of magnitude less reactive than other hydrocarbons so it is often measured separately, and when subtracted from THC or ROG (Reactive Organic Gas), is known as NMHC (non-methane hydrocarbons) or NMOG (non-methane organic gases).

Some hydrocarbons are less ozone forming than others so the EPA has excluded them from the definition of regulated hydrocarbons called Volatile Organic Compounds. While there are several compounds excluded, generally speaking VOCs are the result of subtracting methane and ethane from TOG emission estimates. Ultimately, all of these terms and their varying constituents represent only slight variations in the total mass emission of hydrocarbons. For the purposes of comparison to other inventories, they are converted to and summarized as TOG, but for individual sources may be initially computed as VOCs or THC, depending on the emission factor model used for the particular source.

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 but it is likely standards will be developed in the future. PM2.5 is a criteria pollutant.

The EPA has established a more restrictive limit for PM2.5 concentration that went into effect in December of 2006 which lowered the 24-hr PM2.5 from 65 ug/m3 to 35 ug/m3. Non-attainment designations for fine particulates (PM2.5) based on the new standards are anticipated to take effect in 2010 based on 2007-2009 monitoring data.

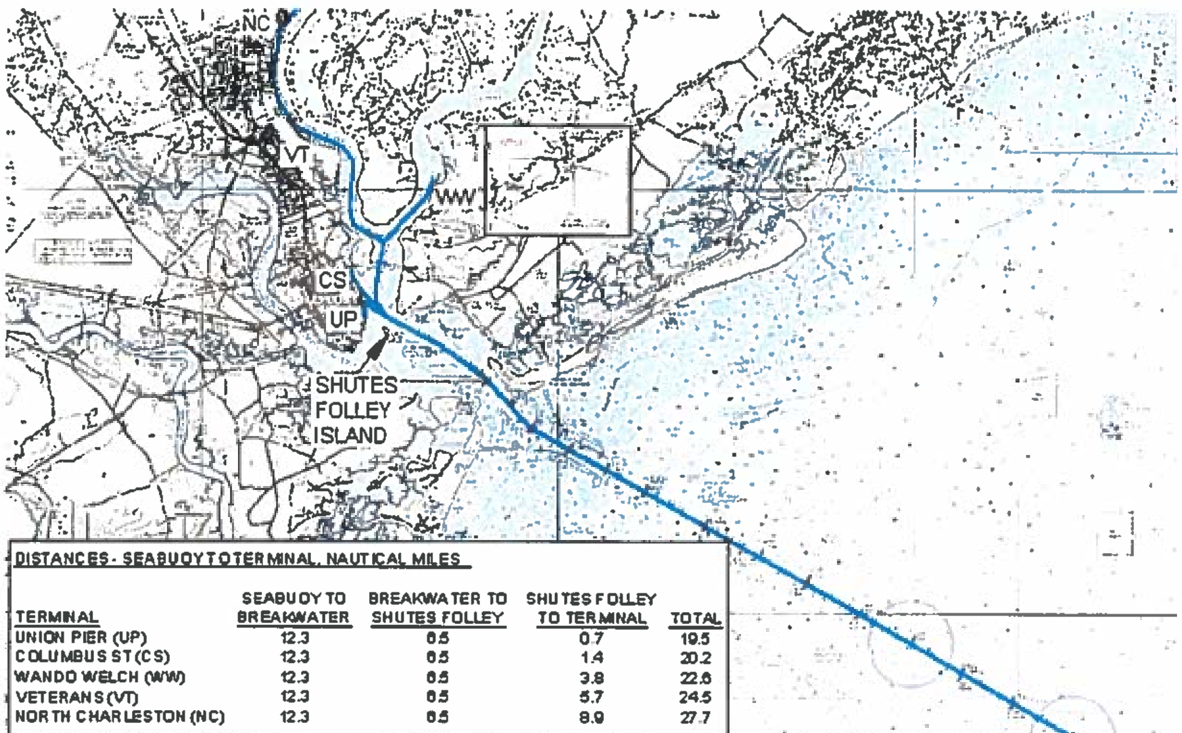
1.6 Project Approach

The emissions inventory was developed using actual 2005 data provided by SCSPA, supplemented by cargo based projections of activity where appropriate. The methods applied were consistent with the EPA guidance for best practices (ICF Consulting, 2006) for preparing port emissions inventories. 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 18% to 93% of total port emissions (see Figure ES-2).

The inventory boundary for vessel emissions is the seabuoy, just over twelve nautical miles outside the tip of the entrance jetties. Figure 2-1 is a navigational chart showing the channels used by ships approaching the SCSPA terminals. The inset table lists the assumed 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 seabuoy 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

2.1 Emission Calculation Approach

The current practice to calculate emissions from OGVs is to use energy-based emission factors together with activity profiles for each vessel. The bulk of the work involves determining engine power ratings for each vessel and the development of repetitive activity profiles for 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 Rating Power (kilowatts, kW)
LF = Load Factor (percent of vessel's total power)
A = Activity (hours, h)
EF = Emission Factor (grams per kilowatt-hour, g/kW-h) — Best Practices Guide factors

The emission factor is expressed in terms of emissions per unit of energy from the engine. It is multiplied by the power needed to move the ship in a particular activity or mode.

The detailed emission calculations for OGVs are given in Appendix B.

2.2 Ship Call Data

Detailed ship call data for all vessel calls in calendar year 2005 was provided by SCSPA. A total of 416 unique vessels made a total of 2,014 vessel calls at the Port of Charleston in 2005. Table 2-1 below shows the distribution of call types for each terminal.

Table 2-1: 2005 Ship Call Summary for All SCSPA Terminals

Terminal	Vessel Type	Number of calls	Avg Vessel Length (ft)	Avg Duration at Berth (hrs)
Columbus Street	Container	251	726	18
	Barge	5	343	17
	Cruise	1	895	46
	Ro-Ro	0		
	Breakbulk & Other	42	567	27
North Charleston	Container	350	799	15
	Barge	7	343	13
	Cruise	0	0	0
	Ro-Ro	1	623	13
	Breakbulk & Other	4	790	25
Union Pier	Container	0	0	0
	Barge	0	0	0
	Cruise	46	610	21
	Ro-Ro	170	619	15
	Breakbulk & Other	9	587	29
Wando Welch	Container	1082	799	14
	Barge	46	343	18
	Cruise	0	0	0
	Ro-Ro	0	0	0
	Breakbulk & Other	0	0	0
All SCSPA	Container	1,683	788	15
	Tug & Barge	58	343	17
	Cruise	47	616	22
	Ro-Ro	171	619	15
	Breakbulk & Other	55	587	27
	Total	2,014	751	15

Source: SCSPA data

vessel calls declined since 2005 ~1890 CY2007

hoteling emissions

Figure 2-2 summarizes the number of ship calls at SCSPA's Charleston terminals by type of vessel.

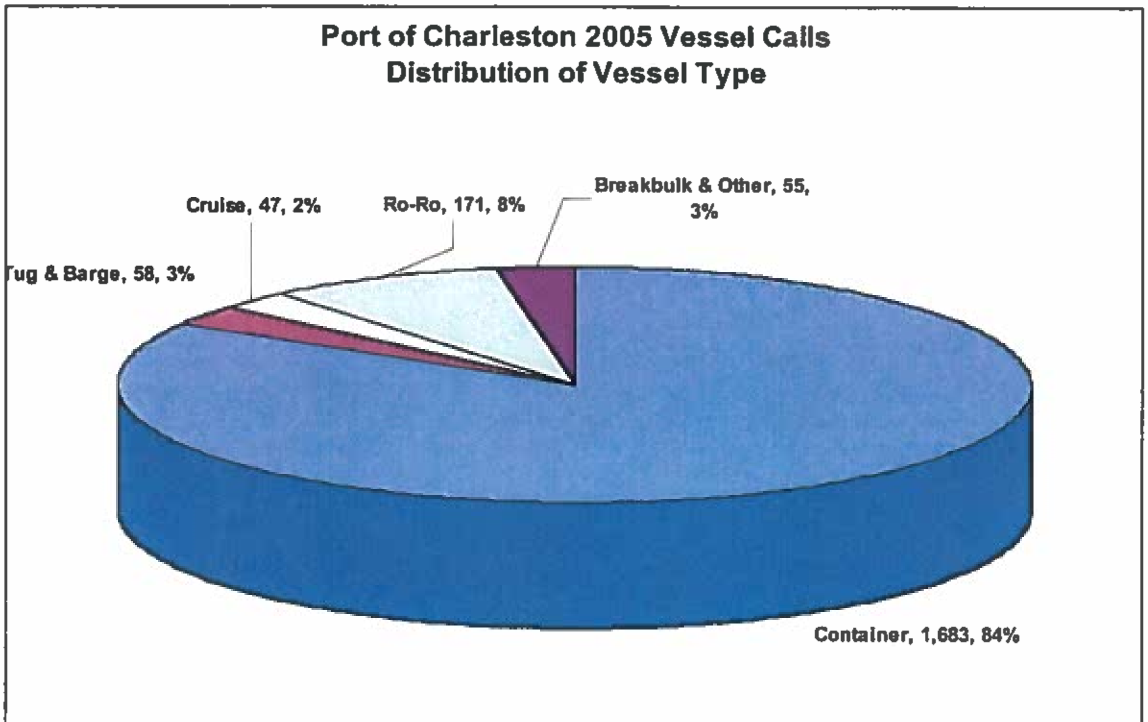


Figure 2-2: 2,014 Vessel Calls in 2005 by Vessel Type

Emissions from different types of OGVs have a similar distribution with an even higher weighting toward container vessels owing to their large horsepower.

Figure 2-3 shows the contribution toward total OGV NOx emission for each type of vessel.

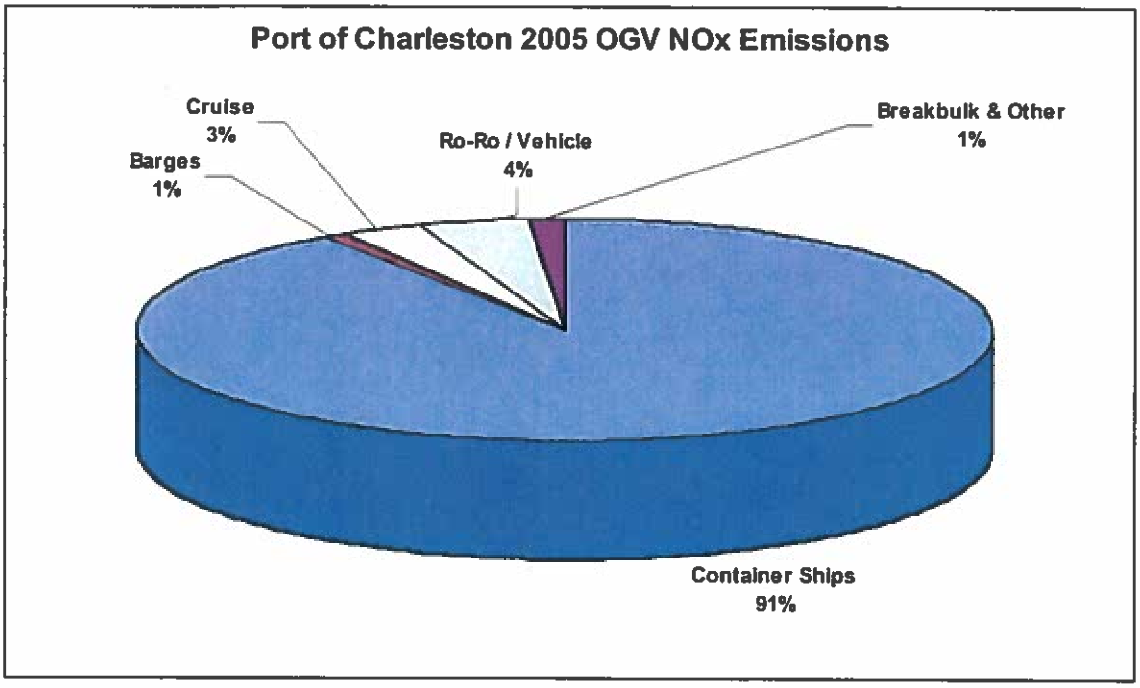


Figure 2-3: Contribution to Total OGV NOx Emissions by Vessel Type

2.3 Vessel Characteristics

A total of 416 individual vessels called on SCSPA terminals in 2005, making a total of 2,014 calls. The characteristics of each of the 416 vessels were researched using the Clarkson Register (April 2008) as well as other sources. Details for the vessels including dimensions, carrying capacity, main and auxiliary engine rated power, engine speeds, fuel type, and service speed were used to calculate emissions for each call. These details for each vessel on each call can be found in Appendix B1. 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.

2.4 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 hoteling 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 hoteling) 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 within the bay were typically 20 to 30% for all but the ocean-going tugs. This analysis does not account for any time vessels spend at anchor.

Table 2-2 summarizes the OGV travel distances, speeds, and times in mode for each terminal in the study.

Table 2-2: OGV Transit Time in Mode

		Distance (naut miles)				Speed (knts)				Time in Mode (hrs) Round Trip or hours per call			
		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	15.0	8	4	0.00	1.64	1.80	0.50
	Barges					9.4	9.0	6	4	0.00	2.73	2.40	0.50
	Ro-Ro					19.0	12.0	8	4	0.00	2.05	1.80	0.50
	Cruise					18.7	12.0	8	4	0.00	2.05	1.80	0.50
	Breakbulk					16.5	12.0	8	4	0.00	2.05	1.80	0.50
Columbus Street	Container Ships	0	12.3	7.9	2	21.5	15.0	8	4	0.00	1.64	1.98	0.50
	Barges					9.4	9.0	6	4	0.00	2.73	2.63	0.50
	Ro-Ro					19.0	12.0	8	4	0.00	2.05	1.98	0.50
	Cruise					18.7	12.0	8	4	0.00	2.05	1.98	0.50
	Breakbulk					16.5	12.0	8	4	0.00	2.05	1.98	0.50
Wando Welch	Container Ships	0	12.3	10.3	2	21.5	15.0	8	4	0.00	1.64	2.58	0.50
	Barges					9.4	9.0	6	4	0.00	2.73	3.43	0.50
	Ro-Ro					19.0	12.0	8	4	0.00	2.05	2.58	0.50
	Cruise					18.7	12.0	8	4	0.00	2.05	2.58	0.50
	Breakbulk					16.5	12.0	8	4	0.00	2.05	2.58	0.50
North Charleston	Container Ships	0	12.3	15.4	2	21.5	15.0	8	4	0.00	1.64	3.85	0.50
	Barges					9.4	9.0	6	4	0.00	2.73	5.13	0.50
	Ro-Ro					19.0	12.0	8	4	0.00	2.05	3.85	0.50
	Cruise					18.7	12.0	8	4	0.00	2.05	3.85	0.50
	Breakbulk					16.5	12.0	8	4	0.00	2.05	3.85	0.50

BW-Breakwater

Hoteling times for vessels are based on the 2005 data provided for each vessel call..

2.5 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 (April 2008). The assumed actual speeds for various legs are given in Table 2-2 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 2-6).

2.6 Auxiliary Engine Load Factor

Ocean-going vessels typically have auxiliary engines which are used to generate electricity and run equipment such as lights, electronics, bow thrusters etc. Auxiliary engine sizes are typically not available in the Clarkson Register (April 2008). Therefore, auxiliary engine sizes and load factors for various size and type vessels were taken from the POLA 2005 Emissions Inventory (Starcrest, 2007) as shown in Table 2-3 below. These data were collected during the Port of Los Angeles' vessel boarding program.

Table 2-3: Auxiliary Engine Sizes & Load Factors

Auxiliary Engine Defaults		Load Default %			Load Defaults (kW)		
Vessel Type	Total Aux Engine Power (kW)	Sea	Maneuvering	Hotelling	Sea	Maneuvering	Hotelling
Auto Carrier	2,850	15%	45%	26%	428	1,283	741
Bulk-General	2,850	17%	45%	10%	485	1,283	285
Bulk-Heavy Load	2,850	17%	45%	10%	485	1,283	285
Bulk Wood Chips	2,850	17%	45%	10%	485	1,283	285
Container - 1,000	2,090	13%	50%	18%	272	1,045	376
Container - 2,000	4,925	13%	43%	22%	640	2,118	1,084
Container - 3,000	5,931	13%	43%	22%	771	2,550	1,305
Container - 4,000	7,121	13%	50%	18%	926	3,561	1,282
Container - 5,000	11,360	13%	49%	16%	1,477	5,566	1,818
Container - 6,000	13,501	13%	50%	15%	1,755	6,751	2,025
Container - 7,000	13,501	13%	50%	15%	1,755	6,751	2,025
Container - 8,000	13,501	13%	50%	15%	1,755	6,751	2,025
Cruise	na	na	na	na	na	na	na
General Cargo	1,776	17%	45%	22%	302	799	391
Ocean Tug	600	17%	45%	22%	102	270	132
Miscellaneous	1,776	17%	45%	22%	302	799	391
Reefer	3,900	15%	45%	32%	585	1,755	1,248
Ro/Ro	2,850	15%	45%	26%	428	1,283	741
Tanker-General	1,911	24%	33%	26%	459	631	497
Tanker-Chemical	1,911	24%	33%	26%	459	631	497
Tanker-Crude-Aframax	2,544	24%	33%	26%	611	840	661
Tanker-Crude-Handyboat	1,911	24%	33%	26%	459	631	497
Tanker-Crude-Panamax	2,520	24%	33%	26%	605	832	655
Tanker-Oil Products	1,911	24%	33%	26%	459	631	497
Tankers (Diesel/Electric)	1,985	24%	33%	26%	476	655	516

Source: Starcrest, 2007

2005 data

2.7 Auxiliary Boiler Load Factors

Auxiliary 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 (April 2008). Therefore, auxiliary boiler size and load data were taken from the POLA 2005 Emissions Inventory (Starcrest, 2007) as shown in Table 2-4. These data were collected during the Port of Los Angeles' vessel boarding program.

Table 2-4: Auxiliary Engine Sizes & Load Factors

	Boiler Energy Defaults (kW)	
Vessel Type	Maneuvering	Hotelling
Auto Carrier	371	371
Bulk-General	109	109
Bulk-Heavy Load	109	109
Bulk Wood Chips	109	109
Container - 1,000	506	506
Container - 2,000	506	506
Container - 3,000	506	506
Container - 4,000	506	506
Container - 5,000	506	506
Container - 6,000	506	506
Container - 7,000	506	506
Container - 8,000	506	506
Cruise	1,000	1,000
General Cargo	106	106
Ocean Tug	0	0
Miscellaneous	371	371
Reefer	464	464
Ro/Ro	109	109
Tanker-General	371	3,000
Tanker-Chemical	371	3,000
Tanker-Crude-Aframax	371	3,000
Tanker-Crude-Handyboat	371	3,000
Tanker-Crude-Panamax	371	3,000
Tanker-Oil Products	371	3,000
Tankers (Diesel/Electric)	346	346

Source: Starcrest, 2007

2.8 Emission Factors

Emission factors for ocean-going vessels were taken from the EPA guidance for best practices (ICF Consulting, 2006) and are given in Table 2-5 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;

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

Table 2-4: OGV Main Engine Emission Factors

Emission Factors for OGV Main Engines using Residual Fuel Oil, g/kwh							
Engine	NOx	CO	HC	PM10	PM2.5	SO2	Assumed Fuel Sulfur %
SSD	18.10	1.40	0.60	1.08	0.99	10.30	2.70
MSD	14.00	1.10	0.50	1.14	1.10	11.10	2.70
ST	2.10	0.20	0.10	1.55	0.66	16.10	2.70

Source: ICF Consulting, 2006

Propulsion emissions at low loads are adjusted per the low load correction factors given in Table 2-6.

Table 2-5: OGV Low Load Adjustment Factors multiplier

Emission Factor Adjustment Factors at Low Loads					
Load	Nox	CO	HC	PM	SO2
1%	11.47	20.00	89.44	19.17	1.00
2%	4.63	10.00	31.62	7.29	1.00
3%	2.92	6.67	17.21	4.33	1.00
4%	2.21	5.00	11.18	3.09	1.00
5%	1.83	4.00	8.00	2.44	1.00
6%	1.60	3.33	6.09	2.04	1.00
7%	1.45	2.86	4.83	1.79	1.00
8%	1.35	2.50	3.95	1.61	1.00
9%	1.27	2.22	3.31	1.48	1.00
10%	1.22	2.00	2.83	1.38	1.00
11%	1.17	1.82	2.45	1.30	1.00
12%	1.14	1.67	2.15	1.24	1.00
13%	1.11	1.54	1.91	1.19	1.00
14%	1.08	1.43	1.71	1.15	1.00
15%	1.06	1.33	1.54	1.11	1.00
16%	1.05	1.25	1.40	1.08	1.00
17%	1.03	1.18	1.28	1.06	1.00
18%	1.02	1.11	1.17	1.04	1.00
19%	1.01	1.05	1.08	1.02	1.00
20%	1.00	1.00	1.00	1.00	1.00

Source: ICF Consulting, 2006

Auxiliary engines are all assumed to be medium speed diesels. Emission factors vary by fuel type and are given in Table 2-7. The fuel types included are Residual Fuel Oil (RO), Marine Diesel Oil (MDO), and Marine Gas Oil (MGO).

Table 2-6: OGV Auxiliary Engine Emission Factors

Emission Factors for OGV Aux Engines, g/kwh (assumes all MSD engines)							
Fuel	Assumed Fuel Sulfur %	NOx	CO	HC	PM10	PM2.5	SO2
RO	2.70	14.70	1.10	0.40	1.14	1.10	11.10
MDO	1.50	13.90	1.10	0.40	0.75	0.28	6.16
MGO	0.50	13.90	1.10	0.40	0.42	0.23	2.05

Source: ICF Consulting, 2006

Based on the California Air Resources Board 2005 Ocean Ship Survey Summary of Results (CARB, 2005), 25% of OGVs were assumed to burn distillate fuels (marine gas oil) and 75% were assumed to burn residual fuels in their auxiliary engines.

Auxiliary boiler emission factors are taken from EPA EPA-42 and are summarized in Table 2-8.

Table 2-7: OGV Boiler Emission Factors

Emission Factors for OGV Boilers Burning Residual Fuel Oil, g/kwh					
Assumes 2.7% fuel sulfur content					
NOx	CO	HC	PM10	PM2.5	SO2
2.13	0.19	0.05	0.80	0.48	16.62

Source: EPA AP-42

3. Harbor Craft

3.1 Ship Assist Events

Harbor craft emissions were estimated only for the harbor tugs involved in ship assist work for vessels calling on SCSPA's Charleston terminals. 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

Port of Charleston- Harbor Craft Ship Assist Emissions - 2005
Harbor Craft Emissions

2005 Assumed Sulfur Content [illegible] ppm [illegible]%

Terminal	Vessel Type	Number of calls	Avg Vessel Length ft	Avg Duration at Berth hrs	Avg # Sailing Tugs	Avg # Docking Tugs	Avg Tug Power (Kw)	Tug Yard to Shutes Folley Isl: Dist (nm)	Tug Yard to Shutes Folley Isl: Speed (kts)	Shutes Folley Island to Terminal: Dist (nm)	Shutes Folley Island to Terminal: Speed (kts)	Terminal to Tug Yard: Dist (nm)	Terminal to Tug Yard: Speed (kts)	Maneuvering Time At Berth (hrs)	Total Time per Tug per Vessel Tug (hrs)	Total Sailing Tug Hours	Total Docking Tug Hours	Total Tug Hours	Avg Load Factor	NOX	CO	HC	PM10	PM2.5	SO2
CS	Container	711	736	16	1.7	1.8	2,300	6.00	6	1.40	6	4.50	6	0.25	1.61	730	711	1,441	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Barge	6	343	17	3.0	2.0	2,300	6.00	6	1.40	6	4.50	6	0.25	2.01	30	30	60	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Cruise	1	866	46	3.0	3.0	2,300	6.00	6	1.40	6	4.50	6	0.25	1.01	3	3	6	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Ro-Ro	0					2,300	6.00	6	1.40	6	4.50	6	0.25	1.01	[illegible]	0	0	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Breakbulk	42	567	22	1.7	1.6	2,270	6.00	6	1.40	6	4.50	6	0.25	1.01	114	108	222	31%	13.000	2.600	0.270	0.300	0.291	0.630
NC	Container	366	799	16	1.6	1.6	2,300	6.00	6	0.90	6	3.75	6	0.25	2.40	1,344	1,300	2,739	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Barge	7	343	13	2.0	1.9	2,300	6.00	6	0.90	6	3.75	6	0.25	2.83	30	17	76	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Cruise	0	0	0	0.0	0.0	2,300	6.00	6	0.90	6	3.75	6	0.25	2.40	3	0	0	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Ro-Ro	1	623	13	1.0	1.0	2,300	6.00	6	0.90	6	3.75	6	0.25	2.40	2	2	5	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Breakbulk	4	770	25	2.0	2.1	2,270	6.10	6	0.90	6	3.75	6	0.25	2.44	20	22	47	31%	13.000	2.600	0.270	0.357	0.291	0.630
UP	Container	0	0	0	0.0	0.0	2,300	6.00	6	0.70	6	6.25	6	0.25	1.53	3	0	0	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Barge	0	0	0	0.0	0.0	2,300	6.00	6	0.70	6	6.25	6	0.25	2.86	3	0	0	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Cruise	40	610	21	2.0	2.0	2,300	6.00	6	0.70	6	6.25	6	0.25	1.62	149	147	296	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Ro-Ro	170	610	15	1.6	1.6	2,300	6.00	6	0.70	6	6.25	6	0.25	1.62	422	435	873	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Breakbulk	9	567	25	1.6	1.6	2,270	6.10	6	0.70	6	6.25	6	0.25	1.57	26	26	52	31%	13.000	2.600	0.270	0.350	0.291	0.630
WT	Container	1062	799	14	1.7	1.7	2,300	6.00	6	3.0	6	6.25	6	0.25	3.01	3,700	[illegible]	7,363	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Barge	46	343	10	1.7	1.7	2,300	6.00	6	3.0	6	6.25	6	0.25	3.43	193	187	380	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Cruise	0	0	0	0.0	0.0	2,300	6.00	6	3.0	6	6.25	6	0.25	3.01	3	0	0	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Ro-Ro	0	0	0	3.0	0.0	2,300	6.00	6	3.0	6	6.25	6	0.25	2.01	3	0	0	31%	13.000	2.600	0.270	0.300	0.291	0.630
	Breakbulk	0	0	0	3.4	0.0	2,270	6.00	6	3.0	6	6.25	6	0.25	2.01	3	0	0	31%	13.000	2.600	0.270	0.300	0.291	0.630
Total	Container	1,453	799	16	1.7	1.7										5,666	[illegible]	11,741							
	Tug & Barge	59	343	17	1.8	1.7										253	244	496							
	Cruise	47	610	22	2.0	2.0										152	151	303							
	Ro-Ro	171	619	15	1.6	1.6										400	430	843							
	Breakbulk & Other	55	567	27	1.7	1.7										160	158	318							
	Total	2,814	[illegible]	16	1.7	1.7										[illegible]	[illegible]	[illegible]							

Emission Factors (g/kw-hr) - assuming MDO 1.5% S

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

Figure 3-1: Location of Tug Companies, Terminals, and Shutes Folley Island

tugs pick up here

3.2 Vessel Characteristics

The representative ship assist harbor tug is assumed to be roughly 3,000 hp.

assumes tug returns to their base after each tug - makes it more conservative

3.3 Load Factors

Load factors for ship assist tugs were taken from the EPA guidance for best practices (ICF Consulting, 2006) and are summarized in Table 3-2 below.

Table 3-2: Harbor Craft Load Factors

Vessel Category	Engine Power (hp)
Assist Tugboat	31%
Dredge Tenders	69%
Recreational	21%
Other Categories	43%
Recreational, Auxiliary	32%
Other Auxiliaries	43%

Source: ICF Consulting, 2006

3.4 Emission Factors

Emission factors for harbor craft were taken from the EPA guidance for best practices (ICF Consulting, 2006) and are shown in Table 3-3 below.

Figure 3-3: Harbor Craft Emission Factors

Minimum Power		Emission Factors (g/kWh)				
kW	hp	NOx	CO	HC	PM_{10}	SO_2
37	50	11.0	2.0	0.27	0.9	0.63
75	100	10.0	1.7	0.27	0.4	0.63
130	175	10.0	1.5	0.27	0.4	0.63
225	300	10.0	1.5	0.27	0.3	0.63
450	600	10.0	1.5	0.27	0.3	0.63
560	750	10.0	1.5	0.27	0.3	0.63
1,000	1,341	13.0	2.5	0.27	0.3	0.63

assumes running diesel

Source: ICF Consulting, 2006

The SO_2 emission factors above are based on an assumed sulfur content of 1.5%.

4. Cargo Handling Equipment

4.1 Equipment List

CHE emissions were calculated for equipment exceeding 25 hp using EPA's NONROAD 2004 emissions model and the equipment list and 2005 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 of Equipment	Avg Power (hp)	Avg Annual Usage (hrs/piece of equip)	Total Annual Usage (hrs for fleet)	Avg Model Year	Avg Age (yrs)
Columbus Street Terminal						
Container Handler, Full	12	258	1,547	18,566	1998	7
Crane, Container	1	1,000	228	228	1976	29
Crane, RTG	3	685	2,440	7,321	1999	6
Forklift 36K	3	175	261	782	2001	4
Assumed Avg Hostler	9	250	1,800	16,924	2001	4
North Charleston Terminal						
Container Handler, Full	12	274	1,936	23,232	1997	8
Crane, Container	2	800	197	394	1982	24
Crane, RTG	7	577	2,676	18,733	1994	11
Container Handler, Empty	5	223	1,703	8,515	2000	5
Backhoe	1	90	50	50	1997	8
Forklift 36K	4	169	1,014	4,055	1998	7
Assumed Avg Hostler	15	250	1,800	27,808	2001	4
Union Pier Terminal						
Forklift 55K	2	185	495	990	1999	6
Wando Welch Terminal						
Container Handler, Full	18	250	2,571	46,276	1998	8
Crane, Container	2	800	220	440	1982	24
Crane, RTG	20	627	2,536	50,716	1999	6
Container Handler, Empty	11	230	2,228	24,506	2000	5
Forklift 36K	7	153	813	5,693	1996	9
Assumed Avg Hostler	34	250	2,200	75,536	2001	4

Source: SCSPA data

hours collected from Steve Kemp

4.2 Hours of Operation

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 SPA. Hostler hours were estimated assuming four hostler hours per dock crane hour. The number of hostlers was calculated by dividing the estimated annual operating hours by the average daily hours per hostler from other ports. Typical hostler horsepower and age was also based on other studies of container terminal operations.

4.3 Load Factors

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

Load factors is an area where there is substantial room for refinement in port inventories. It is debatable whether the NONROAD default load factors represent actual operating conditions. M&N's container terminal model calculates the required horsepower of a piece of equipment for each component of its cycle and reports the percent of time a piece of equipment spends in each portion of the cycle. This is used in the model to generate a more accurate load factor. However, given the established practice of using default NONROAD load factors in port inventories, it was decided to maintain consistency and leave the refinement of load factors for the future if it becomes an acceptable practice by the appropriate resource agencies.

4.4 NONROAD Model Runs

The EPA's NONROAD model runs were performed with detailed spreadsheets using the EPA NONROAD model input files and various lookup functions to:

- Assign the proper Tier for an engine based on its model year and engine size.
- 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 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 CO_2 and SO_2 emission factors based on the brake specific fuel consumption and assumed sulfur content as given by NONROAD depending on the year of analysis.
- 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 result is a calculation of emissions for each piece of equipment. The general equation for the calculation is:

Emissions = (installed hp) x (annual hours of operation) x (load factor) x (adjusted emission factor)

This equation is applied for seven separate pollutants. NONROAD calculates CO_2 emissions and those results are therefore reported in the detailed CHE emission estimates of Appendix D. However, this inventory analysis is limited to the six pollutants listed in Section 1.5 of this report, so CO_2 emissions are not shown in the summary tables.

5. Rail Locomotives

5.1 Locomotive Hours

SC Public Railroad

Locomotive hours for switchers operated by SCPR were provided by SCPR. Line haul locomotive hours were estimated for the percentage of containerized port cargo that entered or left the tri-county area through the nearby NS or CSX intermodal rail yards. Line haul locomotive activity was developed by M&N's container terminal model. For line haul activity, the model predicts the number of trains of a given length needed to accommodate the given rail cargo throughput. All line haul emissions are off-terminal. Line haul emissions are based on the number of trains per year estimated, assumed average rail speed and distance to the tri-county boundary.

None of the activities within the NS or CSX intermodal terminals were included in this inventory.

5.2 Locomotive Characteristics

Switcher locomotive horsepower is based on the information provided by the SCPR. Line haul locomotive characteristics were based on typical industry practice for the size of the locomotive and number of locomotives used in trains of various lengths.

5.3 Locomotive Emission Factors

Locomotive emission factors are based on a detailed analysis of the 1998 Locomotive Emission Standards Regulatory Support Document. The procedure for determining emission factors for locomotives is different from that used for other sources. The current practice in the literature is to calculate a load factor and an emission factor for each of ten engine settings (dynamic braking, idling, and eight notch positions). Composite emission factors are developed based on a percentage of time in each notch for typical switching and line haul activity. Sulfur content in locomotive fuel was projected using the EPA's NONROAD road model forecast.

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

Table 5-1: Rail Assumptions Summary

SPA 2005 Rail Related Emissions

Line Haul - Container Train Traffic in/out of Charleston only. Not including siding, switching or cargo handling in private railyards

Annual Rail* TEU Estimate	TEU per Train	No. of Trains
348,746	360	969

	Annual # Trains	Assumed Locomotive Hp	Locomotives per Train	Avg Speed (mph)	Avg Dist To Tri-County Border (mi)	Annual Locomotive Hrs	Avg Hp in Use	Emission Factors (lbs/hr) NOx	PM10	PM2.5	HC	CO	SO2	Est Fuel Use	Annual Est'd Diesel Consumption
Line Haul Locomotive Hours	969	3,500	4	40	35	3,391	972	26.52	0.60	0.58	0.89	3.34	1.492	326.5	154,824
Total Line Haul															154,824

Switcher Emissions - PTR and PUC Operated Switchers Only

	Daily Run Hrs (from SCPR)	Avg Locomotive HP	Annual Locomotive Hours	Avg Hp in Use	Emission Factors (lbs/hr) NOx	PM10	PM2.5	HC	CO	SO2	Est Fuel Use	Annual Est'd Diesel Consumption	Reported Annual Consumption	
PTR Switcher serving NCT	3	1,750	780	186	7.16	0.16	0.15	0.31	0.71	0.29	62.51	8,019	6,400	126%
PUC Switcher serving Union Pier & Columbus St	12	1,000	3,120	106	4.09	0.09	0.09	0.18	0.41	0.16	36.72	14,386	17,000	87%
Total Switching			3,900									22,405	23,400	96%

Switcher Emissions based on HP and operating hours of PUC and PTR switchers as provided by SCPR

Line Haul Emissions are an estimate of double-stack line haul emissions of SPA related container cargo out to tri-county line only and do not include any emission within private intermodal yards

6. Heavy Duty Vehicles

Emissions were calculated for a total of nearly two million truck trips and fifty five million vehicle miles including the estimated 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 roll-on, roll-off (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.

We need copy of WSA study

6.1 Truck Trips

Breakbulk truck trips were provided by SCSPA based on terminal records. Container-related truck trips were estimated based on the number of local lifts (non-transshipment lifts), M&N container terminal modeling assumptions, and field data collected as part of a March 2002 study by Wilbur Smith and Associates (WSA). The ratio of local lifts to gate transactions was determined to be 1.3 based on M&N historical modeling.

Based on a review of Wilbur Smith data, the percent of double cycling trucks has been estimated at 50%. The split of truck trip types was based on gate surveys taken in the WSA study and estimated as:

- 10% bare chassis
- 20% bobtails (no chassis or container)
- 70% container (loaded or empty)

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 SPA and data from the 2002 Wilbur Smith study to apportion the remaining containers. The resulting distribution is shown in Table 6-1 below.

Table 6-1: 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%	

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.

The destination of breakbulk trips was split evenly among local rail yards, within local Charleston, and outside the tri-county area.

Table 6-2 summarizes the average travel distances between each terminal and each origin or destination for each type of truck trip.

Table 6-2: 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
Breakbulk	Breakbulk	33.3%	Offsite Railyards	7.00	6.00	5.50	12.75
		33.3%	Local Charleston	15.30	14.30	9.75	16.50
		33.3%	Out of Tri-County	51.00	50.00	40.00	52.00

← centroid of activity

The number of each type of truck trip was calculated for each terminal based on the 2005 throughput at each terminal. The appropriate distances were applied for each truck trip type at each terminal. The results indicate that 1.957 million truck trips generated slightly over 55 million vehicle miles traveled.

6.3 On-Terminal Truck Time

On-terminal time for over the road trucks consists of the time trucks spend idling at the gate, transiting within the terminal, and idling while being serviced inside the terminal. On-terminal truck time was estimated as one hour for each truck visit (one truck visit is made up of two truck trips, therefore the number of visits is half the number of trips). The hour is divided into 0.2 hours idling, 0.2 hours creep idle and 0.6 hours transiting within the terminal.

conservative; they are currently at 1/3 of this

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 1.957 million truck trips in 2005. Trips were broken down by time of day (weekday AM rush hour, weekday PM rush hour, weekday non-rush hour, and weekend) and road speeds were adjusted downward during the more congested rush hour periods. This has an impact on truck emissions as emission factors for trucks are speed specific for some pollutants.

Figure 6-1 shows the results of the Wilbur Smith and Associates giving the distribution of truck trips over the day. This data was used to apportion truck trips to the three times of day (weekday am rush hour 15%, weekday pm rush hour 10%, and weekday non-rush hour 75%).

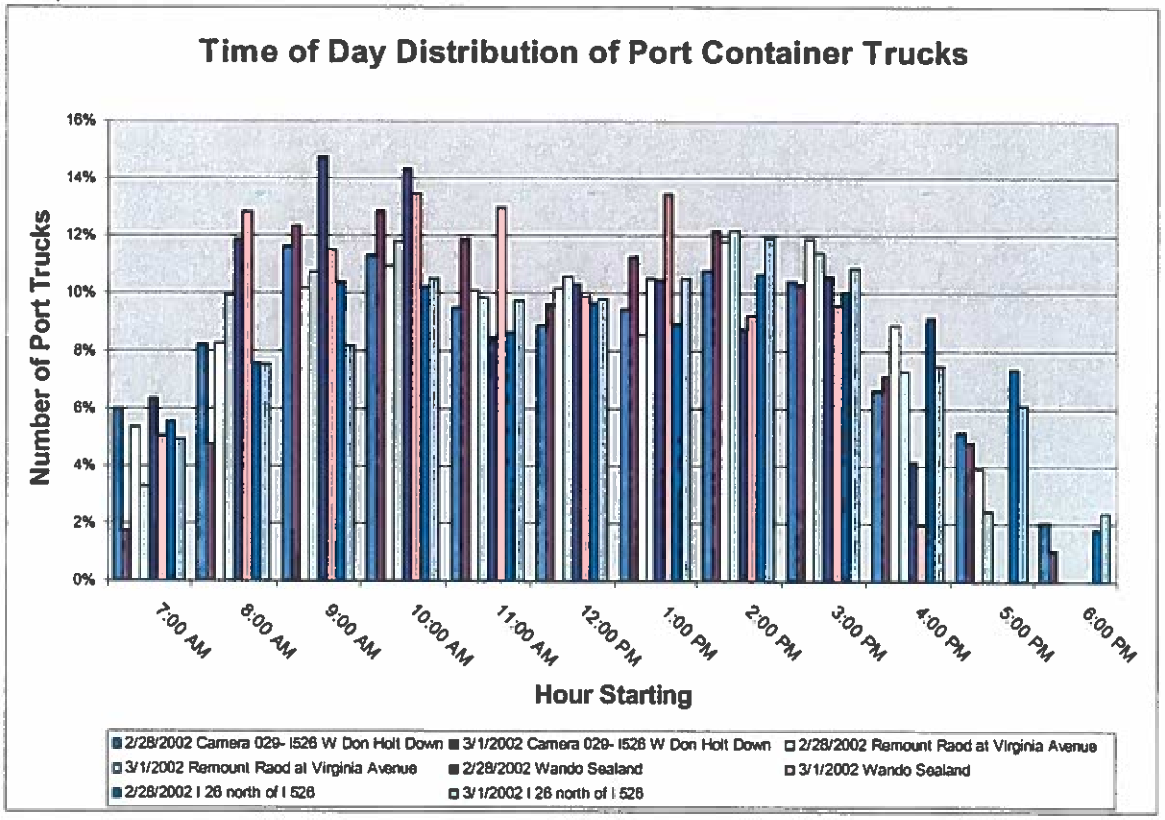


Figure 6-1: Time of Day Distribution of Container Truck Trips. Developed from Gate Count Data in WSA 2002 Study

Table 6-3 below is an example of the on- and off-terminal heavy duty vehicle emissions calculation. The example shown is the Wando Welch Terminal, which represents roughly 60% of the truck trips and nearly 70% of the total HDV emissions at the Port of Charleston. Detailed emission calculations for each of the four Port of Charleston terminals can be found in Appendix E.

Table 6-3: Summary of HDV Emissions Analysis for Wando Welch Terminal

Wando Welch Heavy Duty Vehicles

Container Truck Visits per Year	607,566	<- from cargo / truck trip analysis	
Container Truck Trips	1,215,112		
Breakbulk Visits	2,434	<- from cargo / truck trip analysis	
Breakbulk Truck Trips	4,868		

Road Trucks on terminal

Container Truck Turn Time		1 hrs	Arrivng Trucks	annual hrs	Nox g/hr	Exhaust PM10 g/hr	Exhaust PM2.5 g/hr	VOCs g/hr	SO2 g/hr	CO g/hr	Nox	PM10	PM2.5	VOCs	SO2	CO
Creep idle	20%	0.2 hrs/truck arrival	607,566	121,511	135.00	3.68	3.57	8.01	1.33	85.46	18.08	0.49	0.48	1.07	0.18	11.46
stop idle	20%	0.2 hrs/truck arrival	607,566	121,511	135.00	3.68	3.57	8.01	1.33	85.46	18.08	0.49	0.48	1.07	0.18	11.46
moving (10mph)	60%	0.6 hrs/truck arrival	607,566	364,534	256.03	7.71	7.48	22.11	6.31	192.41	102.89	3.10	3.00	8.88	2.13	77.32
Total per truck arrival (truck visit)		1.00 Truck Turn time	607,566	607,566							139.06	4.08	3.96	11.03	2.49	100.21

Hourly Emission Factors / Emissions (short tons)

Breakbulk Truck Turn Time		1 hrs	Arrivng Trucks	annual hrs	Nox g/hr	Exhaust PM10 g/hr	Exhaust PM2.5 g/hr	VOCs g/hr	SO2 g/hr	CO g/hr	Nox	PM10	PM2.5	VOCs	SO2	CO
Creep idle	20%	0.2 hrs/truck arrival	2,434	487	135.00	3.68	3.57	8.01	1.33	85.46	0.07	0.00	0.00	0.00	0.00	0.06
stop idle	20%	0.2 hrs/truck arrival	2,434	487	135.00	3.68	3.57	8.01	1.33	85.46	0.07	0.00	0.00	0.00	0.00	0.05
moving (10mph)	60%	0.6 hrs/truck arrival	2,434	1,460	256.03	7.71	7.48	22.11	6.31	192.41	0.41	0.01	0.01	0.04	0.01	0.31
Total per truck arrival (truck visit)		1.00 Truck Turn time	2,434	2,434							0.54	0.02	0.02	0.04	0.01	0.40
Total On Terminal											139.60	4.10	3.98	11.07	2.50	100.61

Road Truck Trips (off terminal) 1,219,980 PM2.5 % 97% of PM10

Speed Specific Emission Factors / Emissions (short tons)

Truck Trips	Truck Trips	Truck Type	Time Period		# Trips per Year	Path	% of trips	Seg	Dist (mi)	Avg Speed	VMT	Nox grams	Exhaust PM grams	Exhaust PM2.5 grams	VOCs grams	Sulfur Dioxide (SO2) grams	Carbon Monoxide grams	Nox	PM10	PM2.5	VOCs	SO2	CO
1,215,112	243,022	20% Bobtails	1 Weekday AM Rush Hour - 15%	Arriving / Departing	36,463	Path BA1	100%	Seg 1	3.00	16	109,388	22.72	0.77	0.75	1.77	0.63	13.88	2.74	0.09	0.09	0.21	0.06	1.67
								Seg 2	10.60	46	382,760	20.08	0.77	0.75	0.75	0.63	5.10	8.47	0.33	0.32	0.32	0.22	2.15
						Path BA2	0%	Seg 1	0.00	20	0	20.79	0.77	0.75	1.46	0.63	10.49	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	40	0	19.18	0.77	0.75	0.82	0.63	5.38	0.00	0.00	0.00	0.00	0.00	0.00
						Path BA3	0%	Seg 1	0.00	20	0	20.79	0.77	0.75	1.46	0.63	10.49	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	40	0	19.18	0.77	0.75	0.82	0.63	5.38	0.00	0.00	0.00	0.00	0.00	0.00
			2 Weekday PM Rush Hour - 10%	Arriving / Departing	24,302	Path BA1	100%	Seg 1	3.00	16	72,907	22.72	0.77	0.75	1.77	0.63	13.88	1.83	0.06	0.06	0.14	0.04	1.12
								Seg 2	10.60	46	258,174	20.08	0.77	0.75	0.75	0.63	5.10	5.64	0.22	0.21	0.21	0.15	1.43
						Path BA2	0%	Seg 1	0.00	20	0	20.79	0.77	0.75	1.46	0.63	10.49	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	40	0	19.18	0.77	0.75	0.82	0.63	5.38	0.00	0.00	0.00	0.00	0.00	0.00
						Path BA3	0%	Seg 1	0.00	20	0	20.79	0.77	0.75	1.46	0.63	10.49	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	40	0	19.18	0.77	0.75	0.82	0.63	5.38	0.00	0.00	0.00	0.00	0.00	0.00
			3 Weekday Non-Rush Hour - 75%	Arriving / Departing	182,267	Path BA1	100%	Seg 1	3.00	30	546,800	20.79	0.77	0.75	1.46	0.63	10.49	12.53	0.46	0.45	[illegible]	0.32	[illegible]
								Seg 2	10.60	60	1,912,804	21.61	0.77	0.75	0.70	0.63	5.06	45.60	1.63	1.58	1.49	1.12	10.67
						Path BA2	0%	Seg 1	0.00	30	0	18.94	0.77	0.75	1.05	0.63	6.86	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	60	0	21.61	0.77	0.75	0.73	0.63	5.06	0.00	0.00	0.00	0.00	0.00	0.00
						Path BA3	0%	Seg 1	0.00	30	0	18.94	0.77	0.75	1.35	0.63	6.86	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	60	0	21.61	0.77	0.75	0.73	0.63	5.06	0.00	0.00	0.00	0.00	0.00	0.00
	121,511	10% Chassis	1 Weekday AM Rush Hour - 15%	Arriving / Departing	18,227	OP SRL	100%	Seg 1	3.00	16	54,680	22.72	0.77	0.75	1.77	0.63	13.88	1.37	0.05	0.05	0.11	0.03	0.84
								Seg 2	9.75	36	177,713	19.82	0.77	0.75	0.92	0.63	5.93	3.69	0.15	0.15	0.18	0.10	1.16
						Path CA2	0%	Seg 1	0.00	20	0	20.79	0.77	0.75	1.46	0.63	10.49	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	40	0	19.18	0.77	0.75	0.82	0.63	5.38	0.00	0.00	0.00	0.00	0.00	0.00
						Path CA3	0%	Seg 1	0.00	20	0	20.79	0.77	0.75	1.46	0.63	10.49	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	40	0	19.18	0.77	0.75	0.82	0.63	5.38	0.00	0.00	0.00	0.00	0.00	0.00
			2 Weekday PM Rush Hour - 10%	Arriving / Departing	12,151	OP SRL	100%	Seg 1	3.00	16	36,453	22.72	0.77	0.75	1.77	0.63	13.88	0.91	0.03	0.03	0.07	0.02	0.56
								Seg 2	9.75	36	118,473	19.82	0.77	0.75	0.92	0.63	5.93	2.46	0.10	0.10	0.12	0.07	0.78
						Path CA2	0%	Seg 1	0.00	20	0	20.79	0.77	0.75	1.46	0.63	10.49	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	40	0	19.18	0.77	0.75	0.82	0.63	5.38	0.00	0.00	0.00	0.00	0.00	0.00
						Path CA3	0%	Seg 1	0.00	20	0	20.79	0.77	0.75	1.46	0.63	10.49	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	40	0	19.18	0.77	0.75	0.82	0.63	5.38	0.00	0.00	0.00	0.00	0.00	0.00
			3 Weekday Non-Rush Hour - 75%	Arriving / Departing	91,133	OP SRL	100%	Seg 1	3.00	30	273,400	20.79	0.77	0.75	1.46	0.63	10.49	6.27	0.23	0.22	0.44	0.16	3.16
								Seg 2	9.75	40	888,547	19.18	0.77	0.75	0.82	0.63	5.38	18.79	0.76	0.73	0.80	0.62	6.27
						Path CA2	0%	Seg 1	0.00	30	0	18.94	0.77	0.75	1.05	0.63	6.86	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	60	0	21.61	0.77	0.75	0.73	0.63	5.06	0.00	0.00	0.00	0.00	0.00	0.00
						Path CA3	0%	Seg 1	0.00	30	0	18.94	0.77	0.75	1.35	0.63	6.86	0.00	0.00	0.00	0.00	0.00	0.00
								Seg 2	0.00	60	0	21.61	0.77	0.75	0.73	0.63	5.06	0.00	0.00	0.00	0.00	0.00	0.00
	850,578	70% Loads & Empties	1 Weekday AM Rush Hour - 15%	Arriving / Departing	127,587	OP SRL	18.6%	Seg 1	3.00	16	68,597	22.72	0.77	0.75	1.77	0.63	13.88	1.73	0.06	0.06	0.13	0.04	1.06
								Seg 2	9.75	46	223,014	20.08	0.77	0.75	0.75	0.63	5.10	4.96	0.19	0.18	0.18	0.13	1.26
						LOCAL	18.6%	Seg 1	3.00	16	71,192	22.72	0.77	0.75	1.77	0.63	13.88	1.78	0.06	0.06	0.14	0.04	1.09
								Seg 2	13.50	46	320,357	20.08	0.77	0.75	0.75	0.63	5.10	7.09	0.27	0.26	0.27	0.19	1.80
						Path LA3	62.4%	Seg 1	3.00	16	242,475	22.72	0.77	0.75	1.77	0.63	13.88	6.08	0.21	0.20	0.47	0.14	3.71
								Seg 2	49.00	46	3,961,619	20.08	0.77	0.75	0.75	0.63	5.10	87.74	3.37	3.27	[illegible]	[illegible]	22.27
			2 Weekday PM Rush Hour - 10%	Arriving / Departing	85,064	OP SRL	18.6%	Seg 1	3.00	16	46,511	22.72	0.77	0.75	1.77	0.63	13.88	1.16	0.04	0.04	0.09	0.03	0.70
								Seg 2	9.75	46	149,277	20.08	0.77	0.75	0.75	0.63	5.10	3.30	0.13	0.12	0.12	0.09	0.84
						LOCAL	18.6%	Seg 1	3.00	16	47,462	22.72	0.77	0.75	1.77	0.63	13.88	1.19	0.04	0.04	0.09	0.03	0.73
								Seg 2	13.50	46	213,580	20.08	0.77	0.75	0.75	0.63	5.10	4.73	0.18	0.18	0.18	0.12	1.20
						Path LA3	63.4%	Seg 1	3.00	16	161,790	22.72	0.77	0.75	1.77	0.63	13.88	4.05	0.14	0.13	0.32	0.09	2.48
								Seg 2	49.00	46	2,642,437	20.08	0.77	0.75	0.75	0.63	5.10	[illegible]	[illegible]	[illegible]	2.19	[illegible]	[illegible]
			3 Weekday Non-Rush Hour - 75%	Arriving / Departing	637,934	OP SRL	18.6%	Seg 1	3.00	30	344,448	20.79	0.77	0.75	1.46	0.63	10.49	7.90	0.29	0.28	[illegible]	0.23	[illegible]
								Seg 2	9.75	60	1,119,874	21.61	0.77	0.75	0.70	0.63	5.06	26.67	0.95	0.92	0.87	0.66	6.24
						LOCAL	18.6%	Seg 1	3.00	30	356,562	20.79	0.77	0.75	1.46	0.63	10.49	8.16	0.30	0.29	0.57	0.21	4.11
								Seg 2	13.50	60	1,601,857	21.61	0.77	0.75	0.70	0.63	5.06	38.16	1.36	1.32	1.24	0.94	8.93
						Path LA3	63.4%	Seg 1	3.00	30	1,213,358	20.79	0.77	0.75	1.46	0.63	10.49	27.81	1.03	1.00	1.96	0.71	14.03
								Seg 2	49.00	60	19,818,059	21.61	0.77	0.75	0.70	0.63	5.06	472.17	16.84	16.33	[illegible]	[illegible]	[illegible]
4,868	4,868	Breakbulk Trips	1 Weekday AM Rush Hour - 15%	Arriving / Departing	730	Path BB1	33.3%	Seg 1	3.00	16	730	22.72	0.77	0.75	1.77	0.63	13.88	0.02	0.00	0.00	0.00	0.00	0.01
								Seg 2	9.75	46	2,373	20.08	0.77	0.75	0.75	0.63	5.10	0.05	0.00	0.00	0.00	0.00	0.01
						Path BB2	33.3%	Seg 1	3.00	20	730	20.79	0.77	0.75	1.46	0.63	10.49	0.02	0.00	0.00	0.00	0.00	0.01
								Seg 2	13.50	40	3,284	19.18	0.77	0.75	0.82	0.63	5.38	0.07	0.00	0.00	0.00	0.00	0.02
						Path BB3	33.3%	Seg 1	3.00	20	730	20.79	0.77	0.75	1.46	0.63	10.49	0.02	0.00	0.00	0.00	0.00	0.01
								Seg 2	49.00	40	11,927	19.18	0.77	0.75	0.82	0.63	5.38	0.26	0.01	0.01	0.01	0.01	0.07
			2 Weekday PM Rush Hour - 10%	Arriving / Departing	487	Path BB1	33.3%	Seg 1	3.00	16	487	22.72	0.77	0.75	1.77	0.63	13.88	0.01	0.00	0.00	0.00	0.00	0.01
								Seg 2	9.75	46	1,582	20.08	0.77	0.75	0.75	0.63	5.10	0.04	0.00	0.00	0.00	0.00	0.01
						Path BB2	33.3%	Seg 1	3.00	20	487	20.79	0.77	0.75	1.46	0.63	10.49	0.01	0.00	0.00	0.00	0.00	0.01
								Seg 2	13.50	40	2,191	19.18	0.77	0.75	0.82	0.63	5.38	0.05	0.00	0.00	0.00	0.00	0.01
						Path BB3	33.3%	Seg 1	3.00	20	487	20.79	0.77	0.75	1.46	0.63	10.49	0.01	0.00	0.00	0.00	0.00	0.01
								Seg 2	49.00	40	7,951	19.18	0.77	0.75	0.82	0.63	5.38	0.17	0.01	0.01	0.01	0.00	0.05
			3 Weekday Non-Rush Hour - 75%	Arriving / Departing	3,651	Path BB1	33.3%	Seg 1	3.00	30	3,651	20.79	0.77	0.75	1.46	0.63	10.49	0.08	0.00	0.00	0.01	0.00	0.04
								Seg 2	9.75	60	11,866	21.61	0.77	0.75	0.70	0.63	5.06	0.28	0.01	0.01	0.01	0.01	0.07
						Path BB2	33.3%	Seg 1	3.00	30	3,651	18.94	0.77	0.75	1.05	0.63	6.86	0.08	0.00	0.00	0.00	0.00	0.03
								Seg 2	13.50	60	16,430	21.61	0.77	0.75	0.70	0.63	5.06	0.39	0.01	0.01	0.01	0.01	0.09
						Path BB3	33.3%	Seg 1	3.00	30	3,651	18.94	0.77	0.75	1.05	0.63	6.86	0.08	0.00	0.00	0.00	0.00	0.03
								Seg 2	49.00	60	59,633	21.61	0.77	0.75	0.70	0.63	5.06	1.42	0.05	0.05	0.04	0.03	0.31
					1,219,980						37,548,203							675.43	31.91	30.96	33.13	21.58	230.73

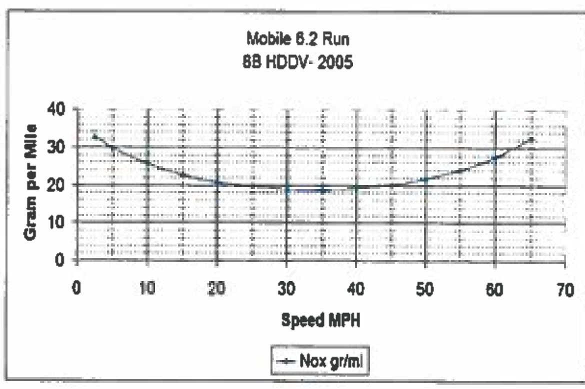
6.5 Emission Factors

Emission factors for over the road trucks were developed using EPA's Mobile 6.2 emissions model. Emission factors in grams per mile for the 8B trucks (>60,000# gross vehicle weight) are calculated based on a given speed. Emission factors for over the road trucks vary widely by model year. Mobile 6.2 provides a default distribution of model years based on the given year of analysis. Examples for 2005 age distribution and emission rate in grams/mi vs. vehicle speed are given in Table 6-4 below.

Table 6-4: Fleet Age Distribution, Over the Road Trucks

Year of Analysis 2005

Model Year	Age	EPA Default Distribution 8B
1981	24	8.29%
1982	23	1.74%
1983	22	1.85%
1984	21	1.99%
1985	20	2.12%
1986	19	2.27%
1987	18	2.42%
1988	17	2.59%
1989	16	2.77%
1990	15	2.97%
1991	14	3.16%
1992	13	3.39%
1993	12	3.62%
1994	11	3.87%
1995	10	4.14%
1996	9	4.42%
1997	8	4.73%
1998	7	5.06%
1999	6	5.41%
2000	5	5.78%
2001	4	6.18%
2002	3	6.61%
2003	2	7.06%
2004	1	7.55%
2005	0	0.00%



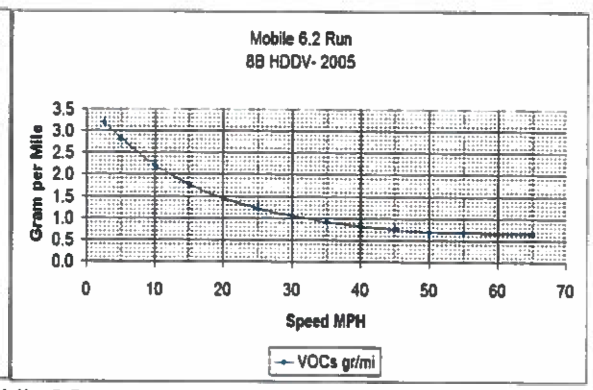


Figure 6-2: Example Emission Factor Output of Mobile 6.2

7. Emission Results

Results of the emission calculations can be broken up by source, mode, pollutant, terminal, and on-terminal vs. off-terminal. More detail is available in calculation spreadsheets included in the appendices of this report. Select results are presented in this section.

7.1 All Sources

Tons of emissions of six different pollutants by five different source categories are shown below, the totals are in the first table, Table 7-1. The same totals are broken up by on- or off-terminal in Tables 7-2 and 7-3.

Table 7-1: Summary Mass Emission Results

Port of Charleston 2005 Air Emissions (tons)						
Pollutant	Source					
	OGV	HC	CHE	HDV	RL	**Total**
NOx	1,492.0	133.9	284.5	1,512.3	54.1	**3,476.8**
CO	145.3	25.7	119.4	510.8	6.4	**807.7**
SO2	1,076.0	6.5	36.2	36.3	2.9	**1,157.9**
TOG	103.4	3.0	21.6	67.9	2.0	**197.9**
PM10	116.8	3.1	18.2	53.5	1.2	**192.8**
PM2.5	101.9	3.0	17.7	51.9	1.2	**175.6**

Table 7-2: On-Terminal Emissions Results

Port of Charleston 2005 On-Terminal Air Emissions (tons)						
Pollutant	Source					
	OGV	HC	CHE	HDV	RL	**Total**
NOx	591.7	0.0	284.5	224.0	9.2	**1,109.3**
CO	45.4	0.0	119.4	161.4	0.9	**327.2**
SO2	596.4	0.0	36.2	4.0	0.4	**637.0**
TOG	17.3	0.0	21.6	18.1	0.4	**57.4**
PM10	49.2	0.0	18.2	6.6	0.2	**74.2**
PM2.5	41.1	0.0	17.7	6.4	0.2	**65.4**

Table 7-3: Off-Terminal Emission Results

Port of Charleston 2005 Off-Terminal Air Emissions (tons)						
Pollutant	Source					
	OGV	HC	CHE	HDV	RL	Total
NOx	900.4	133.9	0.0	1,288.3	45.0	**2,367.6**
CO	99.9	25.7	0.0	349.4	5.5	**480.5**
SO2	479.5	6.5	0.0	32.3	2.5	**520.8**
TOG	86.1	3.0	0.0	49.8	1.6	**140.5**
PM10	67.6	3.1	0.0	46.9	1.0	**118.6**
PM2.5	60.8	3.0	0.0	45.5	1.0	**110.3**

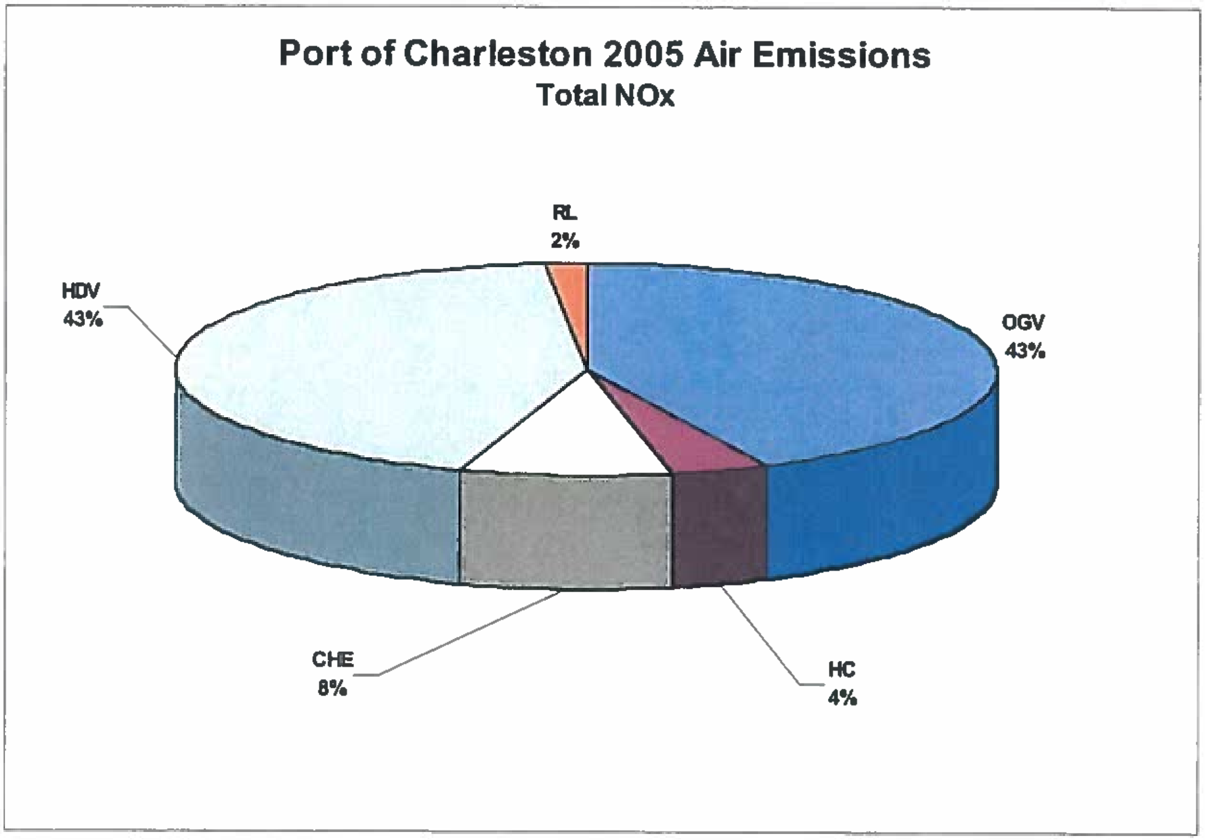


Figure 7-1: Total NOx Emissions by Source Category

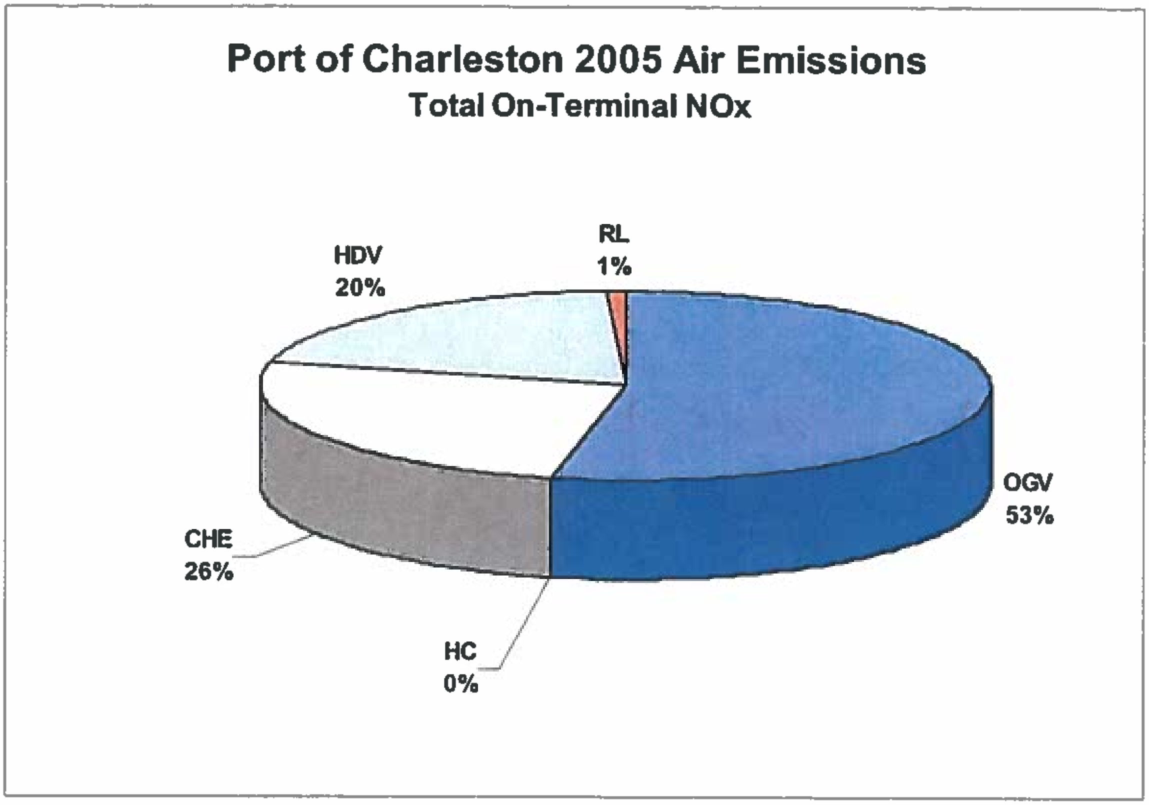


Figure 7-2: On-Terminal NOx Emissions by Source

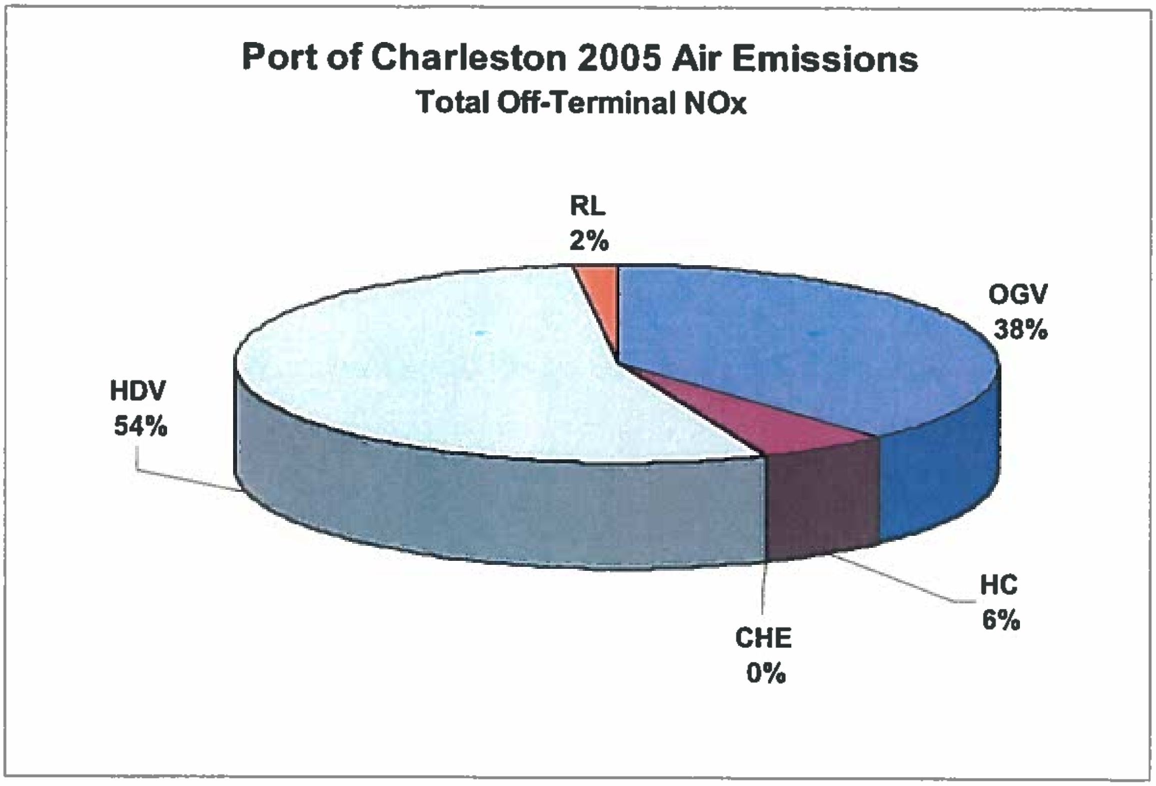


Figure 7-3: Off-Terminal NOx Emissions by Source

7.2 Ocean Going Vessels

The 2005 ocean-going vessel emissions are shown in Table 7-4 below for each of the six pollutants included in the study.

Table 7-4: OGV Emissions Results

Charleston 2005 Baseline Emissions
Ocean Going Vessel Emissions, annual short tons
Total Four Marine Terminals (CS,NC,UP,WT)

		Columbus Street	North Charleston	Union Pier	Wando Welch	Offsite				On-Terminal		Total
		Total	Total	Total	Total	Cruise	Reduced Speed Zone	Maneuvering	Subtotal Offsite	Hoteling	Subtotal On-Terminal	
Container Ships	NOx	182.97	323.45	0.00	845.01	0.00	744.40	80.90	825.29	526.14	526.14	1351.43
	CO	16.49	34.35	0.00	81.89	0.00	82.59	9.77	92.36	40.37	40.37	132.73
	HC	9.41	26.79	0.00	53.86	0.00	65.55	10.12	75.67	14.40	14.40	90.07
	PM10	14.38	26.05	0.00	65.70	0.00	55.33	6.78	62.10	44.03	44.03	106.13
	PM2.5	12.43	22.86	0.00	57.37	0.00	49.71	6.10	55.81	36.86	36.86	92.66
	SO2	147.01	215.28	0.00	606.54	0.00	396.50	37.23	433.73	535.10	535.10	968.83
Barges	NOx	0.86	1.36	0.00	8.47	0.00	8.31	0.29	8.60	2.09	2.09	10.69
	CO	0.07	0.11	0.00	0.69	0.00	0.68	0.04	0.71	0.16	0.16	0.87
	HC	0.03	0.05	0.00	0.31	0.00	0.31	0.03	0.34	0.06	0.06	0.40
	PM10	0.07	0.11	0.00	0.66	0.00	0.67	0.03	0.70	0.14	0.14	0.84
	PM2.5	0.06	0.10	0.00	0.63	0.00	0.65	0.02	0.67	0.13	0.13	0.80
	SO2	0.61	1.01	0.00	6.21	0.00	6.42	0.14	6.57	1.27	1.27	7.84
Cruise	NOx	5.88	0.00	39.26	0.00	0.00	17.66	1.77	19.43	25.70	25.70	45.14
	CO	0.49	0.00	3.53	0.00	0.00	1.79	0.22	2.01	2.01	2.01	4.02
	HC	0.21	0.00	1.80	0.00	0.00	1.07	0.23	1.30	0.71	0.71	2.01
	PM10	0.25	0.00	3.40	0.00	0.00	1.32	0.16	1.48	2.17	2.17	3.65
	PM2.5	0.16	0.00	2.76	0.00	0.00	1.16	0.14	1.30	1.62	1.62	2.92
	SO2	2.05	0.00	40.66	0.00	0.00	12.22	1.03	13.25	29.47	29.47	42.71
Ro-Ro / Vehicle	NOx	0.00	0.43	64.95	0.00	0.00	30.99	3.75	34.74	30.64	30.64	65.38
	CO	0.00	0.04	5.93	0.00	0.00	3.18	0.46	3.65	2.33	2.33	5.98
	HC	0.00	0.03	3.22	0.00	0.00	1.91	0.50	2.41	0.84	0.84	3.25
	PM10	0.00	0.03	4.64	0.00	0.00	2.12	0.31	2.43	2.24	2.24	4.67
	PM2.5	0.00	0.03	4.16	0.00	0.00	1.92	0.28	2.21	1.99	1.99	4.19
	SO2	0.00	0.28	41.85	0.00	0.00	17.14	1.49	18.63	23.51	23.51	42.13
Breakbulk & Other	NOx	14.03	2.21	3.14	0.00	0.00	11.24	1.06	12.30	7.08	7.08	19.39
	CO	1.24	0.22	0.26	0.00	0.00	1.06	0.13	1.18	0.54	0.54	1.72
	HC	0.64	0.15	0.12	0.00	0.00	0.59	0.13	0.72	0.19	0.19	0.92
	PM10	1.09	0.16	0.22	0.00	0.00	0.79	0.09	0.88	0.59	0.59	1.48
	PM2.5	0.97	0.15	0.20	0.00	0.00	0.73	0.08	0.81	0.50	0.50	1.32
	SO2	10.64	1.34	2.28	0.00	0.00	6.89	0.46	7.35	7.11	7.11	14.46
Total	NOx	203.7	327.5	107.4	853.5	0.0	812.6	87.8	900.4	591.7	591.7	1,492.0
	CO	18.3	34.7	9.7	82.6	0.0	89.3	10.6	99.9	45.4	45.4	145.3
	HC	10.3	27.0	5.1	54.2	0.0	69.4	11.0	80.4	16.2	16.2	96.6
	PM10	15.8	26.4	8.3	66.4	0.0	60.2	7.4	67.6	49.2	49.2	116.8
	PM2.5	13.6	23.1	7.1	58.0	0.0	54.2	6.6	60.8	41.1	41.1	101.9
	SO2	160.5	217.9	84.8	612.7	0.0	439.2	40.4	479.5	596.4	596.4	1,076.0

Figure 7-4 shows the relative contribution of the various modes of operation of the OGVs including transiting through the channels (RSZ), maneuvering, and hoteling while at berth.

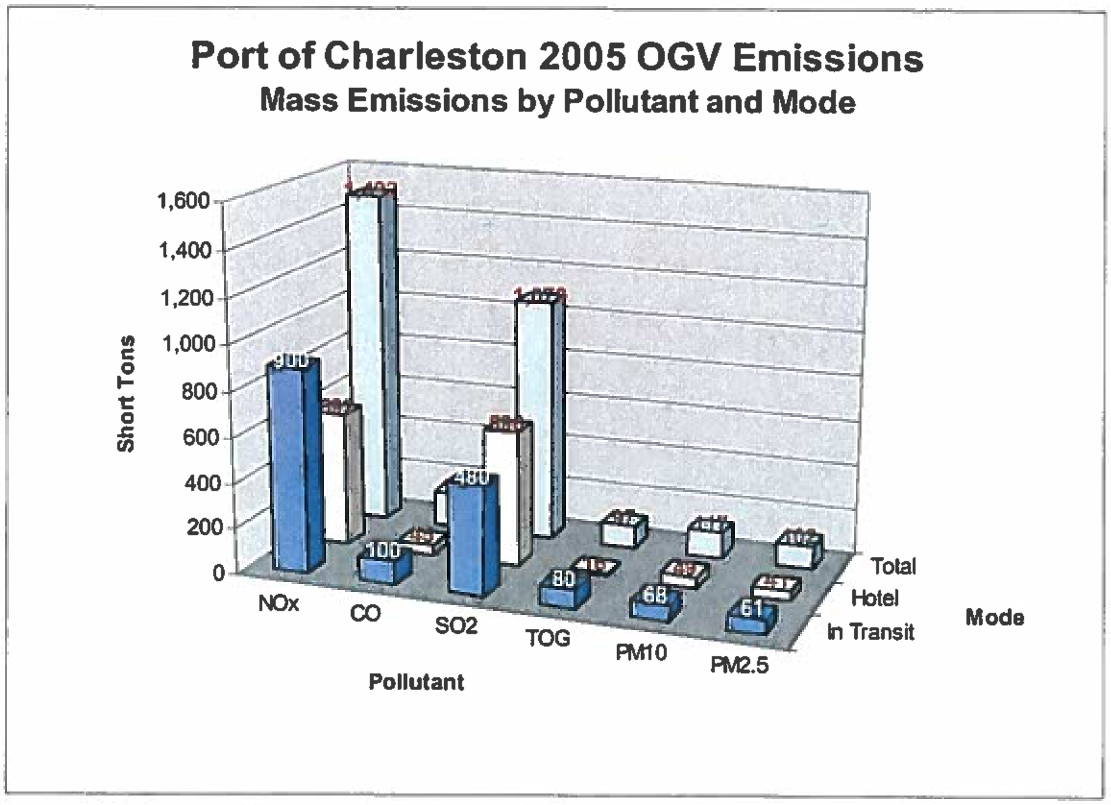


Figure 7-4: OGV Emissions by Pollutant and Mode

Figure 7-5 shows the contribution to NOx emissions by type of vessel.

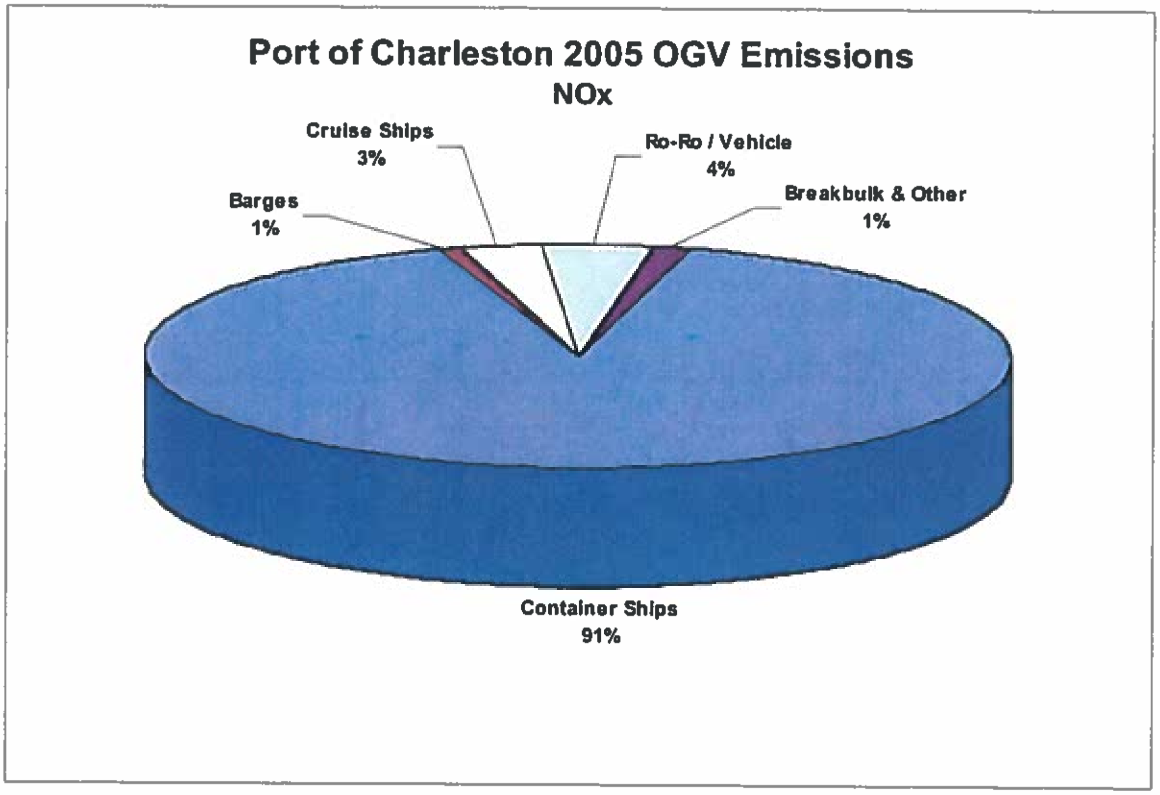


Figure 7-5: OGV NOx Emissions by Vessel Type

7.3 Harbor Craft

Total harbor craft emissions are summarized in Table 7-5 below for each of the pollutants and terminals included in the study.

Table 7-5: Harbor Craft Emissions Results

Port of Charleston- Harbor Craft Ship Assist Emissions - 2005
Harbor Craft Emissions

2005 assumed Sulfur Content 2263 ppm
0.23%

Terminal	Vessel Type	Number of calls	Avg # Sailing Tugs	Avg # Docking Tugs	Avg Tug Power (Kw)	Tug Yard to Shutes Folley Isl: Dist (nm)	Tug Yard to Shutes Folley Isl: Speed (knts)	Shutes Folley Island to Terminal: Dist (nm)	Shutes Folley Island to Terminal: Speed (knts)	Terminal to Tug Yard: Dist (nm)	Terminal to Tug Yard: Speed (knts)	Maneuvering Time At Berth (hrs)	Total Time per Tug per Vessel Trip (hrs)	Total Sailing Tug Hours	Total Docking Tug Hours	Total Tug Hours	NOX	CO	HC	PM10	PM2.5	SO2
CS	Container	251	1.7	1.8	2,200	6.00	8	1.40	8	4.60	8	0.25	1.61	700	711	1,411	13.79	2.66	0.25	0.32	0.31	0.67
	Barge	5	2.0	2.0	2,200	6.00	6	1.40	8	4.60	6	0.25	2.01	20	20	40	0.39	0.06	0.01	0.01	0.01	0.02
	Cruise	1	2.0	2.0	2,200	6.00	8	1.40	8	4.60	8	0.25	1.61	3	3	6	0.06	0.01	0.00	0.00	0.00	0.00
	Ro-Ro	0			2,200	6.00	8	1.40	8	4.60	8	0.25	1.61	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Breakbulk	42	1.7	1.6	2,200	6.00	8	1.40	8	4.60	8	0.25	1.61	114	108	223	2.17	0.42	0.05	0.05	0.05	0.11
																	16.42	3.16	0.34	0.38	0.37	0.80
NC	Container	350	1.6	1.6	2,200	6.00	8	3.90	8	3.75	8	0.25	2.46	1,354	1,380	2,739	26.77	5.15	0.56	0.62	0.60	1.30
	Barge	7	2.0	1.8	2,200	6.00	6	3.90	8	3.75	8	0.25	2.62	39	37	76	0.74	0.14	0.02	0.02	0.02	0.04
	Cruise	0	0.0	0.0	2,200	6.00	8	3.90	8	3.75	8	0.25	2.46	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Ro-Ro	1	1.0	1.0	2,200	6.00	8	3.90	8	3.75	8	0.25	2.46	2	2	5	0.06	0.01	0.00	0.00	0.00	0.00
	Breakbulk	4	2.0	2.2	2,200	6.00	8	3.90	8	3.75	8	0.25	2.46	20	22	42	0.41	0.08	0.01	0.01	0.01	0.02
																	27.97	5.38	0.58	0.66	0.63	1.36
UP	Container	0	0.0	0.0	2,200	6.00	8	0.70	8	5.25	8	0.25	1.62	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Barge	0	0.0	0.0	2,200	6.00	6	0.70	8	5.25	6	0.25	2.06	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Cruise	46	2.0	2.0	2,200	6.00	8	0.70	8	5.25	8	0.25	1.62	149	147	296	2.90	0.56	0.06	0.07	0.06	0.14
	Ro-Ro	170	1.5	1.6	2,200	6.00	8	0.70	8	5.25	8	0.25	1.62	403	435	839	8.18	1.58	0.17	0.19	0.18	0.40
	Breakbulk	9	1.8	1.8	2,200	6.00	8	0.70	8	5.25	8	0.25	1.62	26	26	52	0.51	0.10	0.01	0.01	0.01	0.02
																	11.60	2.23	0.24	0.27	0.26	0.56
WT	Container	1082	1.7	1.7	2,200	6.00	8	3.8	8	5.25	8	0.25	2.01	3,798	3,794	7,592	74.19	14.27	1.54	1.71	1.66	3.60
	Barge	46	1.7	1.7	2,200	6.00	6	3.8	8	5.25	6	0.25	2.43	192	187	380	3.71	0.71	0.08	0.09	0.08	0.18
	Cruise	0	0.0	0.0	2,200	6.00	8	3.8	8	5.25	8	0.25	2.01	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Ro-Ro	0	0.0	0.0	2,200	6.00	8	3.8	8	5.25	8	0.25	2.01	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Breakbulk	0	0.0	0.0	2,200	6.00	8	3.8	8	5.25	8	0.25	2.01	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
																	77.90	14.98	1.62	1.80	1.74	3.78
Total	Container	1,683	1.7	1.7										5,852	5,885	11,741	114.75	22.07	2.38	2.66	2.57	5.56
	Tug & Barge	58	1.8	1.7										252	244	496	4.86	0.93	0.10	0.11	0.11	0.23
	Cruise	47	2.0	2.0										152	151	303	2.96	0.57	0.06	0.07	0.07	0.14
	Ro-Ro	171	1.5	1.6										405	438	843	8.24	1.58	0.17	0.19	0.18	0.40
	Breakbulk & Other	55	1.7	1.7										160	156	316	3.09	0.59	0.06	0.07	0.07	0.15
	Total	2,014	1.7	1.7										6,825	6,874	13,699	133.80	25.75	2.78	3.09	3.00	6.47

Figures 7-6 and 7-7 show the harbor craft emissions by pollutant for each terminal.

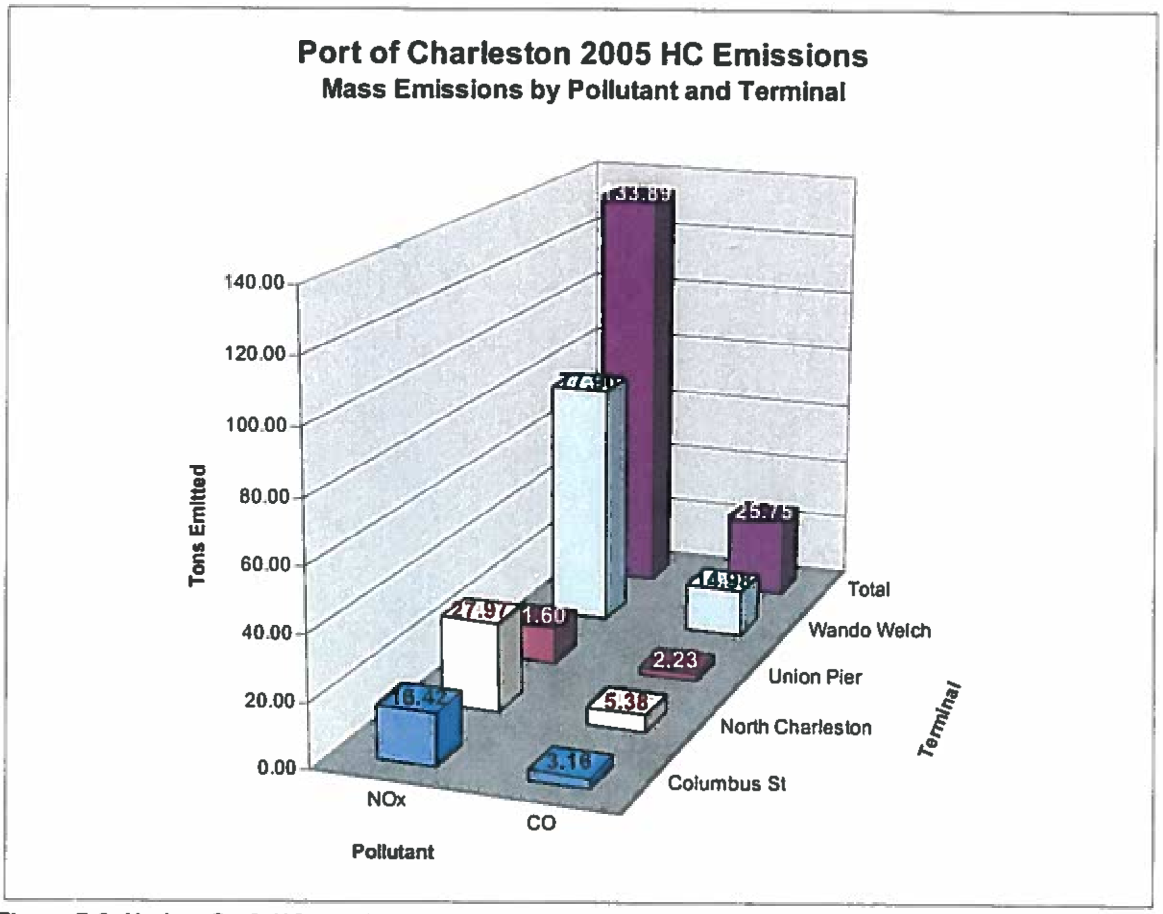


Figure 7-6: Harbor Craft NOx and CO Emissions by Terminal

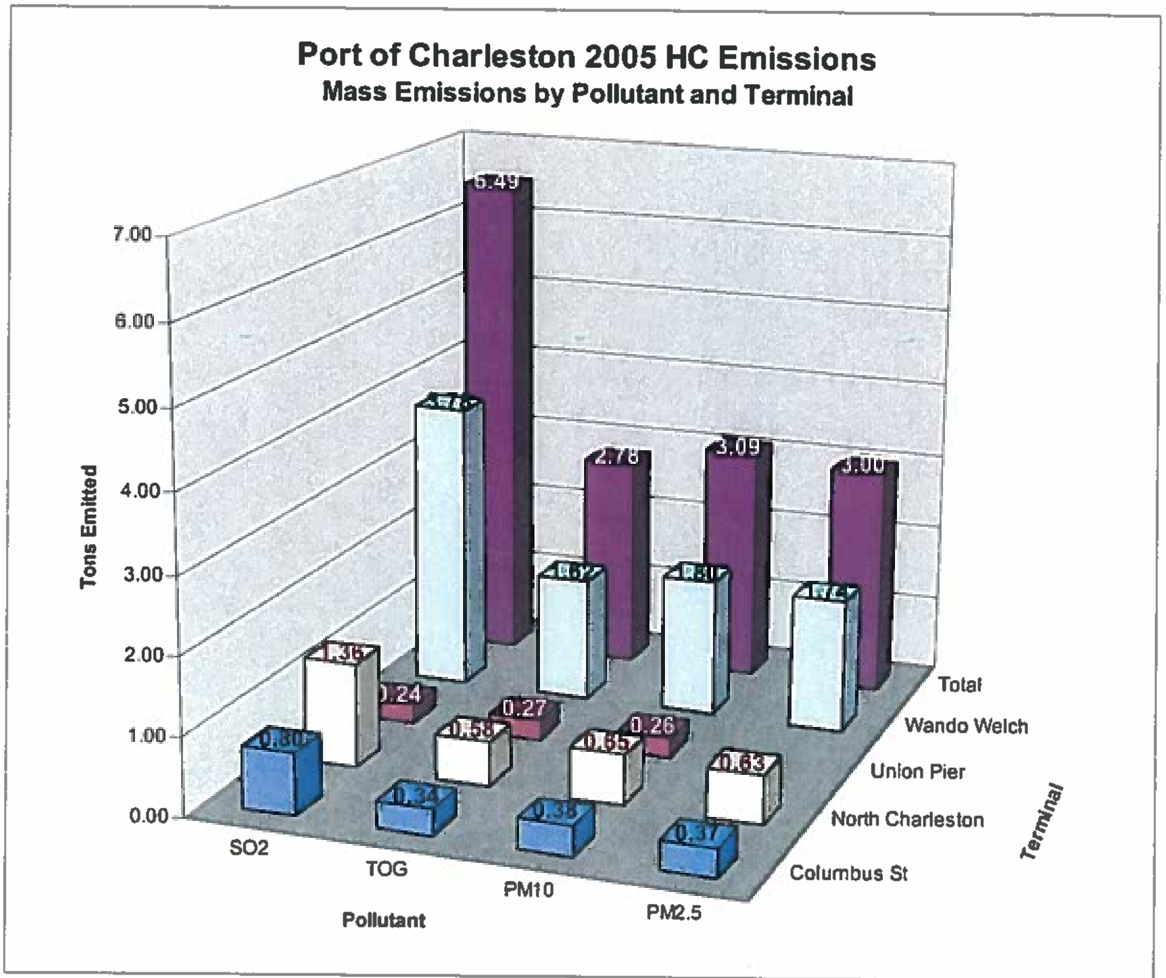


Figure 7-7: Harbor Craft SO2, TOG, PM10 and PM2.5 Emissions by Terminal

7.4 Cargo Handling Equipment

Table 7-6 summarizes the CHE emissions results by pollutant and type of equipment.

Table 7-6: CHE Emissions Results

2005 South Carolina State Port Authority (SCSPA)
Cargo Handling Equipment Emissions
All Terminals
All Fuels

		number equipment	Avg Hp	Avg Hrs	Total hrs	Avg Year	Avg Age yrs	HC tons	CO tons	Nox tons	PM10 tons	PM2 5 tons	SO2 tons	CO2 tons	Total Installed HP-Hrs	Total Hp-hrs	Avg Load Factor
1	Container Handler, Full	42	259	2 097	88,074	1998	7	4 4	15 6	67.3	3.5	3.4	8 0	5.699 3	22.698.340	9.760.286	0 43
2	Crane, Container	5	840	212	1.062	1980	25	0 5	1 7	3 2	0 5	0 4	0 2	128 1	895 000	187 950	0.21
3	Crane, RTG	30	621	2.559	76.770	1998	7	5 5	40 8	74 9	5 4	5.2	9 8	6.989 2	48 312 045	10.145 529	0 21
4	Container Handler, Empty	16	228	2.064	33.021	2000	5	1.2	3 0	19 6	0.9	0 9	2.7	1 924 8	7.661.581	3 294 480	0.43
5	Backhoe	1	90	50	50	1997	8	0 0	0 0	0 0	0 0	0 0	0 0	0 7	4 500	945	0 21
6	Tractor Tow	2	80	357	714	2000	5	0 1	1 7	0 4	0 0	0 0	0 0	24 3	56 160	30 326	0 54
7	Forklift 36K	71	103	461	32.748	1996	9	1 9	30 8	13 8	0 6	0 6	0 9	1.067 3	3 612 226	1 620 303	0 45
8	Sweeper	8	56	118	940	1999	6	0 1	2 1	0 5	0 0	0 0	0 0	30 3	53 353	37 881	0 71
9	Assumed Avg Hostler	59	250	2.032	120.268	2001	4	6 4	23 7	104 8	7 4	7 1	14 7	10 476 9	30 067 000	17.739 530	0 59
	Totals	234			353 647			20.2	119 4	284 5	18 2	17 7	36 2	26 341	113 360 205	42 817 231	0 38

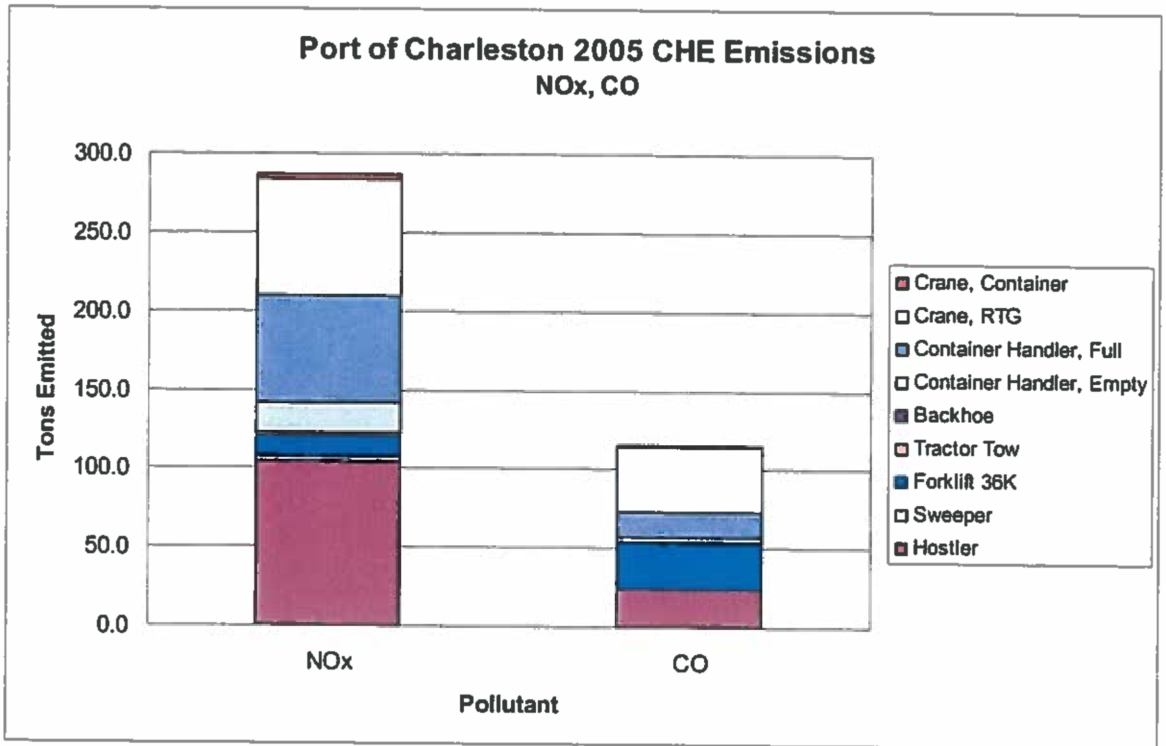


Figure 7-8: CHE NOx and CO Emissions by Type of Equipment

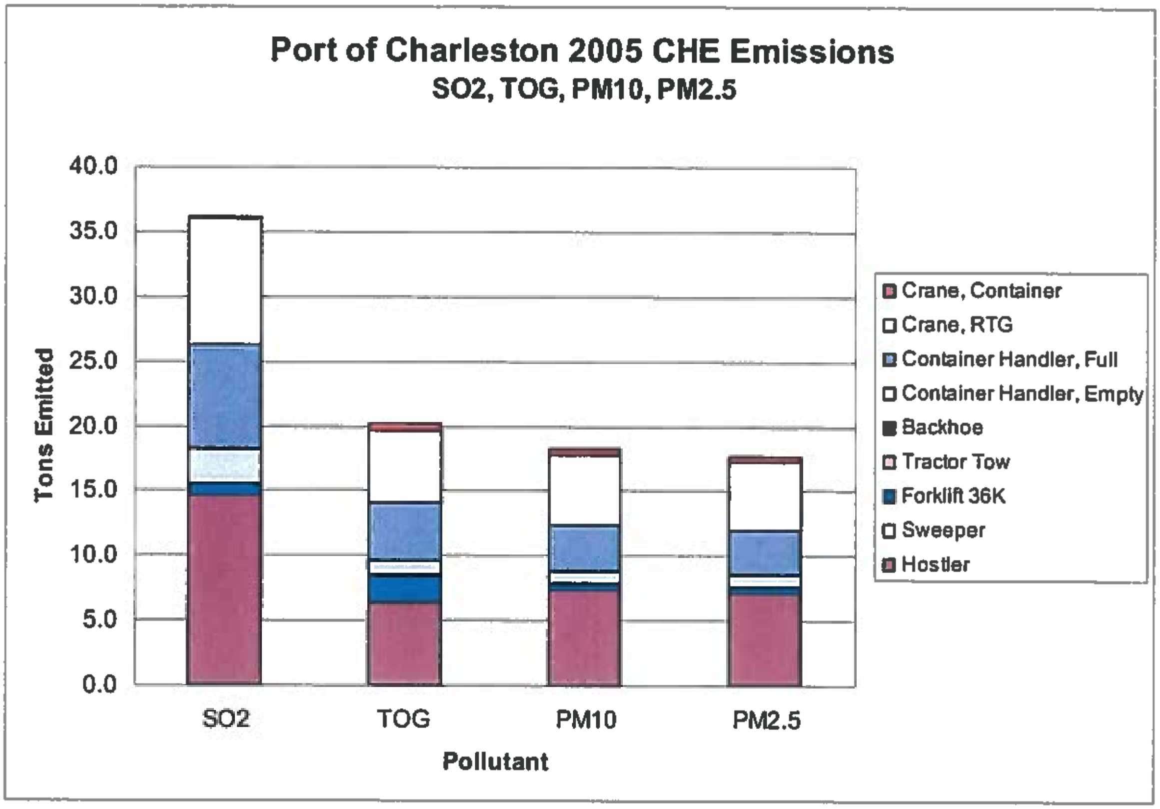


Figure 7-9: CHE SO2, TOG, PM10 and PM2.5 Emissions by Type of Equipment

7.5 Rail Locomotives

Table 7-7 shows the rail emission calculation for 2005.

Table 7-7: RL Emissions Results

SPA 2005 Rail Related Emissions

Line Haul - Container Train Traffic in/out of Charleston only. DNI roadpower idling, switching or cargo handling in private railyards

Annual Rail TEU Estimate	TEU per Train	No. of Trains
348,746	360	969

	Annual # Trains	Assumed Locomotive Hp	Locomotives per Train	Avg Speed (mph)	Avg Dist To Tri-County Border (mi)	Annual Locomotive Hrs	Avg Hp in Use	Line Haul Emissions (tons) NOx	PM10	PM2.5	HC	CO	SO2	Annual Est'd Diesel Consumption
Line Haul Locomotive Hours	969	3,500	4	40	35	3,391	972	44.96	1.02	0.99	1.51	5.50	2.53	154,824
Total Line Haul								44.96	1.02	0.99	1.51	5.50	2.53	154,824

Switcher Emissions - PTR and PUC Operated Switchers Only

	Daily Run Hrs (from SCPR)	Avg Locomotive HP	Annual Locomotive Hours	Avg Hp in Use	Switcher Emissions (tons) NOx	PM10	PM2.5	HC	CO	SO2	Annual Est'd Diesel Consumption	Reported Annual Consumption	
PTR Switcher serving NCT	3	1,750	780	186	2.79	0.06	0.06	0.12	0.28	0.11	6,819	5,400	126%
PUC Switcher serving Union Pier & Columbus St.	12	1,000	3,120	106	6.39	0.14	0.13	0.27	0.63	0.25	15,586	18,000	87%
Total Switching			3,900		9.18	0.20	0.19	0.39	0.91	0.37	22,405	23,400	96%

Switcher Emissions based on HP and operating hours of PUC and PTR switchers as provided by SCPR
Line Haul Emissions are an estimate of double-stack line haul emissions of SPA related container cargo out to tri-county line only and do not include any emission within private intermodal yards

	NOx	PM10	PM2.5	HC	CO	SO2
Totals	54.14	1.22	1.18	1.90	6.41	2.90

The emissions results for each pollutant are presented graphically in the next two figures, Figure 7-10 and 7-11 by type of locomotive (switcher or line haul).

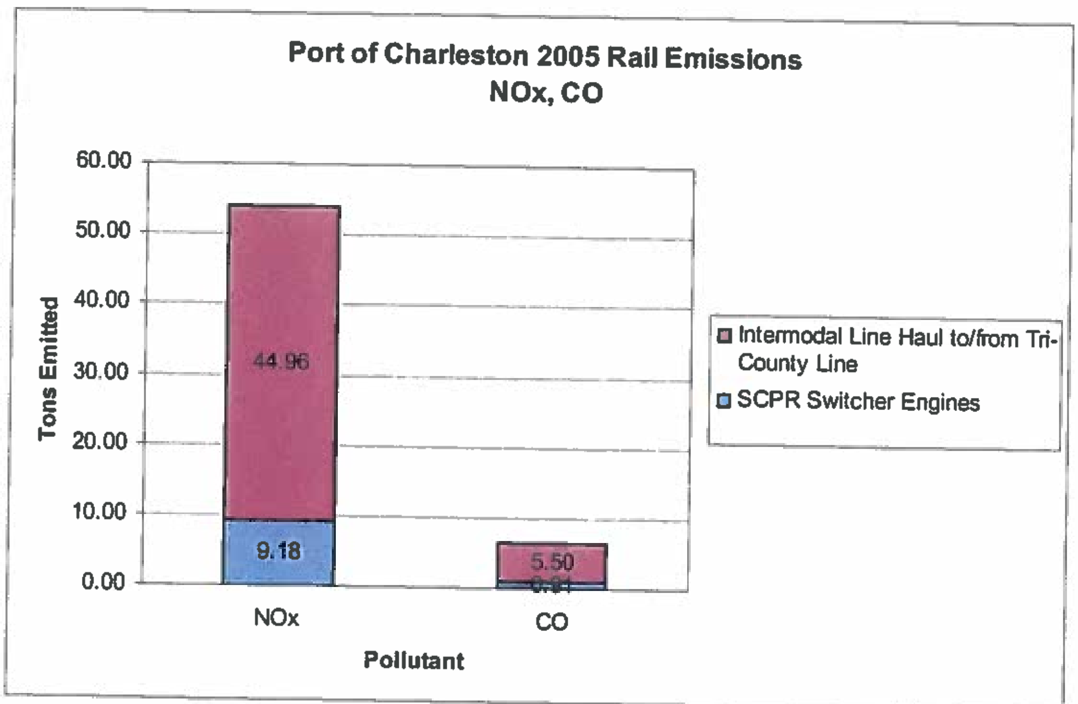


Figure 7-10: CHE SO2, TOG, PM10 and PM2.5 Emissions by Type of Equipment

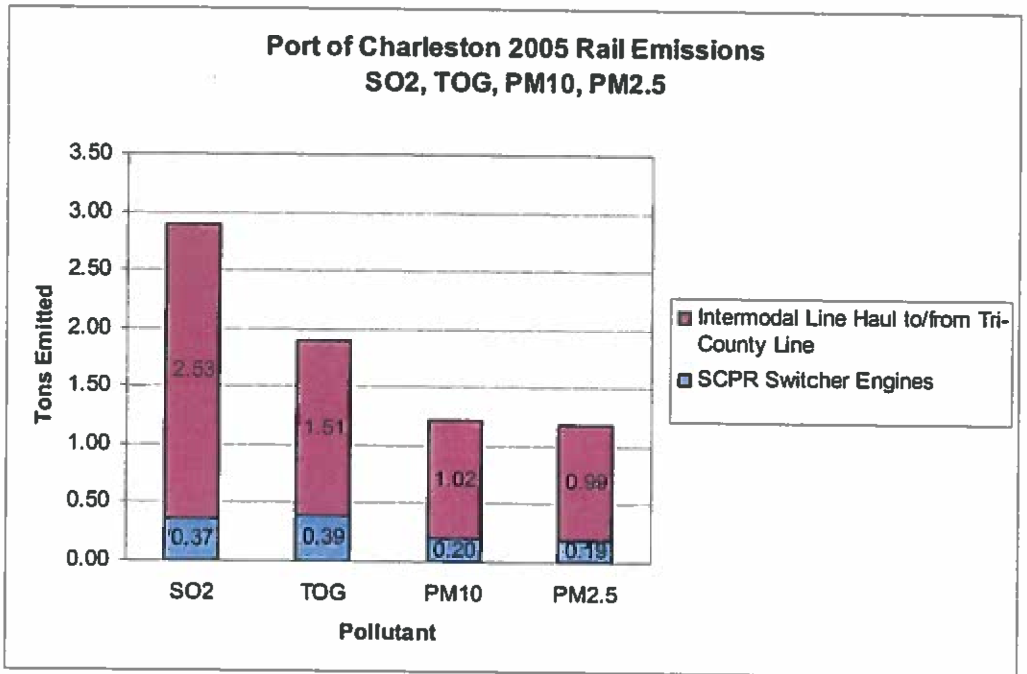


Figure 7-11: CHE SO2, TOG, PM10 and PM2.5 Emissions by Type of Equipment

7.6 Heavy Duty Vehicles

Table 7-8: Truck Emissions Results

South Carolina State Ports Authority
Port of Charelston
Heavy Duty Vehicle Emissions - 2005- Annual Short Tons

Columbus Street	OFF TERMINAL									ON TERMINAL								TOTAL					
	# Trips	Avg Dist	VMT	Nox	PM10	PM2.5	VOCs	SO2	CO	# Visits (1/2 trips)	Hrs/Visit	Nox	PM10	PM2.5	VOCs	SO2	CO	Nox	PM10	PM2.5	VOCs	SO2	CO
Loads & Empties	187,257	35	6,636,351	165.34	5.64	5.47	5.75	3.88	40.96														
Bobtails	53,502	11	604,573	14.16	0.51	0.50	0.62	0.35	4.49														
Chassis	26,751	6	160,506	3.57	0.14	0.13	0.21	0.09	1.49														
Subtotal Containers	267,510	27.7	7,401,429	173.06	6.29	6.10	6.58	4.33	46.93	133,755	1.00	30.61	0.90	0.87	2.43	0.55	22.06	203.67	7.19	6.97	9.01	4.88	69.00
Subtotal Breakbulk	15,392	23.4	360,686	8.31	0.31	0.30	0.32	0.21	2.24	7,696	1.00	1.76	0.06	0.05	0.14	0.03	1.27	10.07	0.36	0.35	0.46	0.24	3.51
Total	282,902	27.4	7,762,115	181.37	6.59	6.40	6.90	4.64	49.17	141,451	1.00	32.37	0.95	0.92	2.57	0.58	23.33	213.74	7.54	7.32	9.47	5.12	72.50

North Charleston	OFF TERMINAL									ON TERMINAL								TOTAL					
	# Trips	Avg Dist	VMT	Nox	PM10	PM2.5	VOCs	SO2	CO	# Visits (1/2 trips)	Hrs/Visit	Nox	PM10	PM2.5	VOCs	SO2	CO	Nox	PM10	PM2.5	VOCs	SO2	CO
Loads & Empties	306,306	28	8,598,497	201.27	7.30	7.09	7.61	6.03	64.37														
Bobtails	87,230	7	588,805	13.79	0.50	0.49	0.70	0.34	5.10														
Chassis	43,615	6	239,884	5.36	0.20	0.20	0.32	0.14	2.30														
Subtotal Containers	436,152	21.6	9,427,186	220.43	8.01	7.77	8.64	6.52	61.76	218,076	1.00	49.91	1.47	1.42	3.96	0.89	35.97	270.34	9.47	9.19	12.60	6.41	97.73
Subtotal Breakbulk	1,700	18.4	31,308	0.72	0.03	0.03	0.03	0.02	0.20	850	1.00	0.19	0.01	0.01	0.02	0.00	0.14	0.91	0.03	0.03	0.04	0.02	0.34
Total	437,852	21.6	9,458,494	221.15	8.04	7.79	8.67	5.53	61.96	218,926	1.00	50.10	1.47	1.43	3.97	0.90	36.11	271.25	9.51	9.22	12.64	6.43	98.07

Union Pier	OFF TERMINAL									ON TERMINAL								TOTAL					
	# Trips	Avg Dist	VMT	Nox	PM10	PM2.5	VOCs	SO2	CO	# Visits (1/2 trips)	Hrs/Visit	Nox	PM10	PM2.5	VOCs	SO2	CO	Nox	PM10	PM2.5	VOCs	SO2	CO
Loads & Empties	0	#DIV/0!	0	0.00	0.00	0.00	0.00	0.00	0.00														
Bobtails	0	#DIV/0!	0	0.00	0.00	0.00	0.00	0.00	0.00														
Chassis	0	#DIV/0!	0	0.00	0.00	0.00	0.00	0.00	0.00														
Subtotal Containers	0	#DIV/0!	0	0.00	0.00	0.00	0.00	0.00	0.00	0	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal Breakbulk	16,598	24.4	405,544	9.34	0.34	0.33	0.36	0.24	2.50	8,299	1.00	1.90	0.06	0.05	0.15	0.03	1.37	11.24	0.40	0.39	0.51	0.27	3.87
Total	16,598	24.4	405,544	9.34	0.34	0.33	0.36	0.24	2.50	8,299	1.00	1.90	0.06	0.05	0.15	0.03	1.37	11.24	0.40	0.39	0.51	0.27	3.87

Wando Welch	OFF TERMINAL									ON TERMINAL								TOTAL					
	# Trips	Avg Dist	VMT	Nox	PM10	PM2.5	VOCs	SO2	CO	# Visits (1/2 trips)	Hrs/Visit	Nox	PM10	PM2.5	VOCs	SO2	CO	Nox	PM10	PM2.5	VOCs	SO2	CO
Loads & Empties	850,678	38.3	32,604,371	763.16	27.70	26.87	28.04	19.07	199.78														
Bobtails	243,022	13.5	3,280,802	78.81	2.79	2.70	3.25	1.92	23.37														
Chassis	121,511	12.8	1,549,268	33.48	1.32	1.28	1.72	0.91	11.76														
Subtotal Containers	1,215,112	30.8	37,434,441	873.45	31.80	30.85	33.01	21.90	234.91	607,556	1.00	139.05	4.08	3.96	11.03	2.49	100.21	1,012.50	35.89	34.81	44.04	24.39	335.12
Subtotal Breakbulk	4,868	27.1	131,842	3.04	0.11	0.11	0.12	0.08	0.81	2,434	1.00	0.56	0.02	0.02	0.04	0.01	0.40	3.60	0.13	0.12	0.16	0.09	1.21
Total	1,219,980	30.8	37,566,283	876.49	31.91	30.96	33.13	21.98	235.72	609,990	1.00	139.60	4.10	3.98	11.07	2.50	100.61	1,016.09	36.01	34.93	44.20	24.48	336.33

Port of Charleston	OFF TERMINAL									ON TERMINAL								TOTAL					
	# Trips	Avg Dist	VMT	Nox	PM10	PM2.5	VOCs	SO2	CO	# Visits (1/2 trips)	Hrs/Visit	Nox	PM10	PM2.5	VOCs	SO2	CO	Nox	PM10	PM2.5	VOCs	SO2	CO
Loads & Empties	1,343,142	35.6	47,839,219	1,119.76	40.64	39.42	41.40	27.99	295.11														
Bobtails	383,755	11.7	4,474,180	104.76	3.80	3.69	4.57	2.62	32.95														
Chassis	191,877	10.2	1,949,657	42.41	1.66	1.61	2.25	1.14	15.55														
Subtotal Containers	1,918,774	28.3	54,263,056	1,266.94	46.10	44.72	48.23	31.76	343.60	959,387	1.00	219.57	6.45	6.25	17.42	3.93	158.24	1,486.51	52.55	50.97	65.65	35.68	501.85
Subtotal Breakbulk	38,558	24.1	929,380	21.41	0.79	0.77	0.82	0.54	5.75	19,279	1.00	4.41	0.13	0.13	0.35	0.08	3.18	25.82	0.92	0.89	1.17	0.62	8.93
Total	1,957,332	28.2	55,192,437	1,288.35	46.89	45.48	49.05	32.29	349.35	978,666	1.00	223.98	6.58	6.38	17.77	4.01	161.42	1,512.33	53.47	51.86	66.82	36.30	510.77

Figures 7-12 and 7-13 below show the contribution of on- and off-terminal HDV NOx and PM10 emissions.

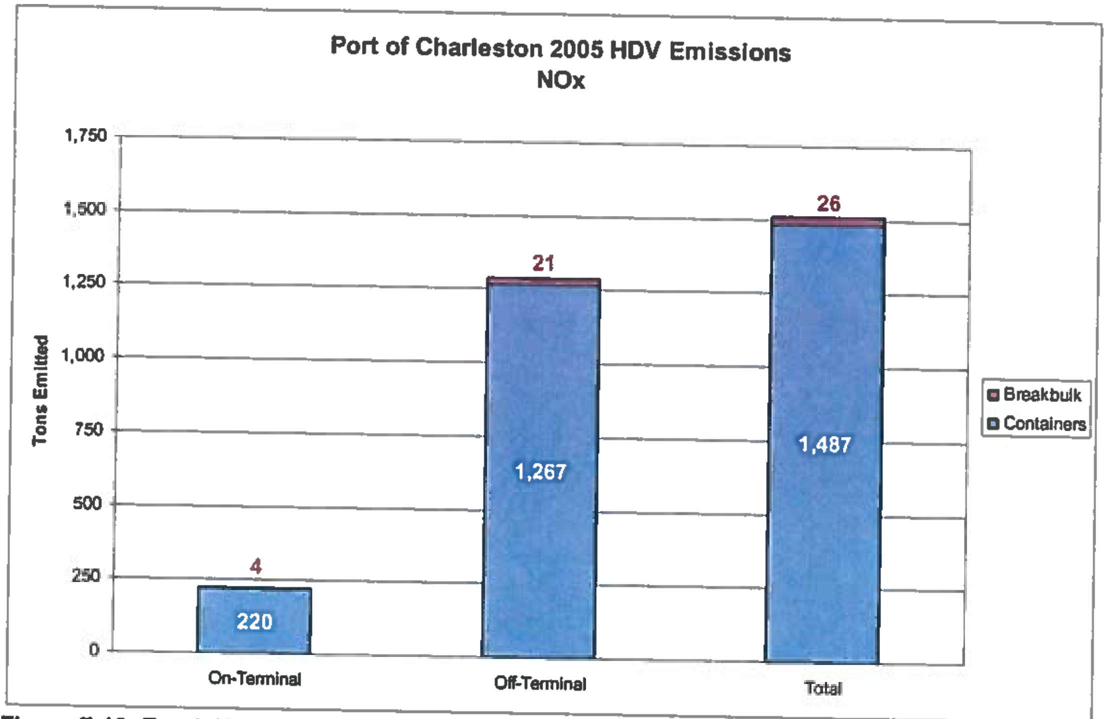


Figure 7-12: Truck NOx Emissions by Location

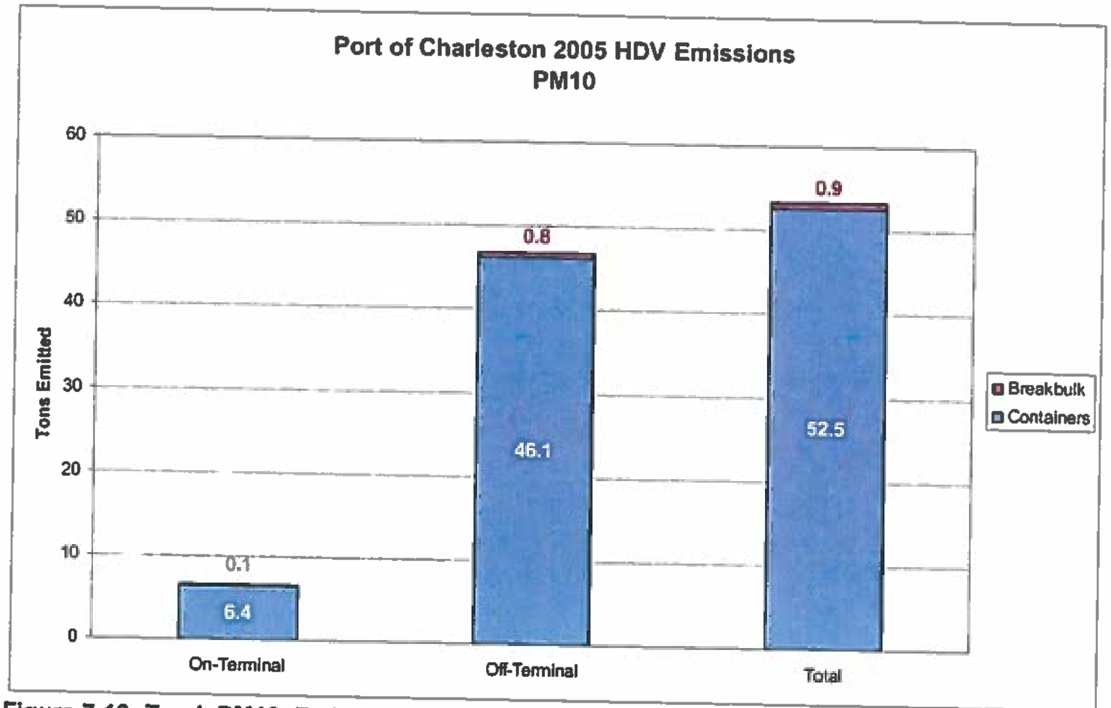


Figure 7-13: Truck PM10 Emissions by Location

7.7 Comparison with Other Port Inventories

It is difficult to compare total annual emissions with those of other ports because emissions depend heavily on throughput, the specific geography of the port surroundings and the geographical extents of the inventory. The main value of an inventory is to understand, track, and target emission sources for a given port over time. However, because this is the baseline inventory for the Port of Charleston, there are no previous inventories with which to compare it. For the sake of comparison, the 2005 mass emissions for the Ports of Los Angeles and Long Beach (as reported in their emissions inventories) were divided by total 2005 throughput to yield an emissions estimate normalized to TEU of throughput which can be compared with the Port of Charleston. The results are shown in the following set of graphs, Figures 7-14 to 7-17.

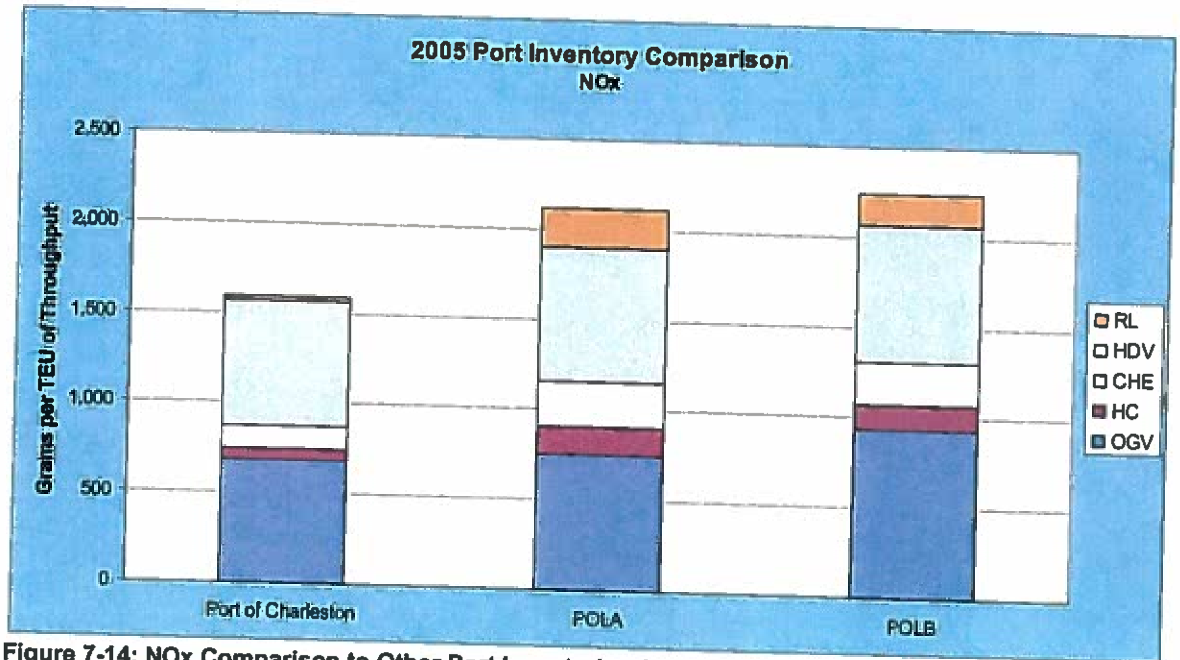


Figure 7-14: NOx Comparison to Other Port Inventories, by g/TEU

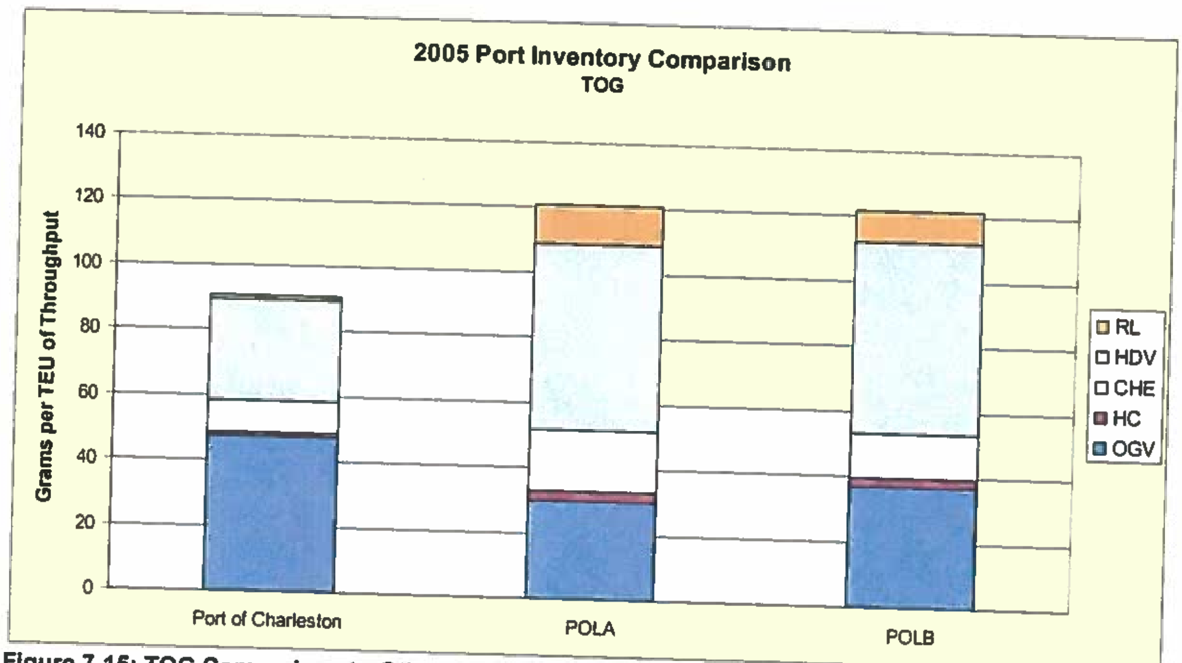


Figure 7-15: TOG Comparison to Other Port Inventories, by g/TEU

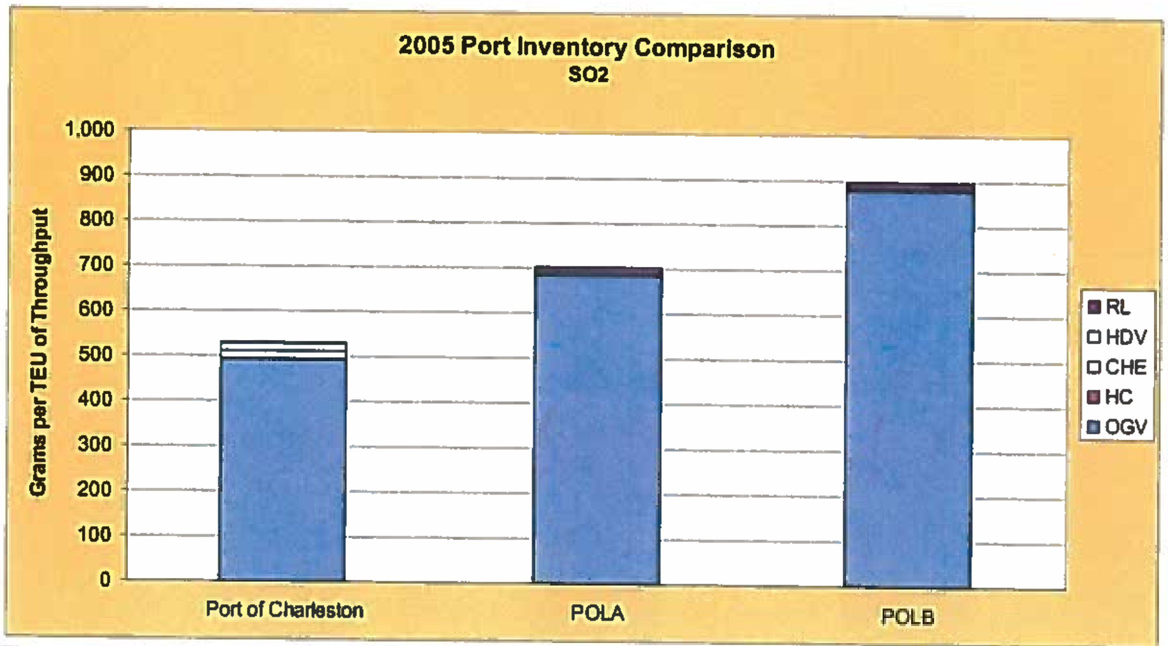
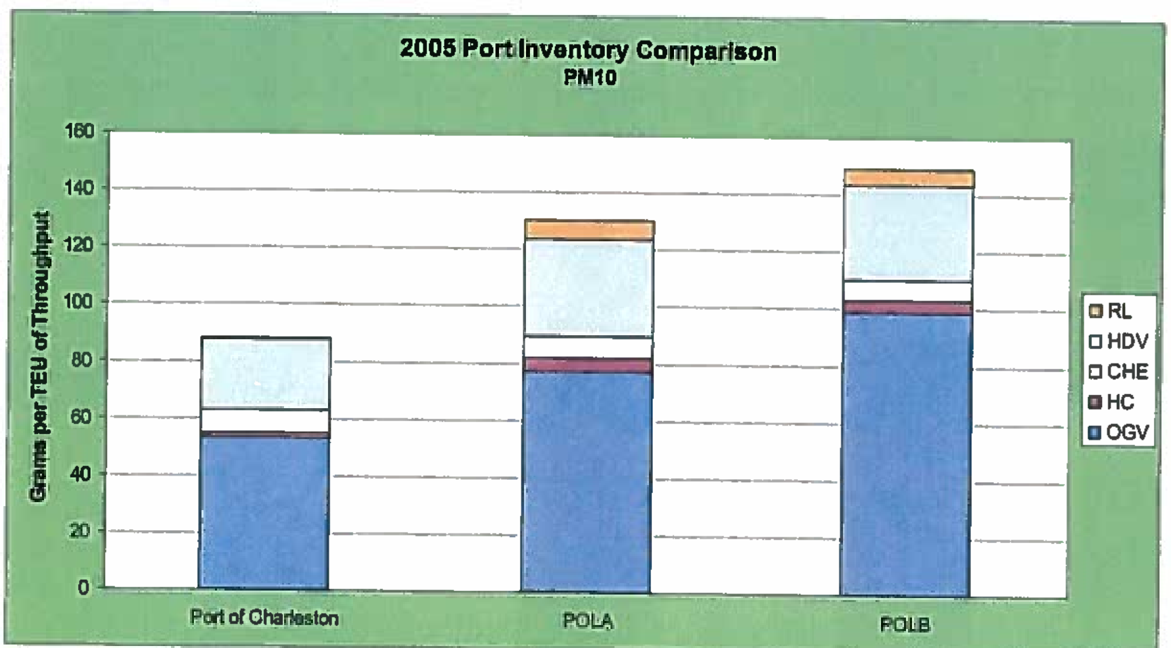


Figure 7-16: SOx Comparison to Other Port Inventories, by g/TEU



pm2.5 graph would look similar

Figure 7-17: PM10 Comparison to Other Port Inventories, by g/TEU

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.

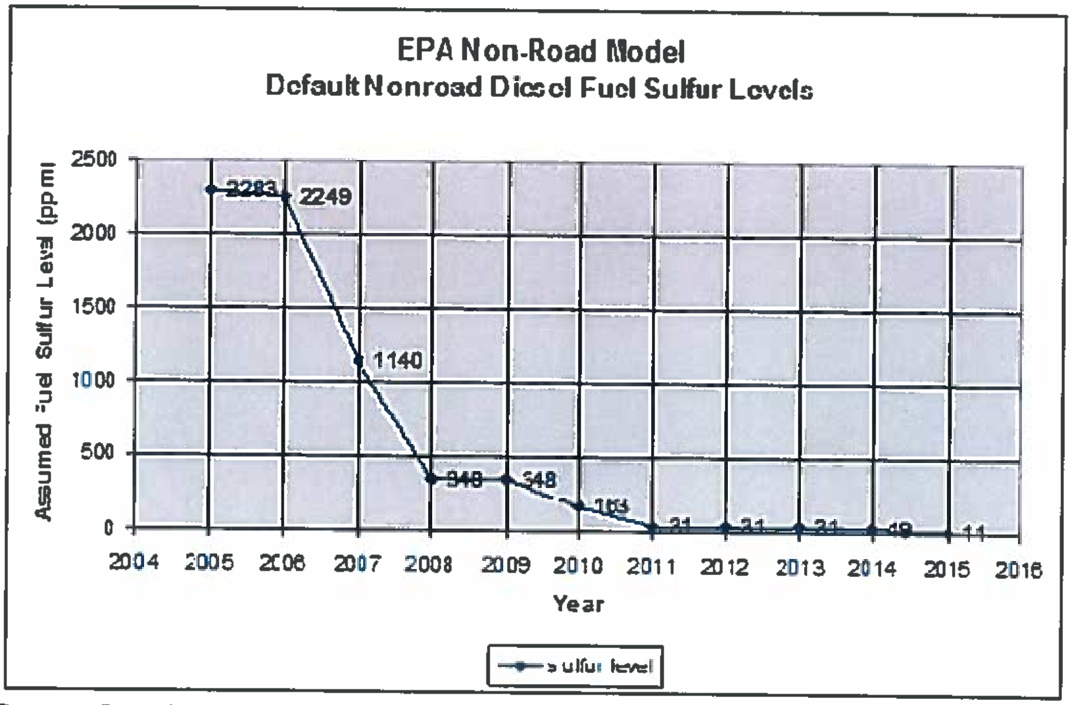
1. Ocean-going vessel emissions are based on published main engine data for each vessel calling in 2005. However, auxiliary engine power and fuel types are based on surveys from other studies. OGV emissions could be refined by surveying shipping lines to obtain more specific information on the auxiliary 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. Cargo handling equipment emissions are based on actual in-use equipment characteristics and documented hours of operation in all cases except hostlers. Because hostlers are not operated by SPA and those data were not available, assumptions were made on hostler hours and typical hostler characteristics. In future updates, CHE inputs and results could be refined by surveying hostler operators.

4. In-use fuel sulfur levels for CHE are based on EPA non-road model assumptions which are based on the year of analysis. Substantial reductions in SOx and some reductions in PM can be achieved by using lower sulfur fuel.

   The results of this study could be refined in the future by surveying fuel vendors to obtain the actual sulfur content of the fuel being used instead of relying on EPA assumptions. Table 8.1 shows the EPA default fuel sulfur levels by year.



Source: Developed from data tables in EPA NONROAD 2004
Figure 8-1: EPA Default Nonroad Diesel Fuel Sulfur Levels

5. 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.

6. 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.

7. 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 2005. 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.

8. This study only includes truck trips associated with containerized cargo and breakbulk cargo. It does not include truck traffic associated with ro/ro cargo through the Union Pier Terminal. This is not expected to be significant.

9. This study includes rail switcher activity for all types of cargo but line haul rail estimates (from local railyards to tri-county boundary) are 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.

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