The Port of New York and New Jersey
Port Commerce Department
2013 Multi-Facility Emissions Inventory

Cargo Handling Equipment
Heavy-Duty Diesel Vehicles
Railroad Locomotives
Commercial Marine Vessels

January 2015

Prepared by:
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THE PORT AUTHORITY OF NEW YORK AND NEW JERSEY

PORT COMMERCE DEPARTMENT

2013 MULTI-FACILITY EMISSIONS INVENTORY OF CARGO HANDLING EQUIPMENT, HEAVY-DUTY DIESEL VEHICLES, RAILROAD LOCOMOTIVES, AND COMMERCIAL MARINE VESSELS

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LIST OF ACRONYMS

AIS	automatic identification system
CHE	cargo handling equipment
CH_4	methane
CMV	commercial marine vessel
CO	carbon monoxide
CO_2	carbon dioxide
CO_2Eq	carbon dioxide equivalents
EPA	United States Environmental Protection Agency
EPAMT	Elizabeth Port Authority Marine Terminal
GHGs	greenhouse gases
g/hp-hr	grams per horsepower hour
g/mi	grams per mile
g/hr	grams per hour
g/MMGTM	grams of emissions per million gross ton-miles
GTM	gross ton-miles
GVWR	gross vehicle weight rating
HDDV	heavy-duty diesel vehicle
hp	horsepower
hp-hr	horsepower hour
kW	kilowatt
LPG	liquefied petroleum gas
MOBILE6.2	EPA on-road vehicle emission estimating model, superseded by the MOVES model
MOVES	EPA's new-generation motor vehicle emission estimating model
NO_x	oxides of nitrogen
N_2O	nitrous oxide
NYCT	New York Container Terminal
NYNJHS	New York/New Jersey Harbor System
NYNJLINA	New York/New Jersey Long Island Non-Attainment Area
OGV	ocean-going vessel
PM_{10}	particulate matter less than 10 microns in diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PNCT	Port Newark Container Terminal
ppm	parts per million
RAT	Regional Air Team
SCC	source classification code
SO_2	sulfur dioxide
TEUs	twenty-foot equivalent units
tpy	tons per year
VOCs	volatile organic compounds
VMT	vehicle miles traveled

EXECUTIVE SUMMARY

The purpose of this inventory is to estimate air emissions generated in 2013 by land-based mobile sources (cargo handling equipment, heavy-duty diesel vehicles, and locomotives) and commercial marine vessels (ocean-going vessels and harbor craft) associated with marine terminal activity linked to facilities maintained by the Port Authority of New York and New Jersey (Port Authority) and leased to private terminal operators. This report is an update of the 2012 Multi-Facility Emissions Inventory, which covers the same categories of land-based mobile sources and commercial marine vessels associated with the Port Authority facilities leased to private operators. While prior emissions inventories were conducted every 2 years, this 2013 report marks the first of a series of annual emissions inventories.

ES.1 Key Findings

Although the primary purpose of the 2013 calendar year emissions inventory and report is to provide an update to the emission estimates presented in the 2012 inventory report, there are additional findings that should be discussed. Most emissions decreased between 2012 and 2013 inventory years. To be able to evaluate 2013 emissions with respect to previous inventories (2006, 2008, 2010 and 2012) and to assess changes over the years, emissions estimated for the earlier years have been adjusted to account for emissions modeling changes (updates to the MOVES model) and the addition of a major container terminal and a cruise terminal, discussed in the 2012 emissions inventory report. Emissions have also been evaluated on the basis of tons-per-year changes and on an emissions-per-unit of throughput basis (tons per twenty-foot equivalent unit, tons/TEU). The following findings, based on the totals for 2013 shown in Tables ES.1 and 1.14, can be reported:

- Port Authority maritime emissions of oxides of nitrogen (NO_x) related to the Port Authority marine terminals were unchanged in tons between 2013 and 2012, and 25% lower than in 2006. On an emissions-per-TEU basis, emissions in 2013 were 1% higher than the 2012 estimates and 31% lower than the 2006 estimates. Emissions of NO_x in 2013 constituted less than two-and-a-half percent (2.4%) of the overall NYNJLINA NO_x emissions.
- Port Authority maritime emissions of particulate matter less than 10 microns (PM_{10}) related to the Port Authority marine terminals were 19% lower in tons in 2013 than in 2012 and 48% lower than in 2006. On an emissions-per-TEU basis, emissions in 2013 were 18% lower than the 2012 estimates and 52% lower than the 2006 estimates. Emissions of PM_{10} in 2013 constituted approximately one half of a percent (0.5%) of the overall NYNJLINA PM_{10} emissions.
- Port Authority maritime emissions of particulate matter less than 2.5 microns ($PM_{2.5}$) related to the Port Authority marine terminals were 17% lower in tons in 2013 than in 2012 and 46% lower than in 2006. On an emissions-per-TEU basis, emissions in 2013 were 15% lower than the 2012 estimates and 50% lower than the 2006 estimates. Emissions of $PM_{2.5}$ in 2013 constituted approximately one percent of the overall NYNJLINA $PM_{2.5}$ emissions.

- Port Authority maritime emissions of volatile organic compounds (VOCs) related to the Port Authority marine terminals were 2% higher in tons in 2013 than in 2012 and 7% lower than in 2006. On an emissions-per-TEU basis, emissions in 2013 were 3% higher than the 2012 estimates and 13% lower than the 2006 estimates. Emissions of VOCs in 2013 constituted approximately two tenths of a percent (0.2%) of the overall NYNJLINA VOC emissions.
- Port Authority maritime emissions of carbon monoxide (CO) related to the Port Authority marine terminals were 2% higher in tons in 2013 than in 2012 and 13% lower than in 2006. On an emissions-per-TEU basis, emissions in 2013 were 3% higher than the 2012 estimates and 19% lower than the 2006 estimates. Emissions of CO in 2013 constituted approximately one-tenth of one percent (0.1%) of the overall NYNJLINA CO emissions.
- Port Authority maritime emissions of sulfur dioxide (SO_2) related to the Port Authority marine terminals were 62% lower in tons in 2013 than in 2012 and 83% lower than in 2006. On an emissions-per-TEU basis, emissions in 2013 were 62% lower than the 2012 estimates and 85% lower than the 2006 estimates. Emissions of SO_2 in 2013 constituted approximately 1.3% of the overall NYNJLINA SO_2 emissions.
- Emissions of greenhouse gases[1] (GHG) related to the Port Authority marine terminals were 2% higher in tons in 2013 than in 2012, but 10% lower than in 2006. On an emissions-per-TEU basis, emissions in 2013 were 3% higher than the 2012 estimates, but 16% lower than the 2006 estimates. Emissions of GHG in 2013 constituted approximately half of a percent (0.5%) of the overall NYNJLINA GHG emissions.

Comparisons with interim year inventory results can be seen in Table 1.14 in the Introduction. Overall, the greatest reductions have been seen in emissions of SO_2, which have been reduced by restrictions in the sulfur content of fuels used by all emission source categories included in the inventory. By 2013 all land-based emission sources as well as harbor craft were using ultra-low sulfur diesel fuel (ULSD) and ocean-going vessels were using marine fuel with greatly reduced sulfur content. The lower fuel sulfur levels also contributed to the reductions seen in particulate matter, although greater contributions to particulate reductions were made by increased use of lower-emission trucks and cargo handling equipment, which are increasingly equipped with particulate filters that greatly reduce emissions of PM_{10} and $PM_{2.5}$. Emissions of NOx have been substantially reduced since 2006, although there was essentially no change in the overall inventory between 2012 and 2013. This is primarily due to a slight increase in NOx emissions from the heavy-duty diesel vehicle (HDDV) source category, possibly resulting from increased terminal congestion (as reported on-terminal turn times were higher in 2013 than in 2012) but also possibly influenced by incomplete fleet data on the prevalence of the newest trucks, which emit far less NOx than trucks even a few years old. This possibility is discussed in Section 3 of this emissions inventory report. Emissions of VOCs and CO do not consistently show decreases, primarily because those two pollutants are not considered priorities in the setting of emission standards for the diesel engines that make up the vast majority of emission sources covered by the inventory. The pollutants addressed most strongly by emission

[1] Greenhouse gases limited to the fuel combustion-related gases carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4).

standards affecting diesel engines are particulate matter and NO_x, which, as discussed, are being reduced over time. Emissions of CO_2 also do not consistently show decreases, because CO_2 emissions are directly related to fuel consumption and are very difficult to reduce without significant efficiency improvements or a shift away from fossil fuels toward more carbon-neutral power sources.

ES.2 Major Changes in 2013

"Real-world" changes and changes in methodology have affected the 2013 emission estimates compared with the previous emissions inventory covering calendar year 2012. Differences between the 2013 inventory and the previous 2012 inventory that had an impact on the emissions presented in this report include:

- The North American Emission Control Area (ECA) was in effect for the full year in 2013 as opposed to only the latter part of the year in 2012. The ECA came into effect August 1, 2012, bringing stricter controls on fuel sulfur content, which reduced emissions of SO_2 and PM from ocean-going vessels (OGVs). The sulfur content limit on fuel oil for OGVs in 2013 was 1.0% S.
- The Port Authority of New York and New Jersey Clean Vessel Incentive (CVI) Program[2] was in effect the full year in 2013. This program aims to provide incentives to vessel operators that perform better in reducing air emissions than required by the current international emissions standards. In 2013, 229 vessels that visited the Port Authority marine terminals participated in the CVI program, making a total of 552 calls that earned incentive payments for reducing emissions by traveling slower and using cleaner fuel than required. The participating vessels switched to lower sulfur fuels than the 1% S ECA requirement while at port. This lowered OGV emissions of SO_2 and PM.
- The sulfur content of fuel used by locomotive and marine engines (category 1 and 2), such as tugboats and towboats, continued to decrease in 2013 with full implementation of ultra-low sulfur fuel requirements and the elimination of remaining exemptions. The average fuel sulfur content used in the emission calculations is 19 ppm[3] in 2013 as compared to 123 ppm in 2012.
- An updated version of the emission estimating model used to estimate emission rates from on-road vehicles has been used for the heavy-duty diesel vehicle (HDDV) source category. The U.S. Environmental Protection Agency (EPA) released MOVES2014 to replace MOVES 2010, making changes to the data and assumptions underlying the model that alter the model results and, therefore, affect the comparisons between 2013 and previous years. The differences in results include increases and decreases for different pollutants and for different types of activity (e.g., different speeds or running vs. idling). For example, the 2012 short-term idling emission factor for NOx (using MOVES2010) was 79.4 g/hr and the 2013 short-term idling emission factor for NOx (using MOVES2014) is higher at 93.2 g/hr, while the 2012 highway/local-speed emission factor for NOx (using MOVES2010) was 17.3 g/hr and the 2013 highway/local-speed emission factor for NOx (using

[2] *http://www.panynj.gov/about/clean-vessel-incentive-program.html*

[3] Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines, EPA420-R-04-007 (May 2004)

MOVES2014) is lower at 15.4 g/hr. Since the 2012 and 2013 fleets were similar as modeled, these differences do not reflect actual increases and decreases of emissions, rather they reflect the best estimates of emissions based on the latest data available to EPA. Adjustments have been made to prior year emission estimates to account for these differences and provide valid comparisons between and among years.

- The MOVES2014 model also newly incorporates the model used to estimate emission rates from non-road equipment, formerly known as the NONROAD model. The MOVES2014 model was used to develop the emission estimates for cargo handling equipment (CHE). While the model and its results have not changed to the extent that the on-road vehicle results have changed, adjustments have been made to prior year emission estimates to account for the differences and provide valid comparisons between and among years.

ES.3 Scope

This inventory includes emissions generated in 2013 that are linked to five Port Authority-associated marine terminals.

The following terminals are located in New Jersey:

- Port Newark
- The Elizabeth Port Authority Marine Terminal
- Port Jersey Port Authority Marine Terminal

The remaining two marine terminals are in New York:

- The Howland Hook Marine Terminal
- The Brooklyn Port Authority Marine Terminal

This inventory does not include emissions from activities linked to the various marine terminals that are entirely privately owned and operated and numerous solid and liquid bulk facilities, including the many oil and fuel depots located along the Arthur Kill and Kill Van Kull waterways – as they are not under the aegis of the Port Authority in any way. This inventory also does not include emissions linked to the Port Authority's non-maritime facilities, such as airports, bridges and tunnels.

The study area for this inventory includes seventeen counties across the states of New Jersey and New York coincident with the New York/Northern New Jersey/Long Island Ozone Non-Attainment Area (NYNJLINA). The NYNJLINA was recognized by the multi-agency Regional Air Team (RAT), of which the Port Authority is a member, as an appropriate boundary to conduct a series of marine-industry related emission inventories that initially looked at the year 2000 commercial marine vessel fleet. The boundary was chosen to coincide with the U.S. Environmental Protection Agency's (EPA) determination that this area has levels of ozone that "persistently exceed the national ambient air quality standards."[4] In 2005 EPA likewise determined that much of this area did not meet the national air quality

[4] *http://epa.gov/oar/oaqps/greenbk/index.html.*

standards for $PM_{2.5}$, although they re-designated New Jersey's nonattainment counties to attainment effective September 4, 2013.[5]

ES.4 Previous Inventories

This report builds on previous Port Authority maritime-related emission inventories covering earlier-year fleets: commercial marine vessels, consisting of ocean-going vessels and harbor craft such as tow boats and assist tugs (2000, 2006, 2008, 2010, and 2012), railroad locomotives (2002, 2006, 2008, 2010, and 2012), heavy-duty diesel vehicles, also known as on-road trucks (2005, 2006, 2008, 2010, and 2012), and cargo handling equipment such as yard tractors, fork lifts, and rubber-tired gantry cranes (2002, 2004, 2006, 2008, 2010, and 2012). This inventory is the fifth study to look at all of the emission source categories within a given year (2006, 2008, 2010, 2012, and 2013) and the first to be prepared on an annual basis.

ES.5 Emissions Surveyed

This inventory report presents estimates of the quantity of emissions from mobile sources tied to the Port Authority leased marine terminals. Most of these emissions are in a category commonly referred to as "criteria pollutants" because the EPA has established health-based or environmentally-based criteria or guidelines for setting ambient limits for them and for the pollutant ozone, which is not emitted directly but develops in the atmosphere, in part as a result of emissions of other pollutants (identified below). In this report, the term "criteria pollutants" refers to the following emissions:

- Oxides of nitrogen (NO_X), an ozone precursor,
- Carbon monoxide (CO),
- Particulate matter less than 10 microns in diameter (PM_{10}),
- Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$),
- Volatile organic compounds (VOCs), an ozone precursor, and
- Sulfur dioxide (SO_2).

The remaining emissions are referred to as greenhouse gas (GHG) emissions because of their contribution to global climate change caused by the global warming phenomenon. The greenhouse gas emissions included in this inventory are:

- Carbon dioxide (CO_2),
- Nitrous oxide (N_2O), and
- Methane (CH_4).

[5] See: *http://www.nj.gov/dep/baqp/aas.html#annualpm.*

Throughout the report, the GHG pollutants are combined into "CO_2 equivalents," a means of expressing the various GHGs in consistent terms relative to the atmospheric activity of CO_2, using factors known as global warming potential (GWP) factors. CO_2 equivalents are calculated by summing the mass emissions of each pollutant multiplied by its GWP, as listed below.

- CO_2 - 1
- N_2O - 310
- CH_4 – 21

The GWP values are subject to change as a result of continuing research into the global warming phenomenon, and a change has been recommended[6] that will likely be implemented in the following emissions inventory. These revised values will be used by EPA in their next update to the next nationwide GHG emissions inventory. The emissions of N_2O and CH_4 from the emission sources included in this Port Authority emissions inventory are very low compared with CO_2 emissions, so the GWP changes will not make an appreciable difference to the inventory's CO_2 equivalent emission estimates.

ES.6 Overall Port Activity

The Port of New York and New Jersey is the largest seaport on the east coast, the third largest in the U.S., and among the top 30 largest container ports in the world. It provides almost immediate access to one of the country's wealthiest regions and rail and truck access to half the nation. The region was first settled because of the Hudson River Valley's advantages as a harbor, and port commerce was integral in the growth of the New York metropolitan region into the economic and cultural center it is today.

One measure of Port activity is the throughput of containerized cargo, commonly expressed in terms of twenty-foot equivalent units (TEUs). In 2013, 5.47 million TEUs passed through the Port, a 1.1% decrease compared with the 5.53 million TEUs moved in 2012. In terms of metric tons of cargo, bulk and general cargo throughput decreased more substantially, decreasing 11.5% from 80.8 million metric tons in 2012 to 71.5 million metric tons in 2013.[7]

ES.7 Emission Estimates

The emission estimates presented in this document are listed in several ways to provide as much information to the reader as possible. The emissions are presented by terminal type, by type of activity, and by county and state. Because of these different modes of display, the numerical values must be rounded, displayed, and summed in different ways. Because of this, it is not always possible to display values in a table that sum exactly to the total shown at the bottom of the table. In developing the tables, priority has been given to maintaining consistent totals for each pollutant across table types.

[6] Fourth Assessment Report of the Intergovernmental Panel on Climate Change, *http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Annex-6-Additional-Information.pdf*
[7] *http://www.panynj.gov/port/trade-stats.html*

The emission estimates developed as described in this report are summarized below. Table ES.1 presents the criteria pollutant and CO_2 equivalent emissions by source category, the total PANYNJ emissions, the total emissions in the NYNJLINA[8] in tons per year, and the percentage that the PANYNJ emissions made up of the total NYNJLINA emissions in 2013.

Table ES.1: Criteria Pollutant and CO_2 Emission Summary by Source Category, tpy

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq
Cargo Handling Equipment	942	63	61	88	371	1.2	140,054
Heavy-Duty Diesel Vehicles	2,521	155	147	177	746	2.7	292,960
Railroad Locomotives	257	9	9	19	49	0.2	18,382
Ocean-Going Vessels	2,495	158	127	149	262	652	139,772
Harbor Craft	384	19	18	15	50	0.5	22,468
Total PANYNJ Emissions	**6,600**	**403**	**361**	**449**	**1,478**	**657**	**613,635**
NYNJLINA Emissions	**280,279**	**76,854**	**37,170**	**266,786**	**1,373,551**	**49,836**	**117,276,953**
PANYNJ Percentage	**2.4%**	**0.5%**	**1.0%**	**0.2%**	**0.1%**	**1.3%**	**0.5%**

Table ES.2 illustrates the percentage contribution of each source category to the total PANYNJ emissions of each pollutant in 2013.

Table ES.2: Criteria Pollutant Emission Summary by Source Category, %

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Cargo Handling Equipment	14%	16%	17%	20%	25%	0.2%
Heavy-Duty Diesel Vehicles	38%	38%	41%	39%	50%	0.4%
Railroad Locomotives	4%	2%	2%	4%	3%	0.0%
Ocean-Going Vessels	38%	39%	35%	33%	18%	99.3%
Harbor Craft	6%	5%	5%	3%	3%	0.1%
Totals	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

[8]2011 National Emission Inventory Database, US EPA.

Tables ES.3 and ES.4 present the emissions and percentages of greenhouse gases.

Table ES.3: Greenhouse Gas Emission Summary by Source Category, tpy

Source Category	CO_2	N_2O	CH_4	CO_2 Eq
Cargo Handling Equipment	138,800	4	8	140,054
Heavy-Duty Diesel Vehicles	292,925	0.3	3.4	292,960
Railroad Locomotives	18,213	0.4	1.4	18,382
Ocean-Going Vessels	137,116	8	3	139,772
Harbor Craft	21,534	5	13	22,468
Totals	**608,588**	**18**	**29**	**613,635**

Table ES.4: Greenhouse Gas Emission Summary by Source Category, %

Source Category	CO_2	N_2O	CH_4	CO_2 Eq
Cargo Handling Equipment	23%	19%	27%	23%
Heavy-Duty Diesel Vehicles	48%	2%	12%	48%
Railroad Locomotives	3%	2%	5%	3%
Ocean-Going Vessels	23%	46%	10%	23%
Harbor Craft	4%	30%	46%	4%
Totals	**100%**	**100%**	**100%**	**100%**

The following figures illustrate the distribution of emissions by source category in terms of tons per year and percent of total, in the context of overall NYNJLINA emissions. The NYNJLINA emissions are broken down into on-road mobile sources, other (non-road) mobile sources, and stationary and area sources. Note that the percentages shown in these charts may not always sum to 100% because of rounding. The charts are intended to illustrate the relative magnitude of emission sources at the port and in the region.

Figure ES.1: Distribution of NO_x Emissions by Source Category, tpy & percent

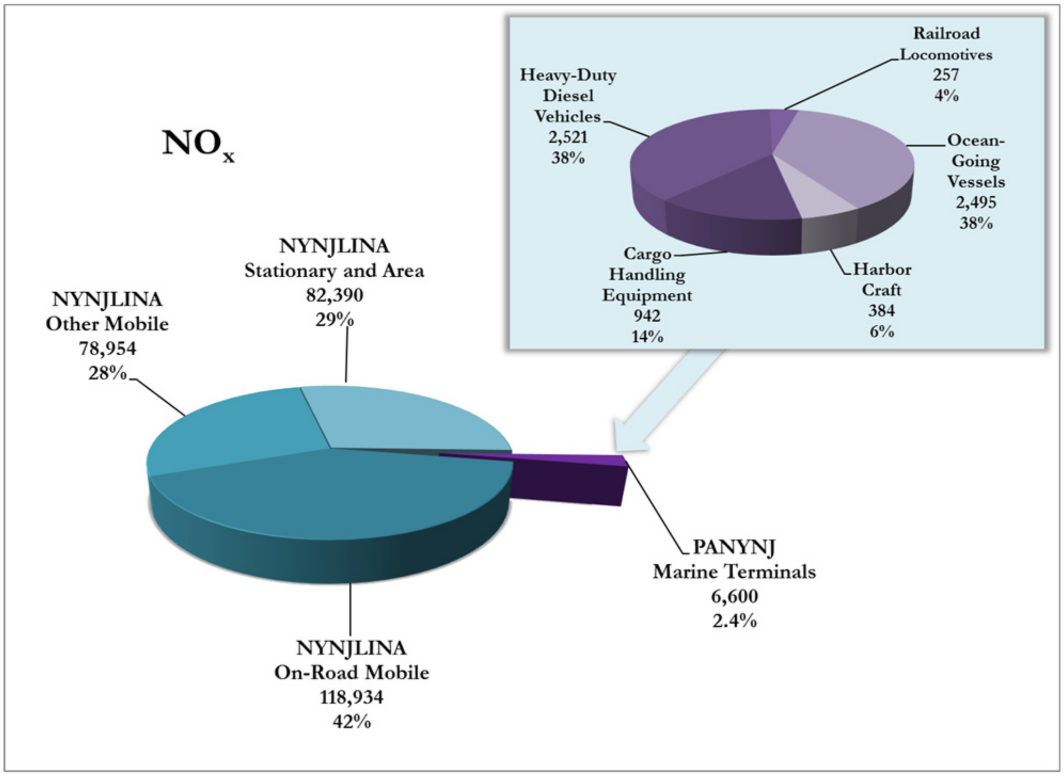


Figure ES.2: Distribution of PM_{10} Emissions by Source Category, tpy & percent

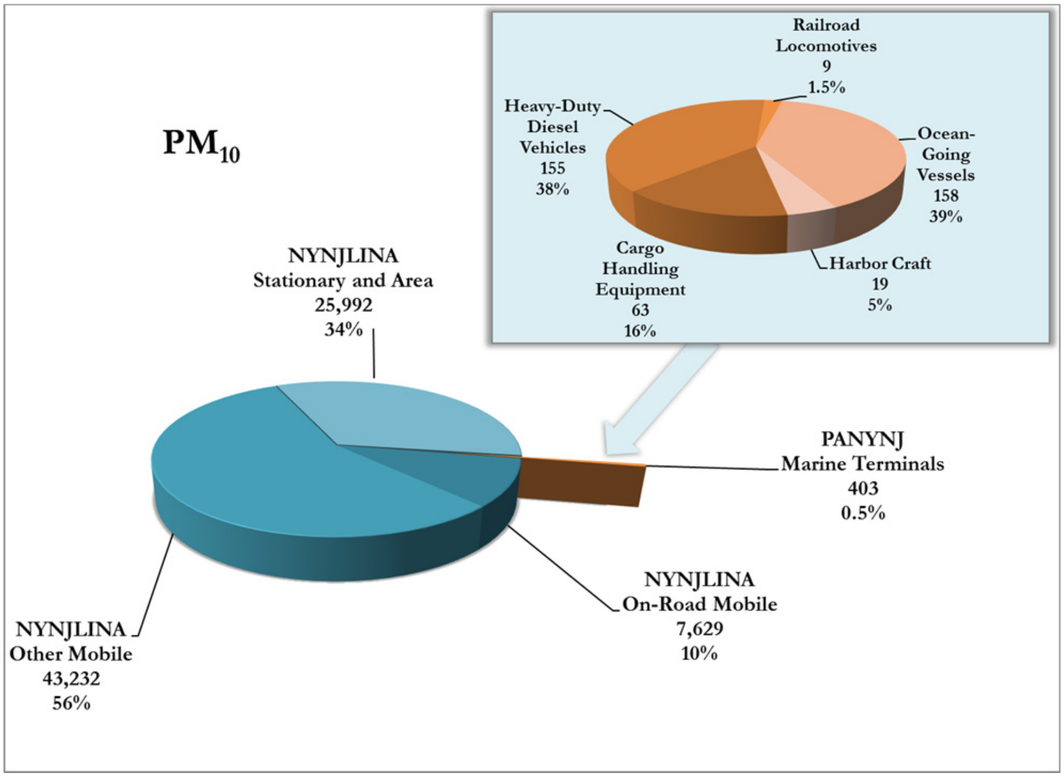


Figure ES.3: Distribution of $PM_{2.5}$ Emissions by Source Category, tpy & percent

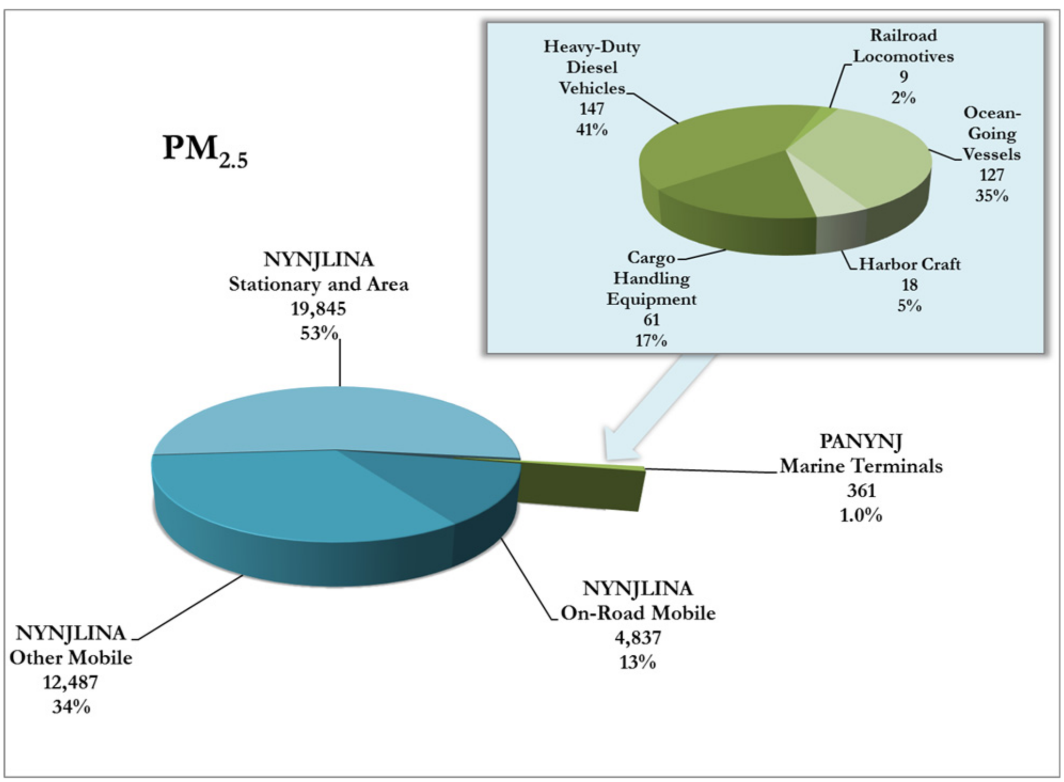


Figure ES.4: Distribution of VOC Emissions by Source Category, tpy & percent

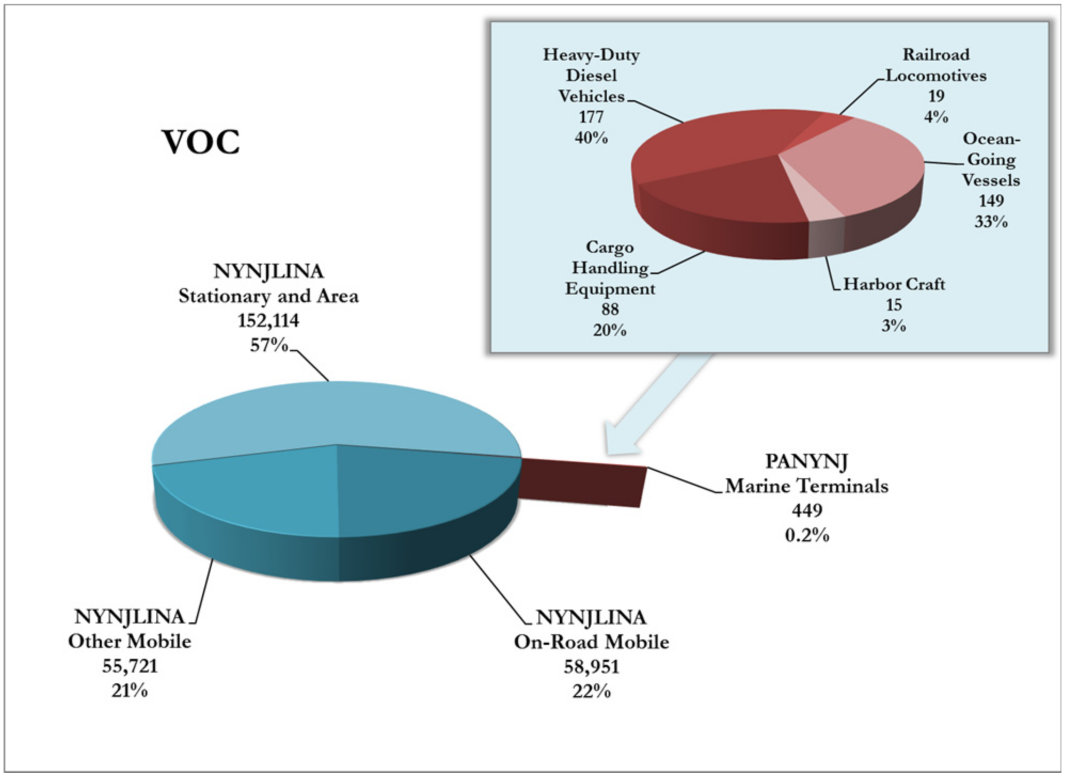


Figure ES.5: Distribution of CO Emissions by Source Category, tpy & percent

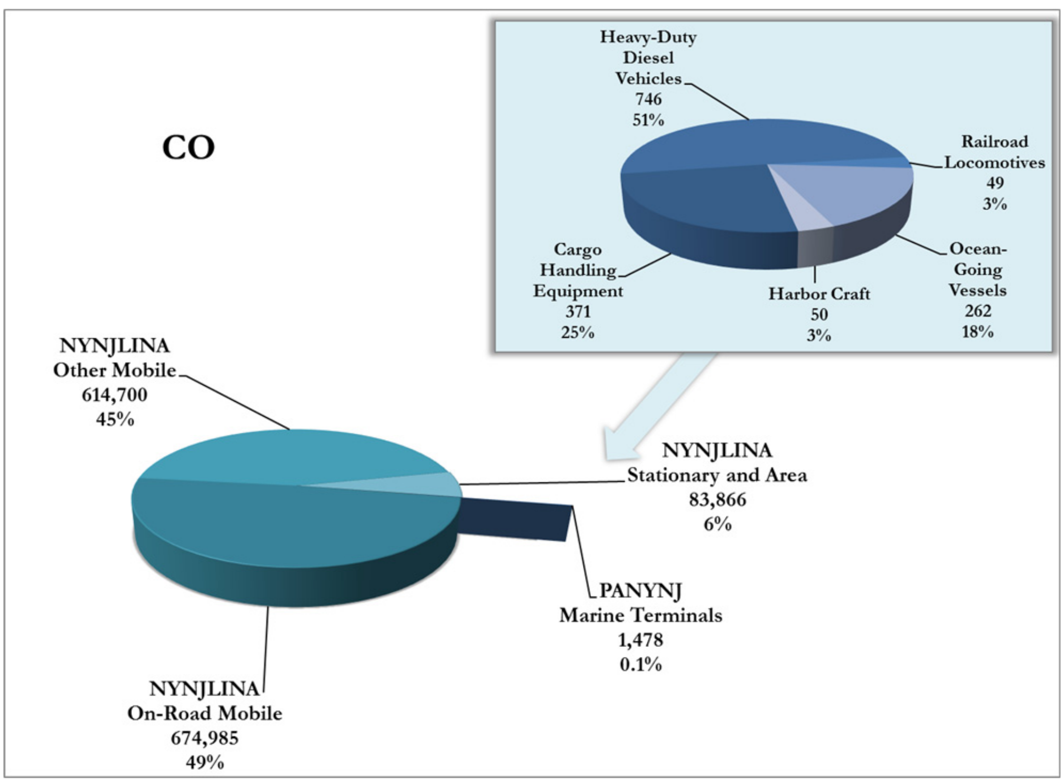


Figure ES.6: Distribution of SO_2 Emissions by Source Category, tpy & percent

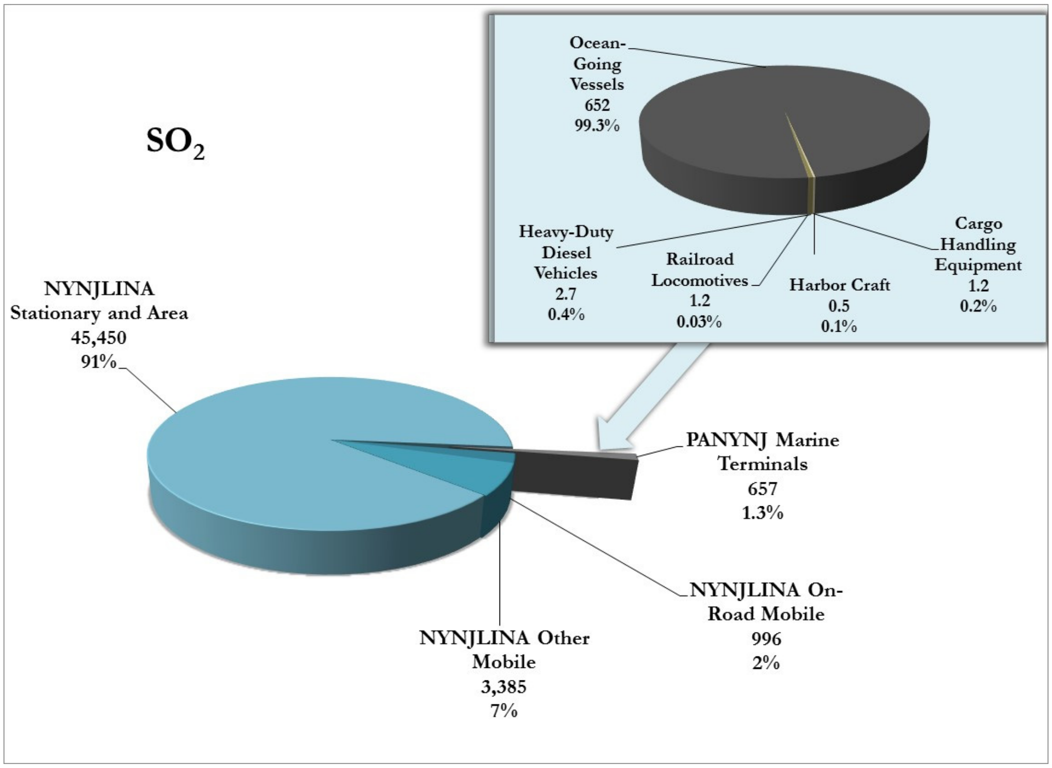
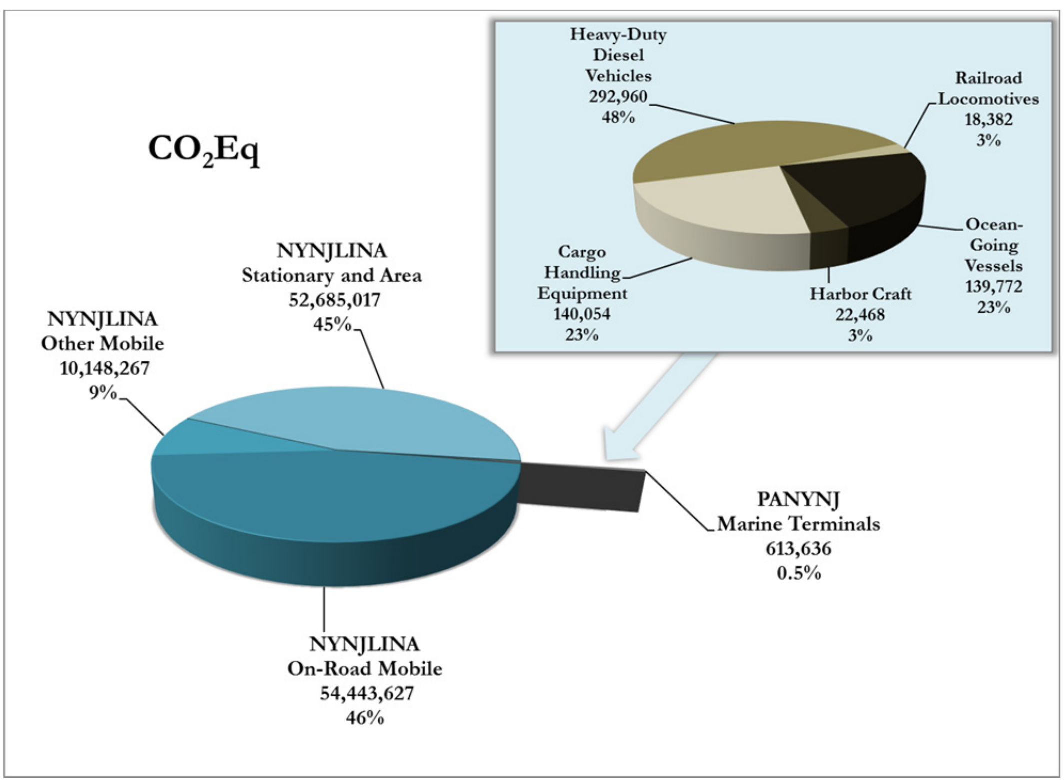


Figure ES.7: Distribution of CO_2 Emissions by Source Category, tpy & percent



SECTION 1: INTRODUCTION

Goods from all over the world enter and leave the United States through the largest port complex on the East Coast of North America, the Port of New York and New Jersey (the Port). With immediate access to extensive interstate highway and railroad networks, marine cargo moves efficiently in and out through the Port's marine terminals, helping to supply the New York/New Jersey metropolitan area, which is one of the busiest freight handling and consumer centers in the country. The Port of New York and New Jersey includes many marine terminals, five of which are under the aegis of the Port Authority of New York and New Jersey (the Port Authority): Port Newark, Elizabeth Port Authority Marine Terminal, and the Port Jersey Port Authority Marine Terminal in New Jersey; and the Howland Hook Marine Terminal and the Brooklyn Port Authority Marine Terminal in New York (see Figure 1.1).

This inventory does not include emissions from activities linked to the various marine terminals that are entirely privately owned and operated – such as numerous solid and liquid bulk facilities, including the many oil and fuel depots located along the Arthur Kill and Kill Van Kull waterways – as they are not under the aegis of the Port Authority in any way. This inventory also does not include emissions linked to the Port Authority's non-maritime facilities, such as airports, bridges and tunnels.

This report furthers ongoing efforts by the Port Authority's Port Commerce Department to assess and evaluate air emissions associated with the Port Authority's marine terminals, including emissions from cargo handling equipment (CHE), heavy-duty diesel vehicles (HDDV, i.e., drayage trucks), locomotives, and commercial marine vessels (CMV), which include ocean going vessels (OGV) and harbor craft. The current inventory covers the activities discussed above associated with the Port Authority's marine terminals that take place within an area known as the New York/Northern New Jersey/Long Island Ozone Non-Attainment Area (NYNJLINA). The NYNJLINA was recognized by the multi-agency Regional Air Team (RAT), of which the Port Authority is a member, as an appropriate boundary to conduct a series of marine-industry related emission inventories that started with the year 2000 commercial marine vessel fleet. The NYNJLINA originally encompassed seventeen counties across the states of New Jersey and New York that constitute the bulk of counties in the designated New York/Northern New Jersey/Long Island/Connecticut ozone non-attainment area and also includes most of the counties designated by the U.S. Environmental Protection Agency (EPA) in 2005 as non-attainment for particulate matter 2.5 microns or less in diameter ($PM_{2.5}$).[9] One of the NYNJLINA counties, Ocean County, New Jersey, has not been included with the NYNJLINA counties listed in various tables in this report because there are no identified Port Authority marine terminal related activities or emissions within the county.

[9] In December of 2012, New Jersey submitted a request to the EPA for re-designation to attainment of the annual 24-hour standards. On August 13, 2013, the USEPA re-designated New Jersey's 13 nonattainment counties to attainment for the annual and the 24-hr NAAQS, effective September 4, 2013. See: *http://www.nj.gov/dep/baqp/aas.html#annualpm*

The Port Authority has previously developed port industry emissions inventories for CHE, HDDVs, railroad locomotives, and CMV associated with the marine terminals maintained by the Port Authority and leased to private operators. The most recent of these inventories was the *2012 Multi-Facility Emissions Inventory* released in August 2014. The purpose of this 2013 emissions inventory is to update the emission estimates presented in the 2012 emissions inventory with a focus on the five Port Authority marine terminals. This current study has evaluated the CHE, HDDV, railroad locomotive, and CMV source categories for the year 2013, which allows for a comparison with the earlier emission estimates for those source categories. The goals of this emissions inventory include:

- Estimate the contribution to overall emissions in the NYNJLINA attributable to CHE, HDDV, locomotive, and CMV associated with the five Port Authority marine terminals;
- Illustrate trends over time in emission rates associated with the five Port Authority marine terminals;
- Reflect, to the extent feasible, the effects of voluntary measures initiated by the Port Authority and their tenants to reduce emissions; and
- Continue to help support a case to obtain funding through grants and other programs for enhancing air quality within the NYNJLINA through targeted port-industry related emission reduction initiatives.

1.1 Approach

Methods used to collect data and to estimate and report emissions from the emission source categories are typical of the approach taken by Starcrest, in concert with the EPA and other regulators, for port emission inventories. The report compares emissions related to terminal operations, including visiting vessels, cargo handling equipment, trucks and locomotives within the NYNJLINA with total area emissions and emissions by county. It does not include the use of dispersion models to predict ambient concentrations of pollutants or the assessment of health impacts.

The approach to developing this activity-based or "bottom-up" emissions inventory was based in large part on interviews and conversations with the tenants who own, operate, maintain, and/or lease equipment. The activity and operational data collected was used to estimate emissions for each of the source categories in a manner consistent with the latest estimating methods. The information that was collected and analyzed, and is presented in this report, improves the understanding of the nature and magnitude of emission sources associated with the five Port Authority marine terminals, and will help facilitate an evaluation of the change in emission levels since the previous inventory year.

1.1.1 Pollutants

This inventory estimates and reports the quantity of emissions from mobile emission sources associated with maritime facilities maintained by the Port Authority and leased to terminal operators. The estimates are based on activities that occurred during calendar year 2013. Most of the emissions are in a category commonly referred to as "criteria pollutants" because the EPA has established health-based or environmentally-based criteria or guidelines that set ambient limits for these emissions or for the pollutant ozone, which is not emitted directly but develops in the atmosphere, in part as a result of emissions of other materials (identified below). In this report, the term "criteria pollutants" refers to the following emissions:

- Oxides of nitrogen (NO_X), an ozone precursor,
- Carbon monoxide (CO),
- Particulate matter less than 10 microns in diameter (PM_{10}),
- Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$),
- Volatile organic compounds (VOCs), an ozone precursor, and
- Sulfur dioxide (SO_2).

The remaining emissions are referred to as greenhouse gas (GHG) emissions because of their contribution to global climate change caused by the global warming phenomenon. The greenhouse gas emissions included in this inventory are:

- Carbon dioxide (CO_2),
- Nitrous oxide (N_2O), and
- Methane (CH_4).

These GHGs have also been combined into "CO_2 equivalents," a means of expressing the various GHGs in consistent terms relative to the atmospheric activity of CO_2, using factors known as "global warming potential" (GWP) values. CO_2 equivalents are calculated by summing the mass emissions of each pollutant multiplied by its GWP, as listed below.

- CO_2 - 1
- N_2O - 310
- CH_4 – 21

The GWP values are subject to change as a result of continuing research into the global warming phenomenon, and a change has been recommended by EPA[10] that will likely be implemented in subsequent emissions inventories. These revised values will be used by EPA in their next update to the next nationwide GHG emissions inventory. The emissions of N_2O and CH_4 from the emission sources included in this Port Authority emissions inventory are very low compared with CO_2 emissions, so the GWP changes will not make an appreciable difference to the inventory's CO_2 equivalent emission estimates.

[10] Fourth Assessment Report of the Intergovernmental Panel on Climate Change, *http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Annex-6-Additional-Information.pdf*

1.1.2 Facilities

The Port Authority maintains five of the Port of New York and New Jersey's marine terminals, three in New Jersey and two in New York (Figure 1). All five are leased to private terminal operators. There are also numerous marine terminals situated within the Port of New York and New Jersey that are privately owned and operated, which are not associated with the Port Authority, and are therefore excluded from this emissions inventory.

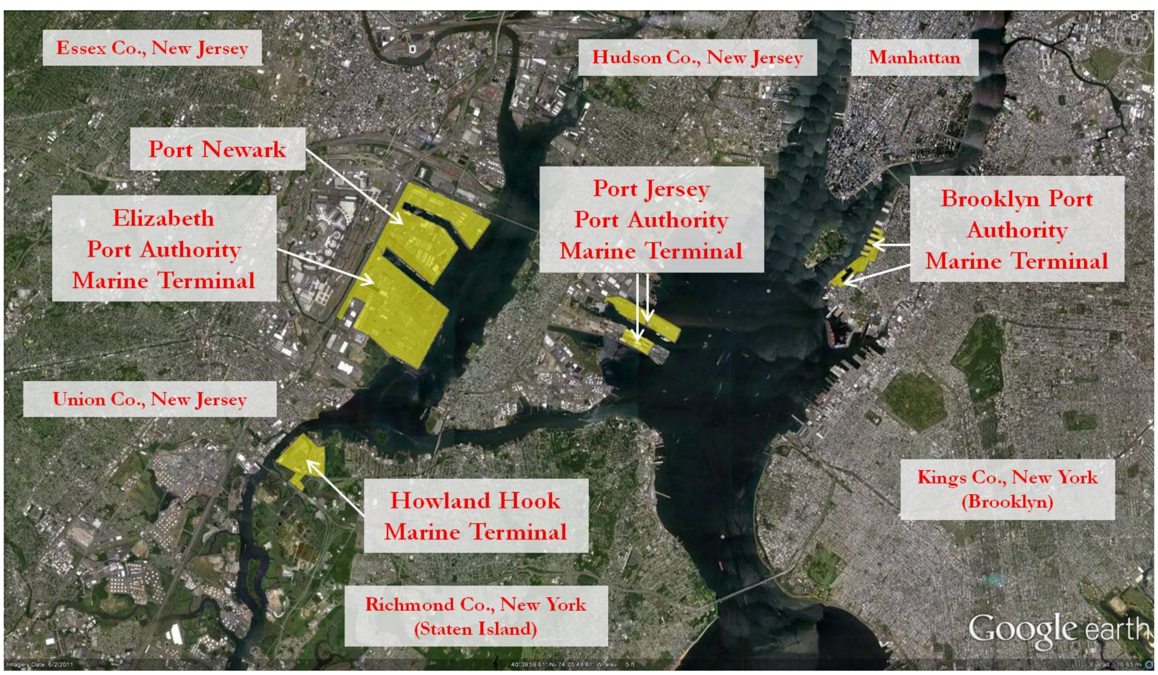
The Port Authority's New Jersey marine terminals are:

- Port Newark (which includes container, auto marine, and on-terminal warehousing operations),
- The Elizabeth Port Authority Marine Terminal (which includes container and on-terminal warehousing operations),
- Port Jersey Port Authority Marine Terminal (in Bayonne and Jersey City which includes container, auto and cruise operations).

The Port Authority's New York marine facilities are:

- The Howland Hook Marine Terminal (at Staten Island which includes container operations),
- The Brooklyn Port Authority Marine Terminal (which includes container operations and the adjacent cruise terminal).

Figure 1.1: Location of the Port Authority of New York & New Jersey Marine Terminals



1.1.3 Major Changes in 2013

"Real-world" changes and changes in methodology have affected the 2013 emission estimates compared with the previous emissions inventory covering calendar year 2012. Differences between the 2013 inventory and the previous 2012 inventory that had an impact on the emissions presented in this report include:

- The North American Emission Control Area (ECA) was in effect for the full year in 2013 as opposed to only the latter part of the year in 2012. The ECA came into effect August 1, 2012, bringing stricter controls on fuel sulfur content, which reduced emissions of SO_2 and PM from ocean-going vessels (OGVs). In the ECAs, the sulfur content of fuel oil for OGVs must be less than 1% S.
- The Port Authority of New York and New Jersey Clean Vessel Incentive (CVI) Program was in effect the full year in 2013. This program aims to provide incentives to vessel operators that perform better in reducing air emissions than required by the current international emissions standards. In 2013, 220 vessels that visited the Port Authority marine terminals participated in the CVI program. The participating vessels switched to lower sulfur fuels than the 1% S ECA requirement while at port. This lowered OGV emissions of SO_2 and PM.
- The sulfur content of fuel used by locomotive and marine engines (category 1 and 2), such as tugboats and towboats, continued to decrease in 2013 with full implementation of ultra-low sulfur fuel requirements and the elimination of remaining exemptions. The average fuel sulfur content used in the emission calculations is 19 ppm[11] in 2013 as compared to 123 ppm in 2012.
- An updated version of the emission estimating model used to estimate emission rates from on-road vehicles has been used for the heavy-duty diesel vehicle (HDDV) source category. EPA released MOVES2014 to replace MOVES 2010, making changes to the data and assumptions underlying the model that alter the model results and, therefore, affect the comparisons between 2013 and previous years. The differences in results include increases and decreases for different pollutants and for different types of activity (e.g., different speeds or running vs. idling). Adjustments have been made to prior year emission estimates to account for the differences and provide valid comparisons between and among years.
- The MOVES2014 model also newly incorporates the model used to estimate emission rates from non-road equipment, formerly known as the NONROAD model. The MOVES2014 model was used to develop the emission estimates for cargo handling equipment (CHE). While the model and its results have not changed to the extent that the on-road vehicle results have changed, adjustments have been made to prior year emission estimates to account for the differences and provide valid comparisons between and among years.

[11] Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines, EPA420-R-04-007 (May 2004)

1.2 Report Organization by Section

The sections that follow are organized by source category and detail specific emissions inventory methods and results for cargo handling equipment (Section 2), heavy-duty diesel vehicles (Section 3), locomotives (Section 4), and commercial marine vessels (Section 5).

1.3 Summary of Results

The emission estimates developed as described in this report are summarized in this subsection. Table 1.1 presents the criteria pollutant and CO_2 equivalent emissions by source category, the total PANYNJ emissions (the emissions included in this report), the total emissions in the NYNJLINA[12] in tons per year, and the percentage that the PANYNJ emissions makeup of the total NYNJLINA emissions.

The emission estimates presented in this document are listed in several ways to provide as much information to the reader as possible. The emissions are presented by terminal or facility type, by type of activity, and by county and state. Because of these different modes of display, the numerical values must be rounded, displayed, and summed in different ways. Because of this, it is not always possible to display values in a table that sum exactly to the total shown at the bottom of the table. In developing the tables, priority has been given to maintaining consistent totals for each pollutant across table types.

Table 1.1: Criteria Pollutant Emission Summary by Source Category, tpy

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq
Cargo Handling Equipment	942	63	61	88	371	1.2	140,054
Heavy-Duty Diesel Vehicles	2,521	155	147	177	746	2.7	292,960
Railroad Locomotives	257	9	9	19	49	0.2	18,382
Ocean-Going Vessels	2,495	158	127	149	262	652	139,772
Harbor Craft	384	19	18	15	50	0.5	22,468
Total PANYNJ Emissions	**6,600**	**403**	**361**	**449**	**1,478**	**657**	**613,635**
NYNJLINA Emissions	**280,279**	**76,854**	**37,170**	**266,786**	**1,373,551**	**49,836**	**117,276,953**
PANYNJ Percentage	**2.4%**	**0.5%**	**1.0%**	**0.2%**	**0.1%**	**1.3%**	**0.5%**

[12] Criteria pollutant emissions are from the 2011 National Emissions Inventory: (*http://www.epa.gov/ttn/chief/net/2011inventory.html*)
Greenhouse gas emissions are from the 2011 and 2008 National Emissions Inventories, with stationary and area sources coming from the 2008 Inventory because they are not provided by the 2011 Inventory.
(*http://www.epa.gov/ttn/chief/net/2008inventory.html*)

Table 1.2 illustrates the percentage contribution of each source category to the total PANYNJ emissions of each pollutant, while Tables 1.3 and 1.4 similarly present the emissions and percentages of greenhouse gases.

Table 1.2: Criteria Pollutant Emission Summary by Source Category, percent

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Cargo Handling Equipment	14%	16%	17%	20%	25%	0.2%
Heavy-Duty Diesel Vehicles	38%	38%	41%	39%	50%	0.4%
Railroad Locomotives	4%	2%	2%	4%	3%	0.0%
Ocean-Going Vessels	38%	39%	35%	33%	18%	99.3%
Harbor Craft	6%	5%	5%	3%	3%	0.1%
Totals	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 1.3: Greenhouse Gas Emission Summary by Source Category, tpy

Source Category	CO_2	N_2O	CH_4	CO_2 Eq
Cargo Handling Equipment	138,800	4	8	140,054
Heavy-Duty Diesel Vehicles	292,925	0.3	3.4	292,960
Railroad Locomotives	18,213	0.4	1.4	18,382
Ocean-Going Vessels	137,116	8	3	139,772
Harbor Craft	21,534	5	13	22,468
Totals	**608,588**	**18**	**29**	**613,635**

Table 1.4: Greenhouse Gas Emission Summary by Source Category, percent

Source Category	CO_2	N_2O	CH_4	CO_2 Eq
Cargo Handling Equipment	23%	19%	27%	23%
Heavy-Duty Diesel Vehicles	48%	2%	12%	48%
Railroad Locomotives	3%	2%	5%	3%
Ocean-Going Vessels	23%	46%	10%	23%
Harbor Craft	4%	30%	46%	4%
Totals	**100%**	**100%**	**100%**	**100%**

Figures 1.2 through 1.8 illustrate the contribution of emissions from Port Authority marine terminal emission source categories to overall emissions in the NYNJLINA. Note that the percentages shown in these charts do not always sum to 100% because of rounding. The charts are intended to illustrate the relative magnitude of emission sources at the port and in the region.

Figure 1.2: Distribution of NO_x Emissions by Source Category, tpy & percent

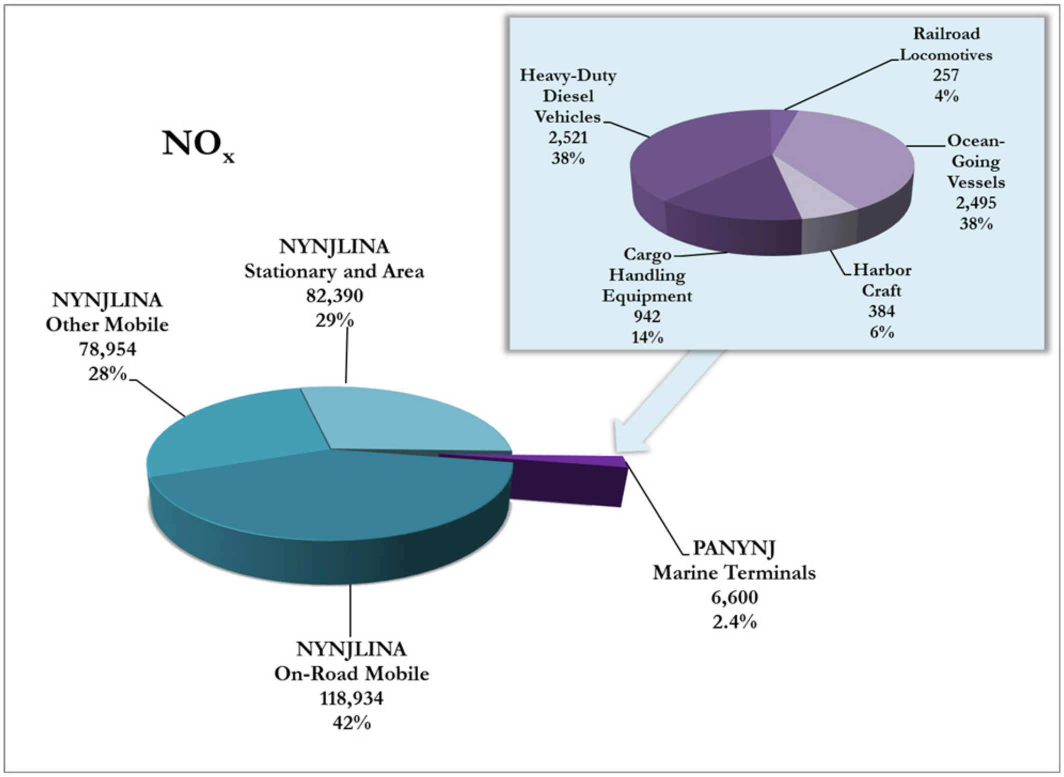


Figure 1.3: Distribution of PM_{10} Emissions by Source Category, tpy & percent

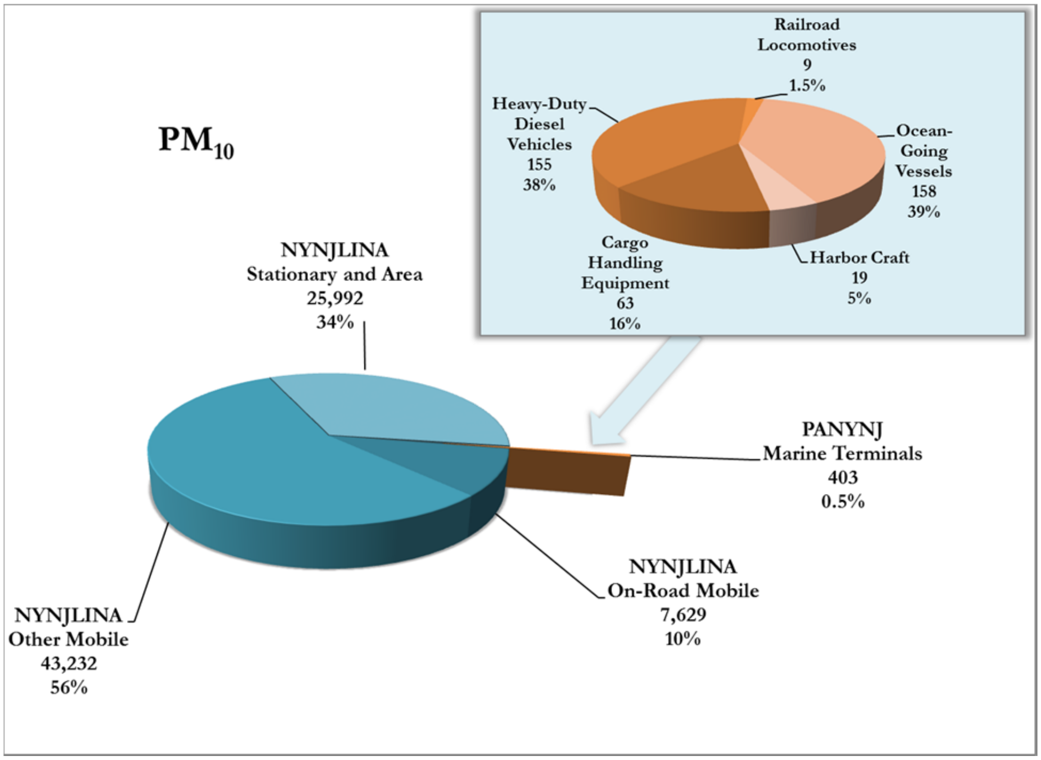


Figure 1.4: Distribution of $PM_{2.5}$ Emissions by Source Category, tpy & percent

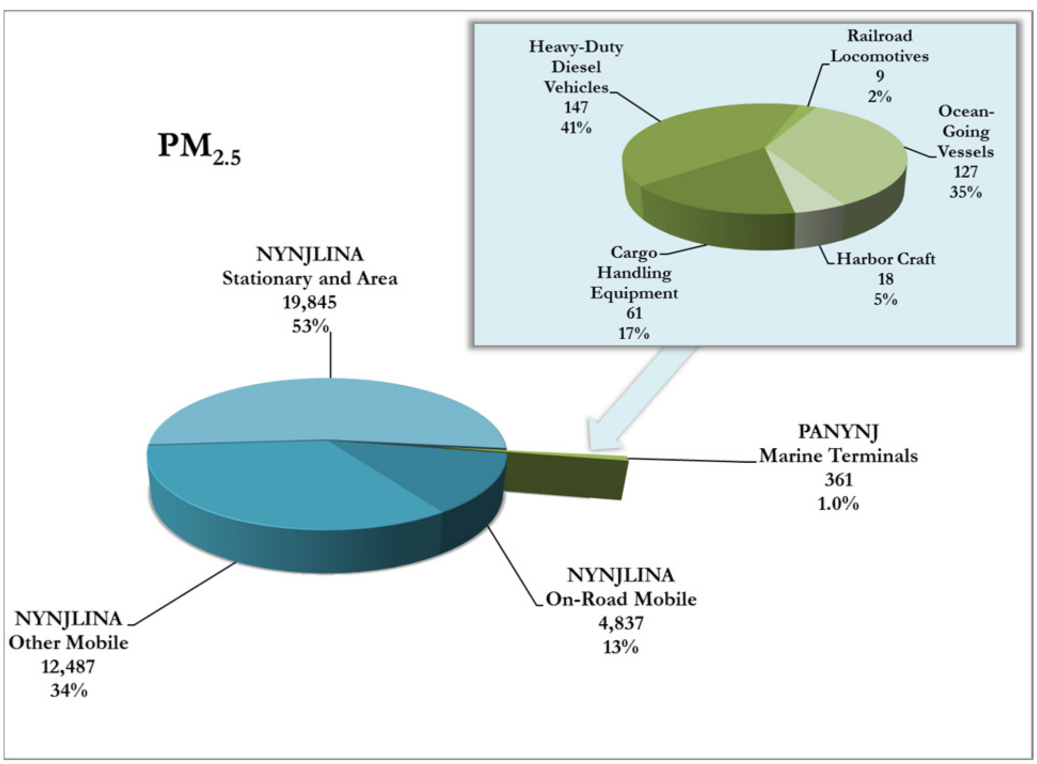


Figure 1.5: Distribution of VOC Emissions by Source Category, tpy & percent

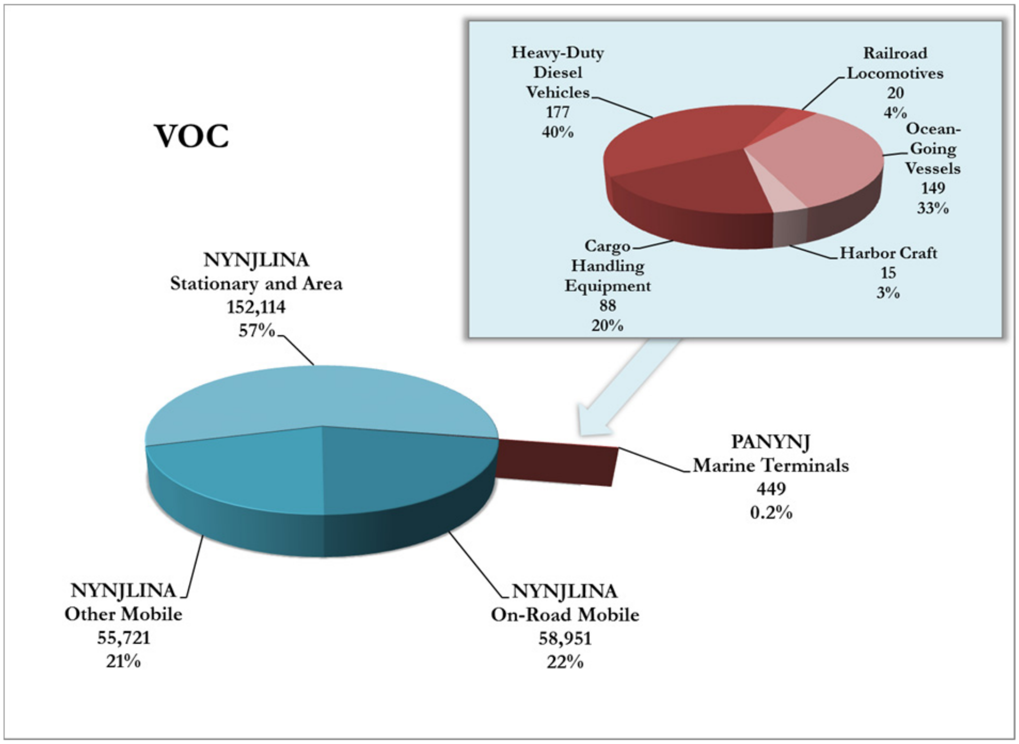


Figure 1.6: Distribution of CO Emissions by Source Category, tpy & percent

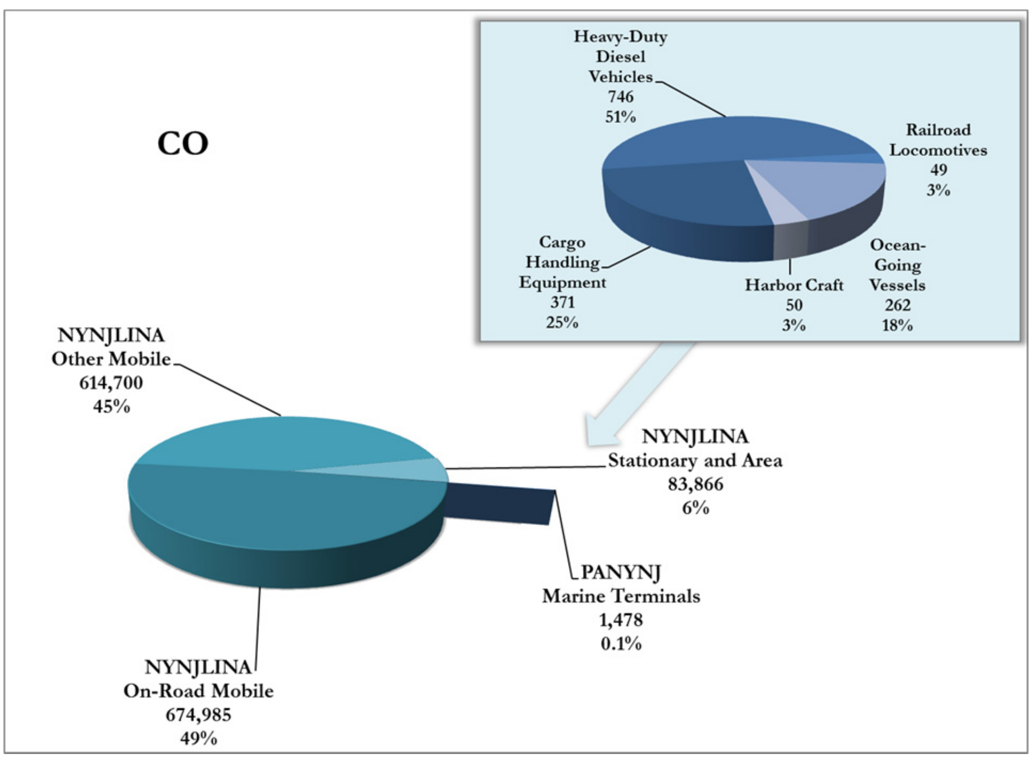


Figure 1.7: Distribution of SO_2 Emissions by Source Category, tpy & percent

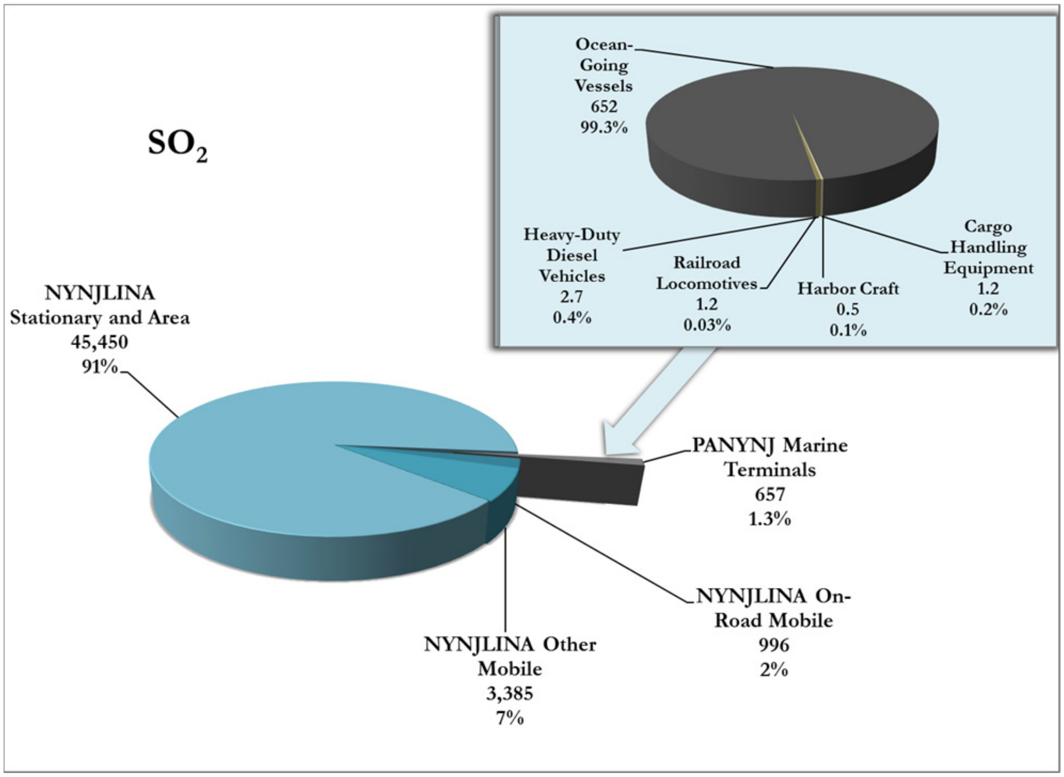
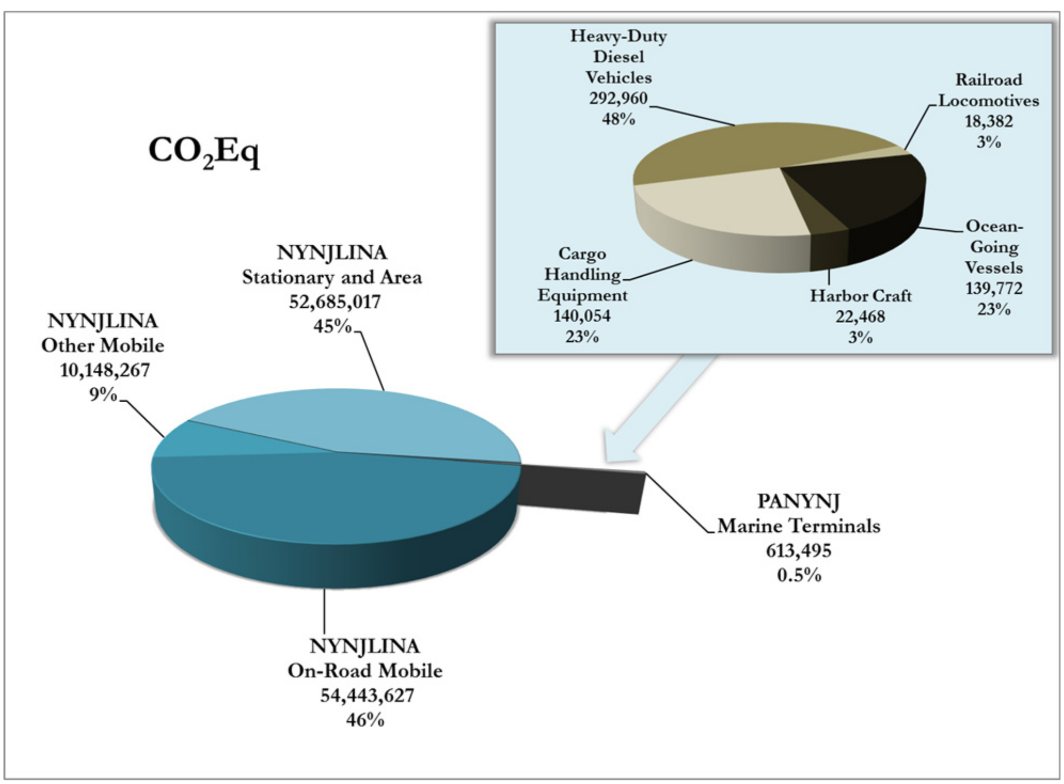


Figure 1.8: Distribution of CO_2 Emissions by Source Category, tpy & percent



1.4 Overall Comparison of Emissions Related to the Port Authority Marine Terminals

This section presents the estimates detailed in the foregoing sections in the context of county-wide and non-attainment area-wide emissions. The emissions from each source category and from all categories combined are compared with all emissions in the NYNJLINA and emissions released in each county are compared with county-wide emissions. Specifically, this subsection compares overall Port Authority marine terminal related emissions with county-level emission totals as reported in the most recent National Emissions Inventory database. [13]

Table 1.5 summarizes by county the estimated emissions from the Port Authority marine terminal related activities covered by this report, and Table 1.6 lists total emissions of each criteria pollutant by county and state, as reported in the most recent National Emissions Inventory database.

Table 1.5: Port Authority Criteria Pollutant and CO_2 Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2Eq
Bergen	NJ	176	9	9	10	48	0	19,403
Essex	NJ	1,562	98	86	107	340	200	151,300
Hudson	NJ	984	58	51	58	190	114	83,693
Middlesex	NJ	494	28	27	30	140	1	57,352
Monmouth	NJ	125	7	6	6	18	16	7,788
Union	NJ	2,052	133	119	170	486	214	189,316
New Jersey subtotal		**5,392**	**332**	**298**	**380**	**1,222**	**545**	**508,852**
Bronx	NY	43	2	2	3	12	0	5,058
Kings (Brooklyn)	NY	318	19	17	17	59	41	25,113
Nassau	NY	76	4	4	5	22	0	8,844
New York	NY	65	5	4	3	9	14	4,765
Orange	NY	45	3	2	3	13	0	5,147
Queens	NY	40	2	2	2	11	0	4,463
Richmond (Staten Island)	NY	487	29	26	30	98	57	38,366
Rockland	NY	54	2	2	3	11	0	4,179
Suffolk	NY	35	2	2	2	9	0	3,639
Westchester	NY	45	3	2	3	12	0	5,070
New York subtotal		**1,208**	**70**	**63**	**69**	**255**	**112**	**104,643**
PANYNJ Total		**6,600**	**403**	**361**	**449**	**1,478**	**657**	**613,635**

[13] 2011 National Emission Inventory Database, US EPA.

Table 1.6: Summary of NYNJLINA Criteria Pollutant and CO_2 Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2Eq
Bergen	NJ	14,798	3,565	2,101	17,028	110,855	679	9,541,143
Essex	NJ	17,195	5,233	2,574	16,814	79,450	2,630	5,003,403
Hudson	NJ	9,585	1,732	1,284	9,244	37,073	1,817	8,462,823
Middlesex	NJ	14,766	4,288	2,335	16,653	87,617	771	8,498,809
Monmouth	NJ	10,366	3,334	1,737	12,551	74,655	671	3,804,952
Union	NJ	12,325	2,787	1,877	11,037	55,299	1,053	13,148,205
New Jersey subtotal		**79,035**	**20,939**	**11,908**	**83,327**	**444,949**	**7,621**	**48,459,335**
Bronx	NY	13,195	2,605	1,474	14,156	52,643	1,769	3,840,799
Kings (Brooklyn)	NY	25,190	4,779	2,693	26,367	101,980	2,021	7,773,726
Nassau	NY	21,973	5,840	2,740	21,541	124,041	3,045	7,248,464
New York	NY	33,432	6,363	3,199	21,185	124,401	6,776	7,334,053
Orange	NY	11,854	7,595	2,462	9,654	48,412	10,728	5,519,423
Queens	NY	31,678	5,244	3,030	27,358	123,921	2,932	15,420,059
Richmond (Staten Island)	NY	10,793	1,885	1,090	6,576	33,262	383	2,684,929
Rockland	NY	5,622	1,993	801	5,701	32,711	461	2,395,107
Suffolk	NY	30,558	12,931	5,117	33,256	182,114	11,488	11,899,339
Westchester	NY	16,949	6,680	2,656	17,665	105,117	2,612	4,701,719
New York subtotal		**201,244**	**55,915**	**25,262**	**183,459**	**928,602**	**42,215**	**68,817,618**
NYNJLINA Total		**280,279**	**76,854**	**37,170**	**266,786**	**1,373,551**	**49,836**	**117,276,953**

The subsequent tables and figures (Tables 1.7 through 1.13 and Figures 1.9 through 1.15, respectively) provide additional pollutant specific detail to this county level data for criteria pollutants and CO_2 equivalent, placing emissions tied to Port Authority owned marine terminals into a local and regional perspective. These figures compare overall emissions related to Port Authority marine terminals on a county level with overall county-wide emissions, and on a regional level with totals of all included counties in each state. Each table (one for each criteria pollutant, and CO_2) shows the county-wide emissions, Port Authority marine terminal-related emissions in each county, and the percentage of each county total made up by the Port Authority emissions. The same information is shown for the sum of counties in each state and for both states combined. A column chart illustrates each such table. As noted previously, not all subtotals and totals exactly equal the sums of individual values in the tables because of rounding of the individual values.

Table 1.7: Comparison of NO_x Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	14,798	176	1.2%
Essex	NJ	17,195	1,562	9.1%
Hudson	NJ	9,585	984	10.3%
Middlesex	NJ	14,766	494	3.3%
Monmouth	NJ	10,366	125	1.2%
Union	NJ	12,325	2,052	16.6%
New Jersey subtotal		**79,035**	**5,392**	**6.8%**
Bronx	NY	13,195	43	0.3%
Kings (Brooklyn)	NY	25,190	318	1.3%
Nassau	NY	21,973	76	0.3%
New York	NY	33,432	65	0.2%
Orange	NY	11,854	45	0.4%
Queens	NY	31,678	40	0.1%
Richmond (Staten Island)	NY	10,793	487	4.5%
Rockland	NY	5,622	54	1.0%
Suffolk	NY	30,558	35	0.1%
Westchester	NY	16,949	45	0.3%
New York subtotal		**201,244**	**1,208**	**0.6%**
NYNJLINA and PANYNJ Totals		**280,279**	**6,600**	**2.4%**

Figure 1.9: Comparison of NO_x Emissions by County, tpy

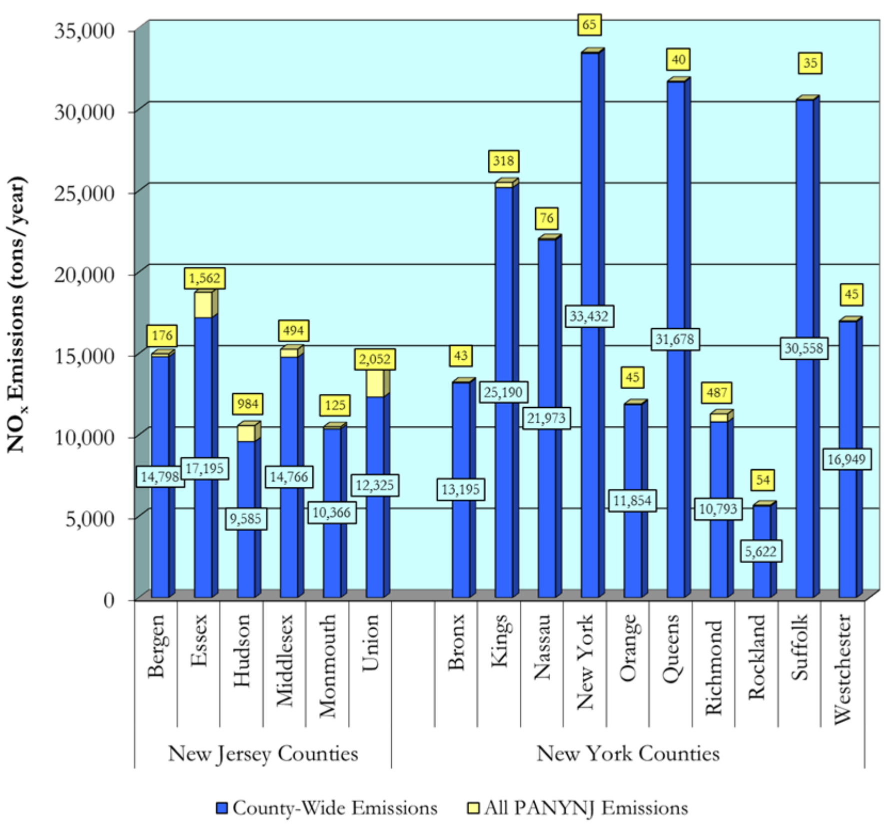


Table 1.8: Comparison of PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	3,565	9	0.3%
Essex	NJ	5,233	98	1.9%
Hudson	NJ	1,732	58	3.3%
Middlesex	NJ	4,288	28	0.7%
Monmouth	NJ	3,334	7	0.2%
Union	NJ	2,787	133	4.8%
New Jersey subtotal		**20,939**	**332**	**1.6%**
Bronx	NY	2,605	2	0.1%
Kings (Brooklyn)	NY	4,779	19	0.4%
Nassau	NY	5,840	4	0.1%
New York	NY	6,363	5	0.1%
Orange	NY	7,595	3	0.0%
Queens	NY	5,244	2	0.0%
Richmond (Staten Island)	NY	1,885	29	1.5%
Rockland	NY	1,993	2	0.1%
Suffolk	NY	12,931	2	0.0%
Westchester	NY	6,680	3	0.0%
New York subtotal		**55,915**	**70**	**0.1%**
NYNJLINA and PANYNJ Totals		**76,854**	**403**	**0.5%**

Figure 1.10: Comparison of PM_{10} Emissions by County, tpy

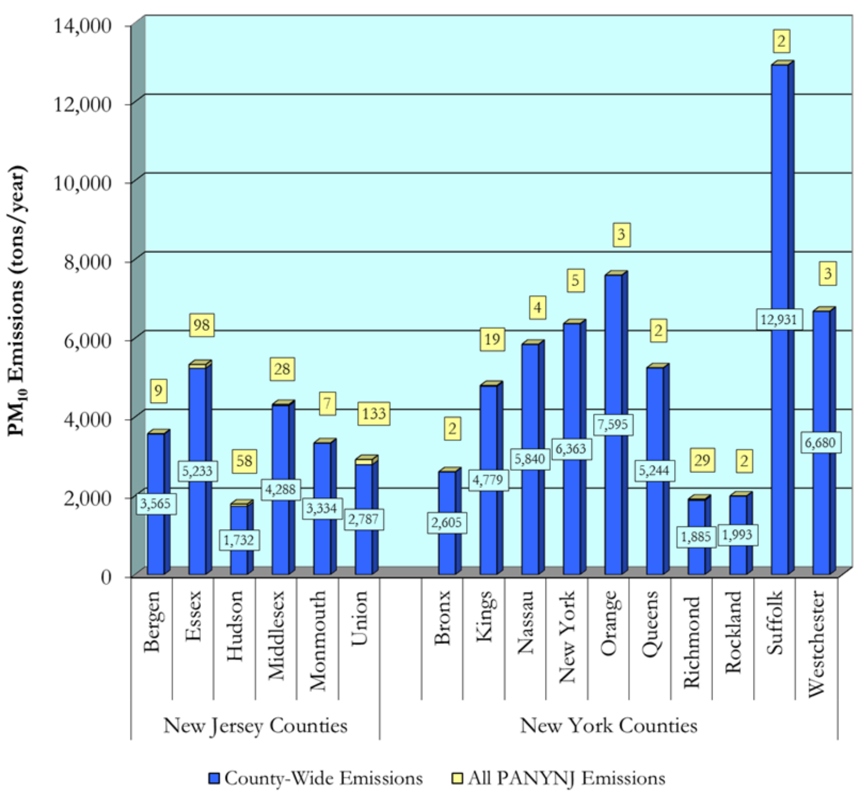


Table 1.9: Comparison of $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	2,101	9	0.4%
Essex	NJ	2,574	86	3.4%
Hudson	NJ	1,284	51	3.9%
Middlesex	NJ	2,335	27	1.2%
Monmouth	NJ	1,737	6	0.3%
Union	NJ	1,877	119	6.3%
New Jersey subtotal		**11,908**	**298**	**2.5%**
Bronx	NY	1,474	2	0.2%
Kings (Brooklyn)	NY	2,693	17	0.6%
Nassau	NY	2,740	4	0.2%
New York	NY	3,199	4	0.1%
Orange	NY	2,462	2	0.1%
Queens	NY	3,030	2	0.1%
Richmond (Staten Island)	NY	1,090	26	2.3%
Rockland	NY	801	2	0.2%
Suffolk	NY	5,117	2	0.0%
Westchester	NY	2,656	2	0.1%
New York subtotal		**25,262**	**63**	**0.2%**
NYNJLINA and PANYNJ Totals		**37,170**	**361**	**1.0%**

Figure 1.11: Comparison of $PM_{2.5}$ Emissions by County, tpy

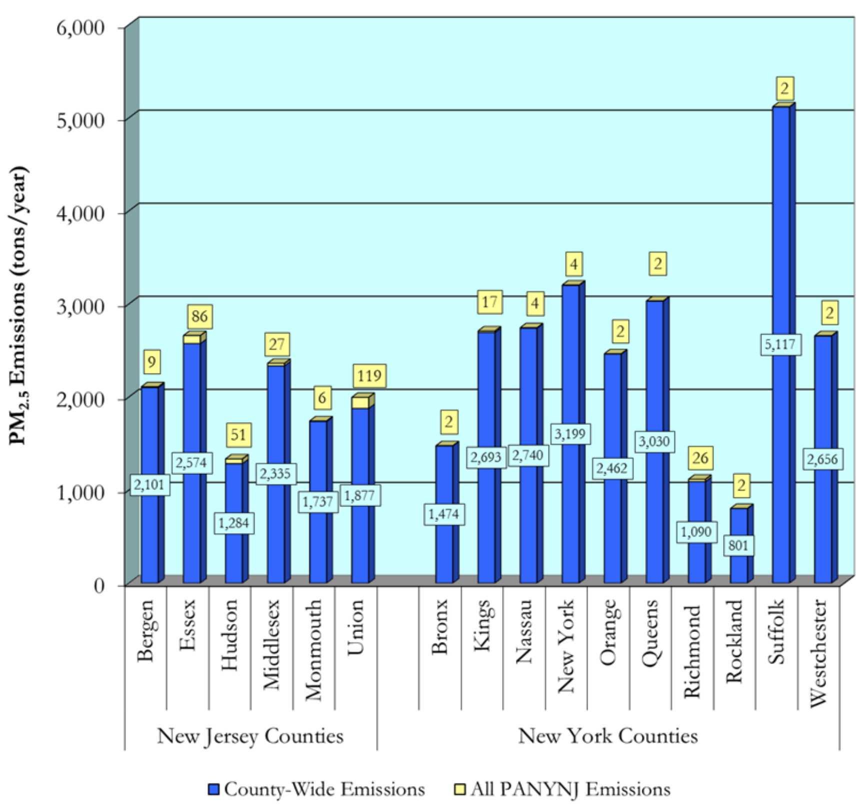


Table 1.10: Comparison of VOC Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	17,028	10	0.1%
Essex	NJ	16,814	107	0.6%
Hudson	NJ	9,244	58	0.6%
Middlesex	NJ	16,653	30	0.2%
Monmouth	NJ	12,551	6	0.0%
Union	NJ	11,037	170	1.5%
New Jersey subtotal		**83,327**	**380**	**0.5%**
Bronx	NY	14,156	3	0.0%
Kings (Brooklyn)	NY	26,367	17	0.1%
Nassau	NY	21,541	5	0.0%
New York	NY	21,185	3	0.0%
Orange	NY	9,654	3	0.0%
Queens	NY	27,358	2	0.0%
Richmond (Staten Island)	NY	6,576	30	0.5%
Rockland	NY	5,701	3	0.0%
Suffolk	NY	33,256	2	0.0%
Westchester	NY	17,665	3	0.0%
New York subtotal		**183,459**	**69**	**0.0%**
NYNJLINA and PANYNJ Totals		**266,786**	**449**	**0.2%**

Figure 1.12: Comparison of VOC Emissions by County, tpy

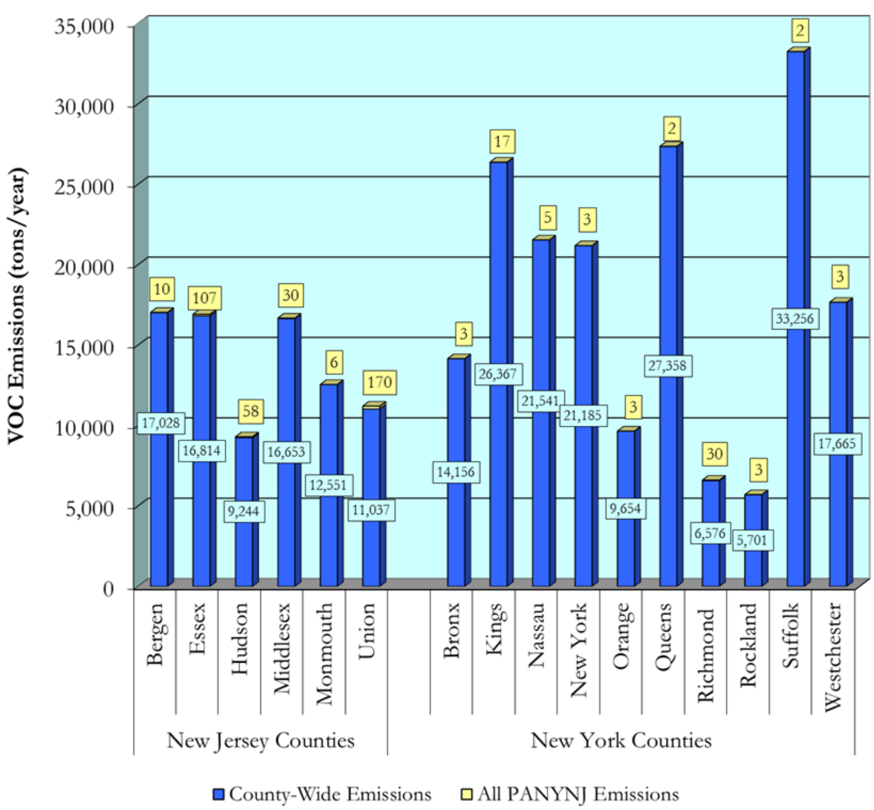


Table 1.11: Comparison of CO Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	110,855	48	0.0%
Essex	NJ	79,450	340	0.4%
Hudson	NJ	37,073	190	0.5%
Middlesex	NJ	87,617	140	0.2%
Monmouth	NJ	74,655	18	0.0%
Union	NJ	55,299	486	0.9%
New Jersey subtotal		**444,949**	**1,222**	**0.3%**
Bronx	NY	52,643	12	0.0%
Kings (Brooklyn)	NY	101,980	59	0.1%
Nassau	NY	124,041	22	0.0%
New York	NY	124,401	9	0.0%
Orange	NY	48,412	13	0.0%
Queens	NY	123,921	11	0.0%
Richmond (Staten Island)	NY	33,262	98	0.3%
Rockland	NY	32,711	11	0.0%
Suffolk	NY	182,114	9	0.0%
Westchester	NY	105,117	12	0.0%
New York subtotal		**928,602**	**255**	**0.0%**
NYNJLINA and PANYNJ Totals		**1,373,551**	**1,477**	**0.1%**

Figure 1.13: Comparison of CO Emissions by County, tpy

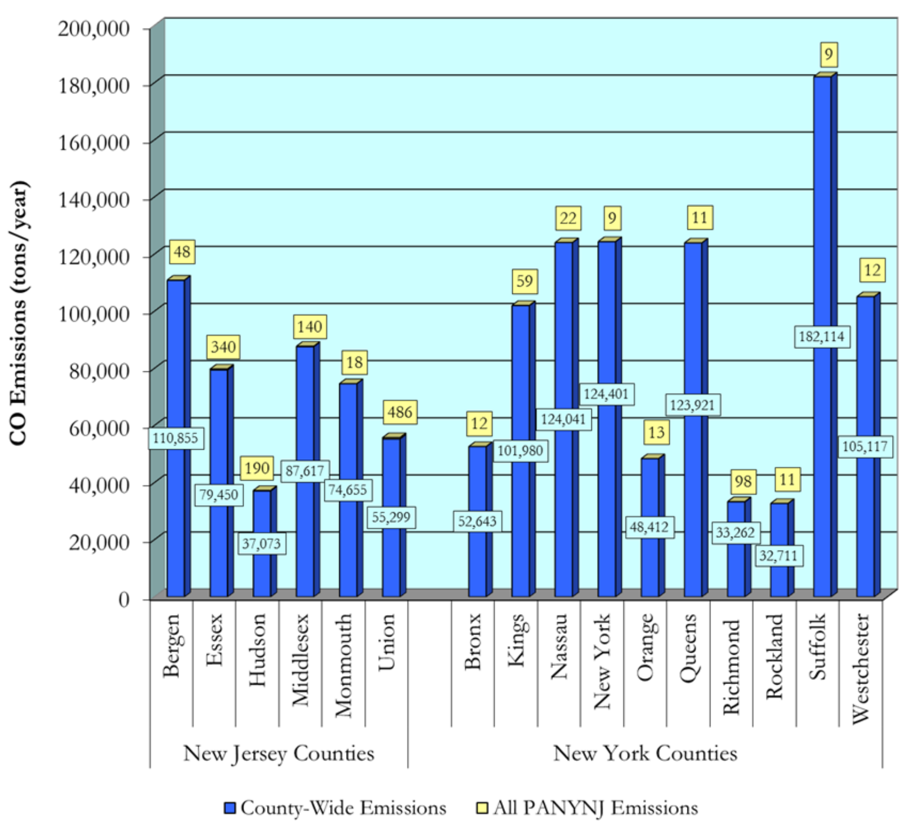


Table 1.12: Comparison of SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	679	0	0.0%
Essex	NJ	2,630	200	7.6%
Hudson	NJ	1,817	114	6.3%
Middlesex	NJ	771	1	0.1%
Monmouth	NJ	671	16	2.4%
Union	NJ	1,053	214	20.3%
New Jersey subtotal		**7,621**	**545**	**7.2%**
Bronx	NY	1,769	0	0.0%
Kings (Brooklyn)	NY	2,021	41	2.0%
Nassau	NY	3,045	0	0.0%
New York	NY	6,776	14	0.2%
Orange	NY	10,728	0	0.0%
Queens	NY	2,932	0	0.0%
Richmond (Staten Island)	NY	383	57	14.8%
Rockland	NY	461	0	0.0%
Suffolk	NY	11,488	0	0.0%
Westchester	NY	2,612	0	0.0%
New York subtotal		**42,215**	**112**	**0.3%**
NYNJLINA and PANYNJ Totals		**49,836**	**657**	**1.3%**

Figure 1.14: Comparison of SO_2 Emissions by County, tpy

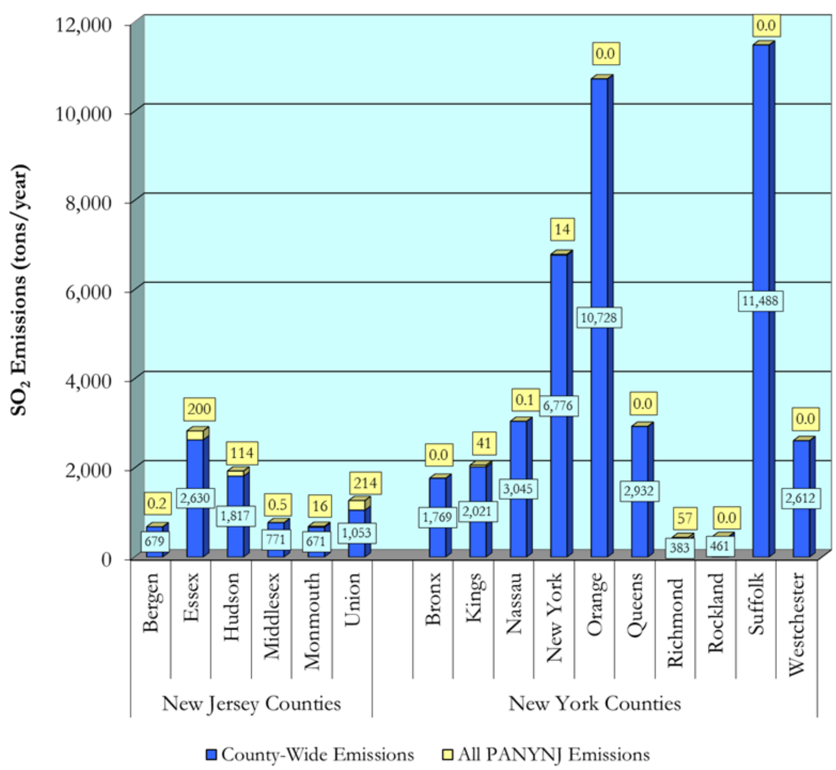
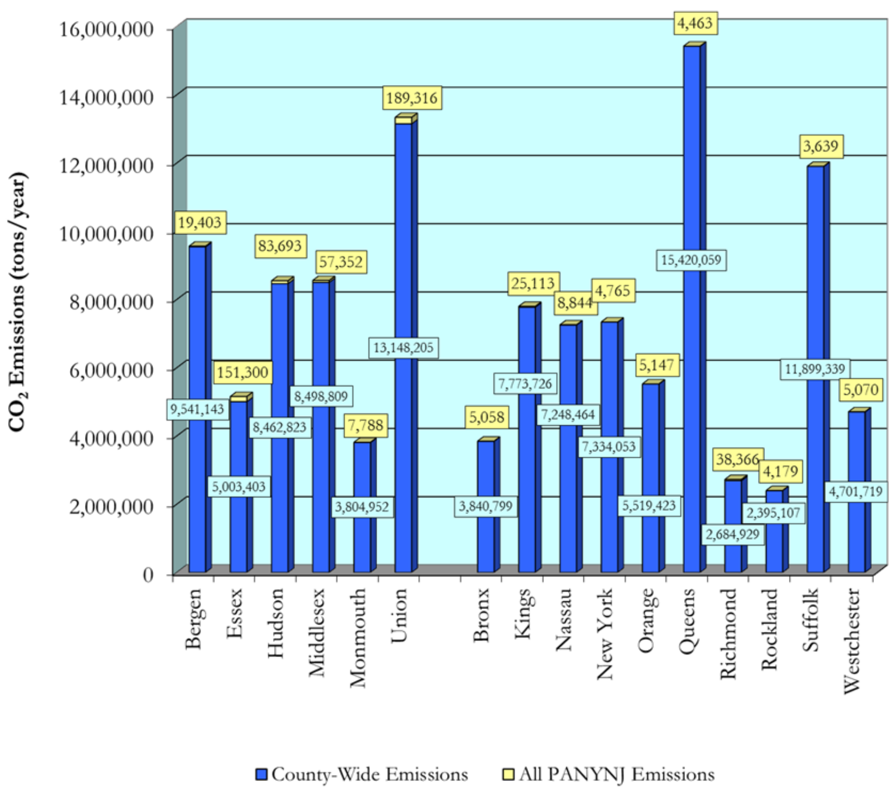


Table 1.13: Comparison of CO_2 Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	9,541,143	19,403	0.2%
Essex	NJ	5,003,403	151,300	3.0%
Hudson	NJ	8,462,823	83,693	1.0%
Middlesex	NJ	8,498,809	57,352	0.7%
Monmouth	NJ	3,804,952	7,788	0.2%
Union	NJ	13,148,205	189,316	1.4%
New Jersey subtotal		**48,459,335**	**508,852**	**1.1%**
Bronx	NY	3,840,799	5,058	0.1%
Kings (Brooklyn)	NY	7,773,726	25,113	0.3%
Nassau	NY	7,248,464	8,844	0.1%
New York	NY	7,334,053	4,765	0.1%
Orange	NY	5,519,423	5,147	0.1%
Queens	NY	15,420,059	4,463	0.0%
Richmond (Staten Island)	NY	2,684,929	38,366	1.4%
Rockland	NY	2,395,107	4,179	0.2%
Suffolk	NY	11,899,339	3,639	0.0%
Westchester	NY	4,701,719	5,070	0.1%
New York subtotal		**68,817,618**	**104,643**	**0.2%**
NYNJLINA and PANYNJ Totals		**117,276,953**	**613,635**	**0.5%**

Figure 1.15: Comparison of CO_2 Emissions by County, tpy



1.5 Comparison of 2013 Emissions with Earlier Emissions Inventories

One purpose of this emissions inventory is to document changes in emissions over time to reflect the effects of increases and decreases in cargo throughput and changes in the emissions characteristics of the various mobile emission sources associated with the port. While cargo throughput changes are market-driven and are beyond the control or influence of the Port Authority, the Port Authority can and does influence the emissions from specific emission sources and emission source categories through the various programs developed and implemented under the Clean Air Strategy. Port Authority tenants and other entities involved with international goods movement also take voluntary actions to reduce their emissions.

To separate the effects of changing cargo throughput, whether higher or lower volumes, from the changes in emissions resulting from the Clean Air Strategy, voluntary actions taken by tenants and others, and normal turnover of engines and equipment, emissions estimated for 2013 and earlier years have been normalized with respect to throughput. That is, emissions have been expressed in terms of mass of emissions per specified unit of throughput, such as tons of emissions per million twenty-foot equivalent units (TEUs). As described in more detail in the 2012 emissions inventory report, adjustments have been made to earlier emission estimates to make them compatible with the 2012 and 2013 estimates to account for changes in emission estimating methodology.

Table 1.14 presents the annual emissions from 2006, 2008, 2010, 2012, and 2013 as published in the respective emissions inventory reports, and as adjusted to be compatible with the 2012 and 2013 estimates. The emissions are expressed as tons per year and as tons per million TEUs, for each adjusted inventory, and the percentage increases or decreases between each prior inventory year and 2013 for both tons per year and tons per million TEUs. This table shows that, while different emissions have either decreased or increased, there has been a general downward trend in emissions in tons per year and tons per million TEUs between 2006 and 2013. The greatest reductions have again been of SO_2, due to continued decreasing levels of sulfur in the fuel used by the various emission source categories, and particulate matter, due to a combination of factors including the Port Authority's truck program that has brought many newer trucks into the fleet of trucks serving the Port's terminals, and lower sulfur fuels. Table 1.14 also lists the TEU throughput from each of the inventory years to illustrate the increases that have taken place. The "as published" TEU numbers include Global Container Terminal TEUs for 2013 and 2012 and for half of 2010, but not for 2008 or 2006. The "with adjustments" TEU figures include the Global Container Terminal TEUs for all inventory years.

Table 1.14: Trends in Emissions over Inventory Years, tons per year and tons per million TEU

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq	Million TEUs
Tons per year, as published								
2013	6,600	403	361	449	1,478	657	613,495	5.467
2012	7,096	501	441	433	1,632	1,735	634,697	5.530
2010	6,894	436	371	362	1,235	2,714	549,158	5.007
2008	7,006	445	379	344	1,306	2,966	542,834	4.711
2006	7,800	537	452	413	1,434	3,597	591,053	4.657
Tons per year, with adjustments								
2013	6,600	403	361	449	1,478	657	613,495	5.467
2012	6,606	497	434	441	1,452	1,735	601,936	5.530
2010	7,169	584	504	440	1,406	2,460	596,731	5.292
2008	8,206	694	599	422	1,615	3,371	648,014	5.265
2006	8,845	778	665	481	1,705	3,973	684,015	5.093
Percent change relative to 2013 - tons per year								
2012 - 2013	0%	-19%	-17%	2%	2%	-62%	2%	-1%
2010 - 2013	-8%	-31%	-28%	2%	5%	-73%	3%	3%
2008 - 2013	-20%	-42%	-40%	6%	-8%	-81%	-5%	4%
2006 - 2013	-25%	-48%	-46%	-7%	-13%	-83%	-10%	7%
Tons per million TEU								
2013	1,207	74	66	82	270	120	112,218	
2012	1,195	90	78	80	263	314	108,849	
2010	1,355	110	95	83	266	465	112,761	
2008	1,559	132	114	80	307	640	123,080	
2006	1,737	153	131	94	335	780	134,305	
Percent change relative to 2012 - tons per million TEU								
2012 - 2013	1%	-18%	-15%	3%	3%	-62%	3%	
2010 - 2013	-11%	-33%	-31%	-1%	2%	-74%	0%	
2008 - 2013	-23%	-44%	-42%	3%	-12%	-81%	-9%	
2006 - 2013	-31%	-52%	-50%	-13%	-19%	-85%	-16%	

SECTION 2: CARGO HANDLING EQUIPMENT

This section presents estimated emissions from the off-road equipment used on Port Authority marine container terminals to handle marine cargo and to support terminal operations. This equipment is known collectively as cargo handling equipment (CHE). The following subsections present estimated CHE emissions in the context of state-wide and NYNJLINA emissions, describe the methodologies used to collect information and estimate emissions, and present a description of the equipment types.

The following six privately operated Port Authority container terminal tenants have been included in the emission estimates:

- Red Hook Container Terminal, LLC at the Brooklyn Port Authority Marine Terminal, along with the secondary barge depot at Port Newark;
- New York Container Terminal (NYCT), at Howland Hook Marine Terminal on Staten Island;
- APM Terminal, at the Elizabeth Port Authority Marine Terminal;
- Maher Terminal, at the Elizabeth Port Authority Marine Terminal;
- Port Newark Container Terminal (PNCT), at Port Newark; and
- Global Marine Terminal at the Port Jersey Port Authority Marine Terminal.

Following an executive summary, the following four subsections focus on:

- 2.1 - Emission Estimates
- 2.2 - Emission Comparisons
- 2.3 - Methodology
- 2.4 - Description of CHE

ES2.1 Executive Summary

Table ES2.1 presents the estimated CHE criteria pollutant and CO_2 equivalent emissions in the context of overall emissions in the states of New York and New Jersey, and in the NYNJLINA, including emissions in tons per year and the percentage that PANYNJ CHE emissions make up of overall NYNJLINA emissions, based on EPA's latest National Emissions Inventory numbers.[14]

Table ES2.1: Comparison of PANYNJ CHE Emissions with State and NYNJLINA Emissions, tpy

Geographical Extent/ Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq
New York and New Jersey	590,117	333,133	120,143	601,318	2,994,198	167,504	229,371,430
NYNJLINA	280,279	76,854	37,170	266,786	1,373,551	49,836	117,276,953
Cargo Handling Equipment	942	63	61	88	371	1.2	140,054
Percent of NYNJLINA Emissions	0.34%	0.08%	0.16%	0.03%	0.03%	0.002%	0.12%

The following figures illustrate the distribution of PANYNJ CHE emissions by type of equipment in terms of tons per year and percent of total CHE emissions, and in the context of overall NYNJLINA emissions. The NYNJLINA emissions are broken down into on-road mobile sources, other (non-road) mobile sources, and stationary and area sources. Note that the percentages shown in these charts do not always sum to 100% because of rounding. The charts are intended to illustrate the relative magnitude of emission sources at the port and in the region.

[14] Criteria pollutant emissions are from the 2011 National Emissions Inventory:
(*http://www.epa.gov/ttn/chief/net/2011inventory.html*)
Greenhouse gas emissions are from the 2011 and 2008 National Emissions Inventories, with stationary and area sources coming from the 2008 Inventory because they are not provided by the 2011 Inventory.
(*http://www.epa.gov/ttn/chief/net/2008inventory.html)*

Figure ES2.1: Distribution and Comparison of NO_x from CHE, tpy and percent

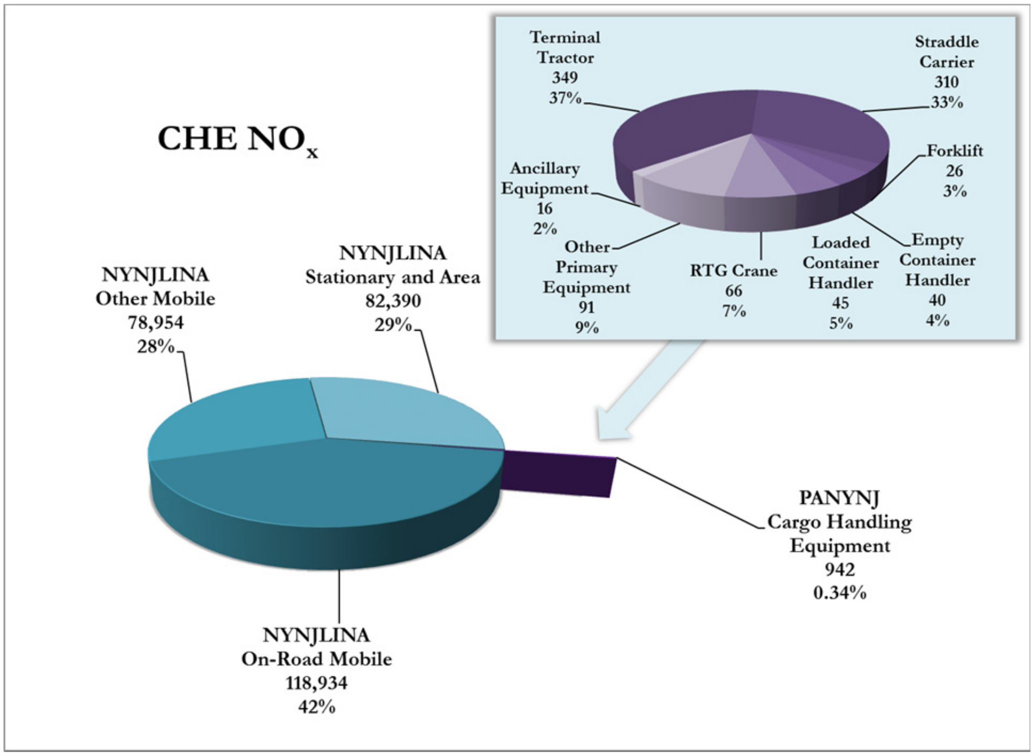


Figure ES2.2: Distribution and Comparison of PM_{10} from CHE, tpy and percent

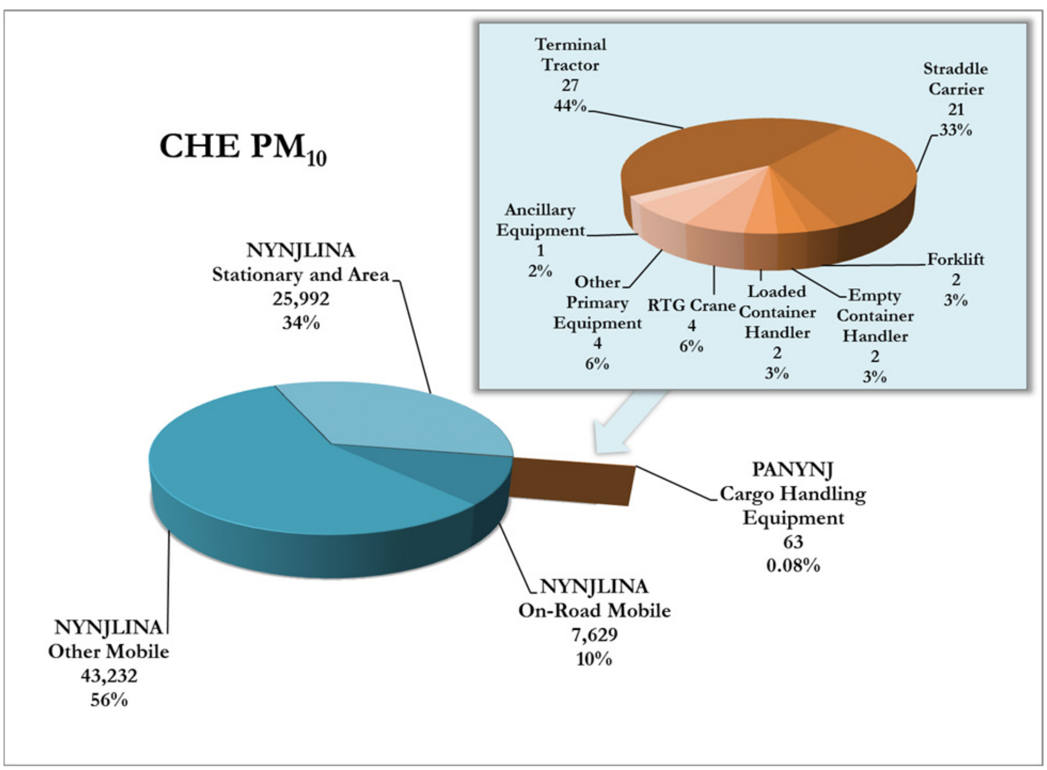


Figure ES2.3: Distribution and Comparison of $PM_{2.5}$ from CHE, tpy and percent

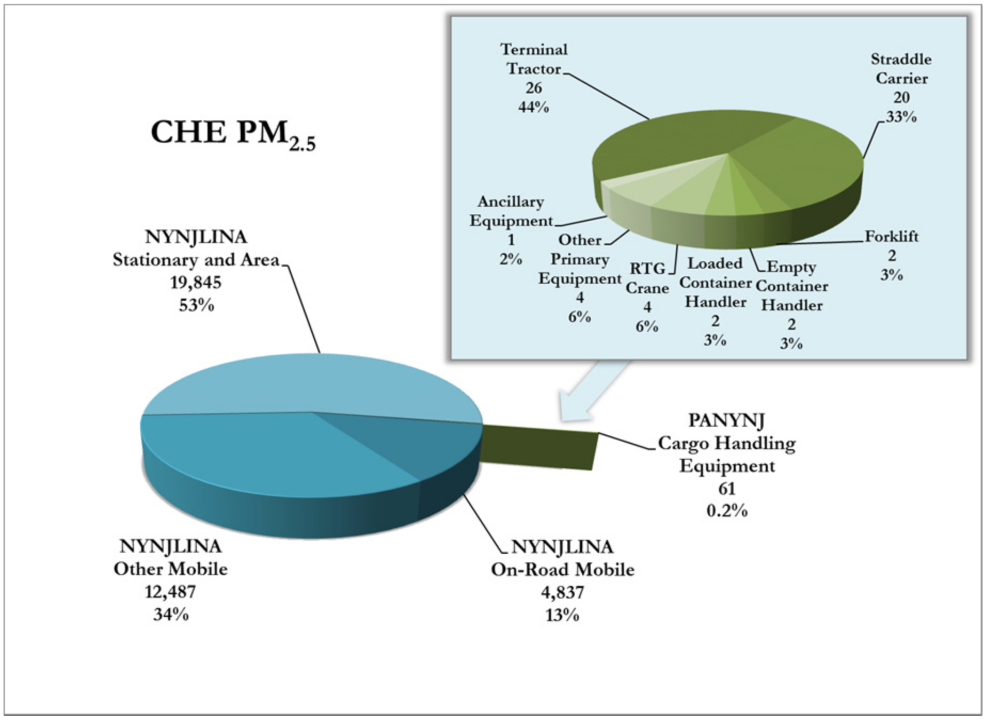


Figure ES2.4: Distribution and Comparison of VOC from CHE, tpy and percent

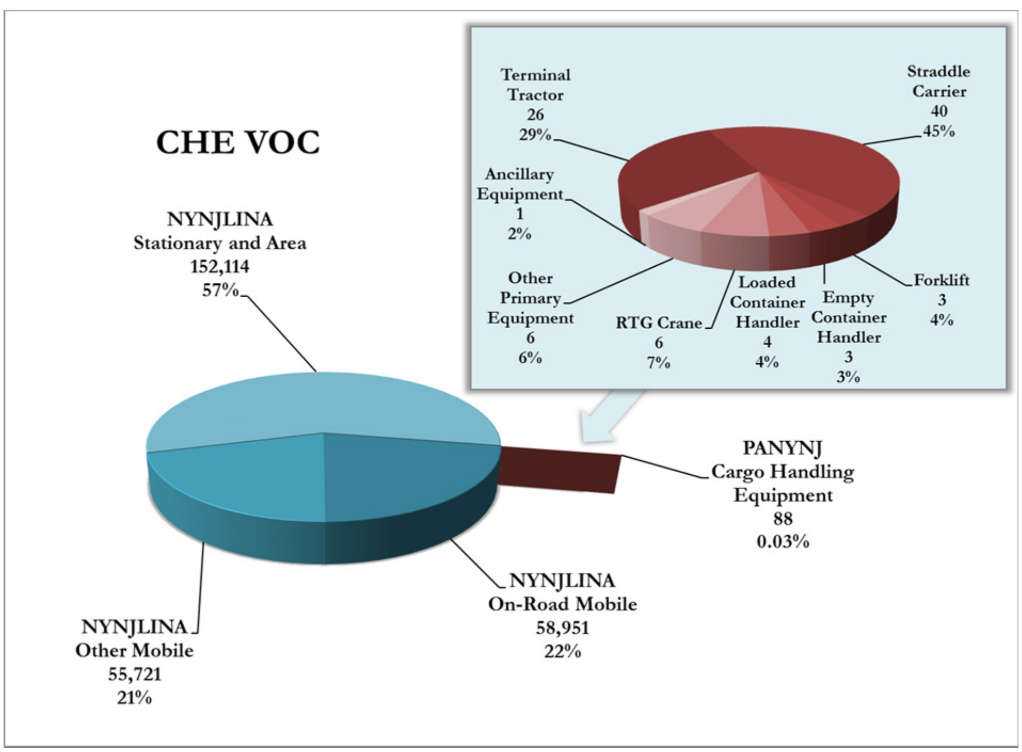


Figure ES2.5: Distribution and Comparison of CO from CHE, tpy and percent

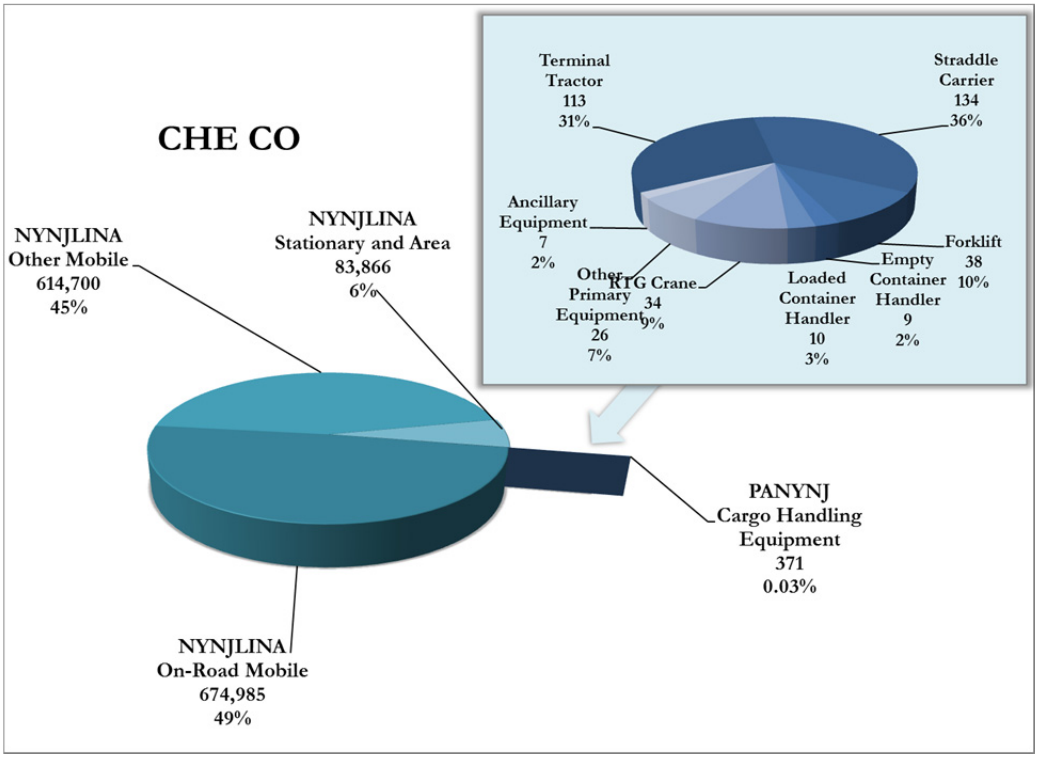


Figure ES2.6: Distribution and Comparison of SO_2 from CHE, tpy and percent

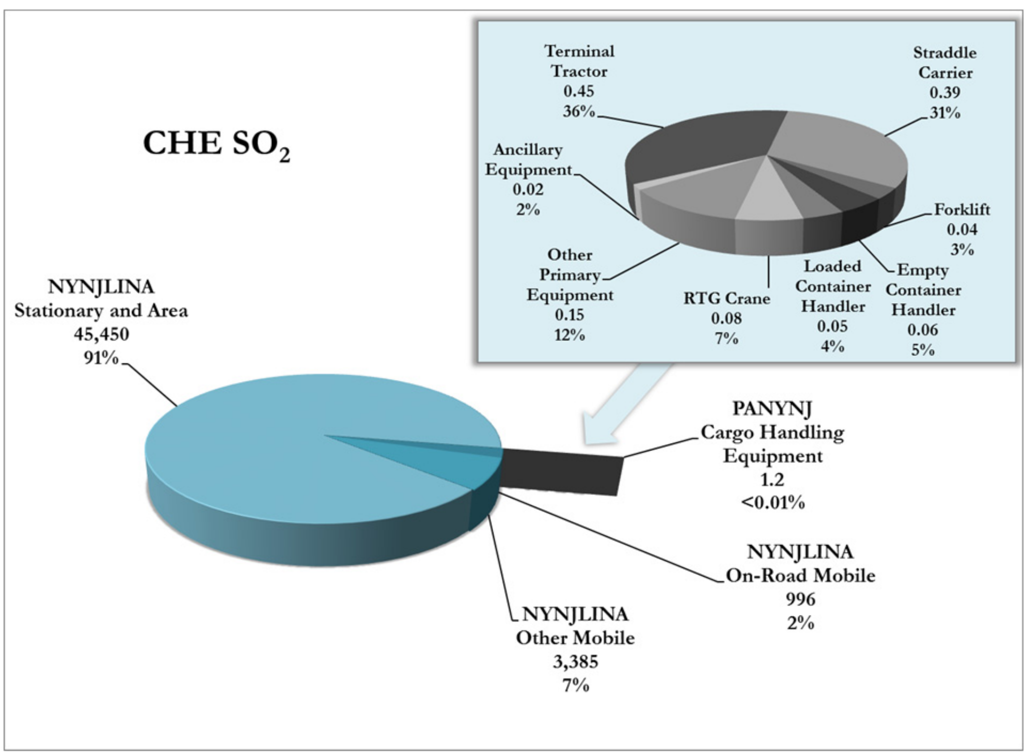
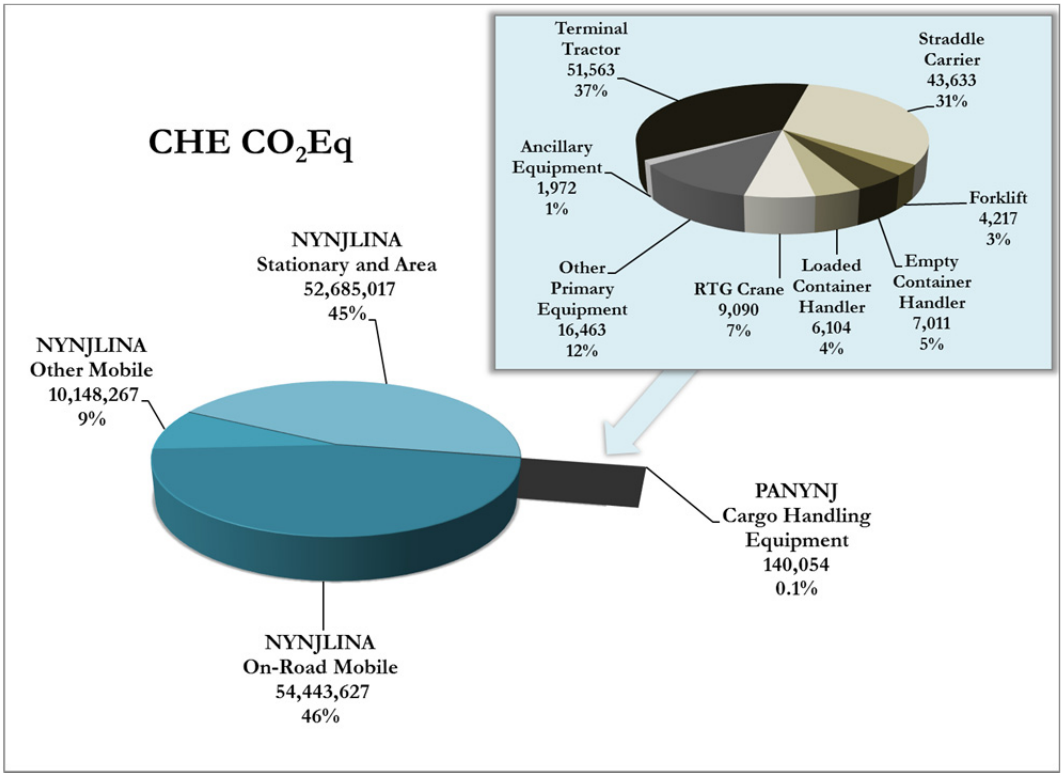


Figure ES2.7: Distribution of CO_2 equivalents from CHE, tpy and percent



2.1 Emission Estimates

This subsection presents the estimated emissions from cargo handling equipment operating at the terminals listed above. Table 2.1 presents criteria pollutant emissions of NO_x, PM_{10}, $PM_{2.5}$, VOCs, CO, and SO_2 sorted by equipment type for all container terminals combined. The equipment types are described later in this section. Estimated greenhouse gas emissions of CO_2, N_2O, and CH_4 are presented in Table 2.2. Figure 2.1 illustrates the distribution of NO_x emissions from the various equipment types. Because of the similarities in engine and fuel types among these equipment types, the distributions of other pollutants show substantially the same patterns – therefore charts have not been presented for the other criteria pollutants. Figure 2.2 illustrates the distribution of greenhouse gases as CO_2 equivalents.

The emission estimates presented in this document are listed in several ways to provide as much information to the reader as possible. The emissions are presented by terminal type, by type of activity, and by county and state. Because of these different modes of display, the numerical values must be rounded, displayed, and summed in different ways. Because of this, it is not always possible to display values in a table that sum exactly to the total shown at the bottom of the table. In developing the tables, priority has been given to maintaining consistent totals for each pollutant across table types.

Table 2.1: Criteria Pollutant Emissions from CHE by Equipment Type, tpy

Equipment Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Terminal Tractor	349	27.2	26.4	25.7	113	0.45
Straddle Carrier	310	20.8	20.2	39.5	134	0.39
Forklift	26	1.9	1.8	3.3	38	0.04
Empty Container Handler	40	1.7	1.7	3.0	9	0.06
Loaded Container Handler	45	1.9	1.9	4	10	0.05
Rubber Tired Gantry Crane	66	3.6	3.5	5.9	34	0.08
Other Primary Equipment	91	4.0	3.9	5.8	26	0.15
Ancillary Equipment	16	1.4	1.3	1.4	7	0.02
Totals	**942**	**63**	**61**	**88**	**371**	**1.2**

Figure 2.1: Emissions of NO_x from CHE by Equipment Type, tpy and percent

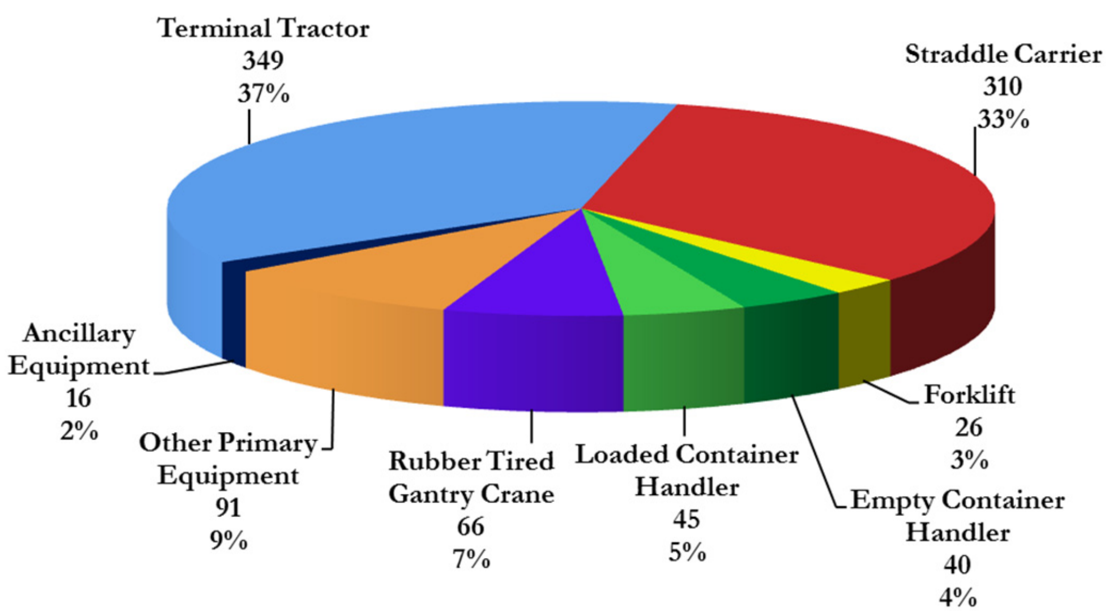
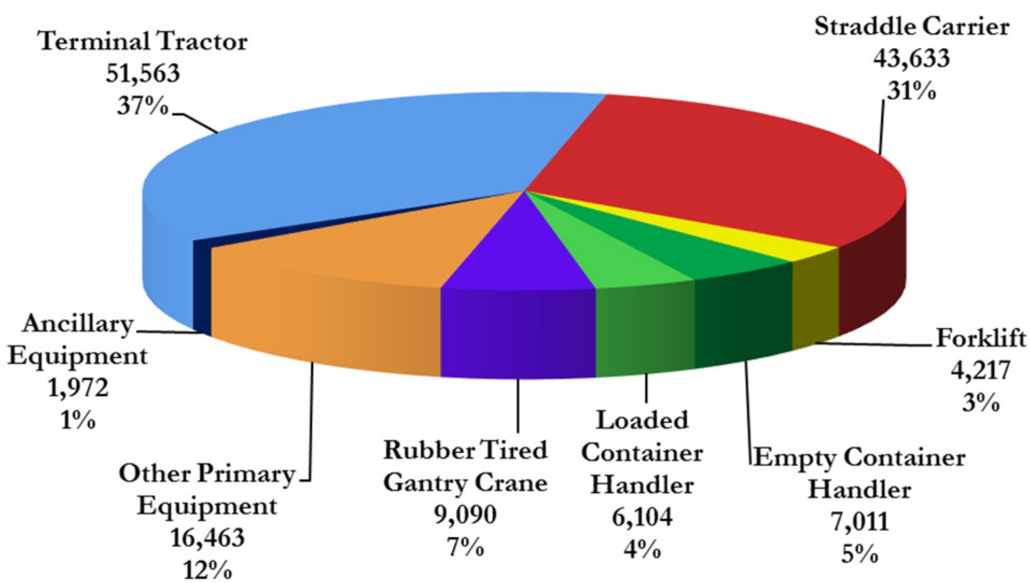


Table 2.2: GHG Emissions from CHE by Equipment Type, tpy

Equipment Type	CO_2	N_2O	CH_4	CO_2Eq
Terminal Tractor	51,104	1.3	2.9	51,563
Straddle Carrier	43,244	1.1	2.4	43,633
Forklift	4,175	0.1	0.3	4,217
Empty Container Handler	6,949	0.2	0.4	7,011
Loaded Container Handler	6,050	0.2	0.3	6,104
Rubber Tired Gantry Crane	9,009	0.2	0.5	9,090
Other Primary Equipment	16,316	0.4	0.9	16,463
Ancillary Equipment	1,955	0.0	0.1	1,972
Totals	**138,800**	**3.5**	**7.8**	**140,054**

Figure 2.2: Emissions of CO_2 Equivalent from CHE by Equipment Type, tpy and percent



2.2 Cargo Handling Equipment Emission Comparisons

This subsection presents Port Authority marine terminal cargo handling equipment emissions in the context of countywide and non-attainment area-wide emissions. Overall county-level emissions were excerpted from the most recent National Emissions Inventory databases.[15] This subsection also presents a comparison of 2013 cargo handling equipment emissions with the results of earlier emissions inventories, with the addition of estimated emissions from cargo handling equipment operating at the Global Container Terminal during those earlier years, as discussed in the Introduction.

2.2.1 Comparisons with County and Regional Emissions

Table 2.3 summarizes criteria pollutant and CO_2 emissions from cargo handling equipment operating at Port Authority marine terminals, broken down by county and state. Immediately following Table 2.3, there are a series of tables and figures (Tables 2.4 – 2.10 and Figures 2.3 – 2.9) that present criteria pollutant emissions from Port Authority marine terminal CHE related activity within each respective county in the NYNJLINA (as described in Section 1). In the figures, each column displays the countywide emissions and the Port Authority marine terminal CHE contribution to total emissions is shown above the countywide column.

Table 2.3: Summary of CHE Criteria Pollutant Emissions by County within the NYNJLINA, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq
Bergen	NJ	0.0	0.0	0.0	0.0	0.0	0.00	0
Essex	NJ	98.5	4.1	4.0	8.8	42.8	0.16	20,234
Hudson	NJ	87.3	5.2	5.1	7.3	32.0	0.13	14,580
Middlesex	NJ	0.0	0.0	0.0	0.0	0.0	0.00	0
Monmouth	NJ	0.0	0.0	0.0	0.0	0.0	0.00	0
Union	NJ	623	43.4	42.1	61.8	234.3	0.76	83,613
New Jersey subtotal		**808**	**53**	**51**	**78**	**309**	**1.0**	**118,427**
Bronx	NY	0.0	0.0	0.0	0.0	0.0	0.00	0
Kings (Brooklyn)	NY	28.6	2.0	1.9	2.2	9.7	0.03	3,440
Nassau	NY	0.0	0.0	0.0	0.0	0.0	0.00	0
New York	NY	0.0	0.0	0.0	0.0	0.0	0.00	0
Orange	NY	0.0	0.0	0.0	0.0	0.0	0.00	0
Queens	NY	0.0	0.0	0.0	0.0	0.0	0.00	0
Richmond (Staten Island)	NY	105	8.0	7.8	8.0	50.8	0.16	18,186
Rockland	NY	0.0	0.0	0.0	0.0	0.0	0.00	0
Suffolk	NY	0.0	0.0	0.0	0.0	0.0	0.00	0
Westchester	NY	0.0	0.0	0.0	0.0	0.0	0.00	0
New York subtotal		**134**	**10**	**10**	**10**	**61**	**0.2**	**21,626**
TOTAL		**942**	**63**	**61**	**88**	**371**	**1.2**	**140,054**

[15] 2011 and 2008 National Emission Inventory Databases, US EPA, as cited above.

Table 2.4: Comparison of CHE NO_x Emissions with Overall NO_x Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	14,798	0	0.0%
Essex	NJ	17,195	99	0.6%
Hudson	NJ	9,585	87	0.9%
Middlesex	NJ	14,766	0	0.0%
Monmouth	NJ	10,366	0	0.0%
Union	NJ	12,325	623	5.1%
New Jersey Subtotal		**79,035**	**808**	**1.0%**
Bronx	NY	13,195	0	0.0%
Kings (Brooklyn)	NY	25,190	29	0.1%
Nassau	NY	21,973	0	0.0%
New York	NY	33,432	0	0.0%
Orange	NY	11,854	0	0.0%
Queens	NY	31,678	0	0.0%
Richmond (Staten Island	NY	10,793	105	1.0%
Rockland	NY	5,622	0	0.0%
Suffolk	NY	30,558	0	0.0%
Westchester	NY	16,949	0	0.0%
New York Subtotal		**201,244**	**134**	**0.1%**
TOTAL		**280,279**	**942**	**0.3%**

Figure 2.3: Comparison of CHE NO_x Emissions with Overall NO_x Emissions by County, tpy

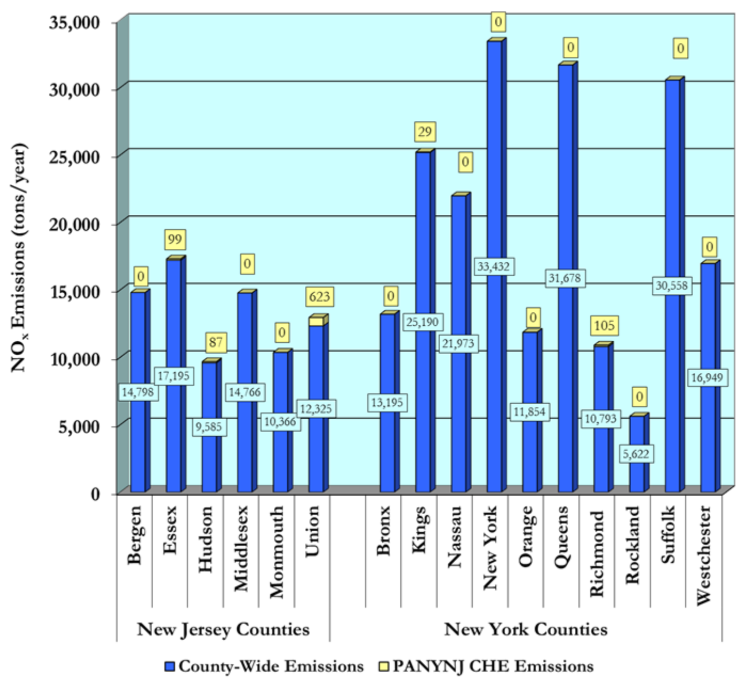


Table 2.5: Comparison of CHE PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	3,565	0.0	0.0%
Essex	NJ	5,233	4.1	0.1%
Hudson	NJ	1,732	5.2	0.3%
Middlesex	NJ	4,288	0.0	0.0%
Monmouth	NJ	3,334	0.0	0.0%
Union	NJ	2,787	43.4	1.6%
New Jersey Subtotal		**20,939**	**53**	**0.3%**
Bronx	NY	2,605	0.0	0.0%
Kings (Brooklyn)	NY	4,779	2.0	0.0%
Nassau	NY	5,840	0.0	0.0%
New York	NY	6,363	0.0	0.0%
Orange	NY	7,595	0.0	0.0%
Queens	NY	5,244	0.0	0.0%
Richmond (Staten Islanc	NY	1,885	8.0	0.4%
Rockland	NY	1,993	0.0	0.0%
Suffolk	NY	12,931	0.0	0.0%
Westchester	NY	6,680	0.0	0.0%
New York Subtotal		**55,915**	**10**	**0.02%**
TOTAL		**76,854**	**63**	**0.1%**

Figure 2.4: Comparison of CHE PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

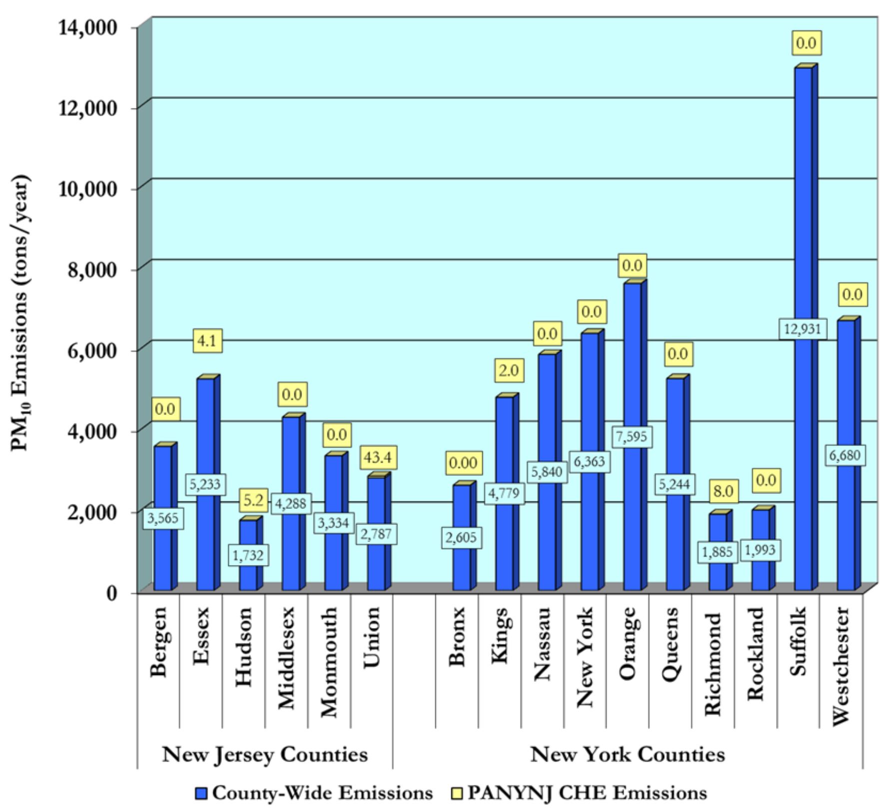


Table 2.6: Comparison of CHE $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	2,101	0.0	0.0%
Essex	NJ	2,574	4.0	0.2%
Hudson	NJ	1,284	5.1	0.4%
Middlesex	NJ	2,335	0.0	0.0%
Monmouth	NJ	1,737	0.0	0.0%
Union	NJ	1,877	42.1	2.2%
New Jersey Subtotal		**11,908**	**51**	**0.4%**
Bronx	NY	1,474	0.0	0.0%
Kings (Brooklyn)	NY	2,693	1.9	0.1%
Nassau	NY	2,740	0.0	0.0%
New York	NY	3,199	0.0	0.0%
Orange	NY	2,462	0.0	0.0%
Queens	NY	3,030	0.0	0.0%
Richmond (Staten Island)	NY	1,090	7.8	0.7%
Rockland	NY	801	0.0	0.0%
Suffolk	NY	5,117	0.0	0.0%
Westchester	NY	2,656	0.0	0.0%
New York Subtotal		**25,262**	**10**	**0.04%**
TOTAL		**37,170**	**61**	**0.16%**

Figure 2.5: Comparison of CHE $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

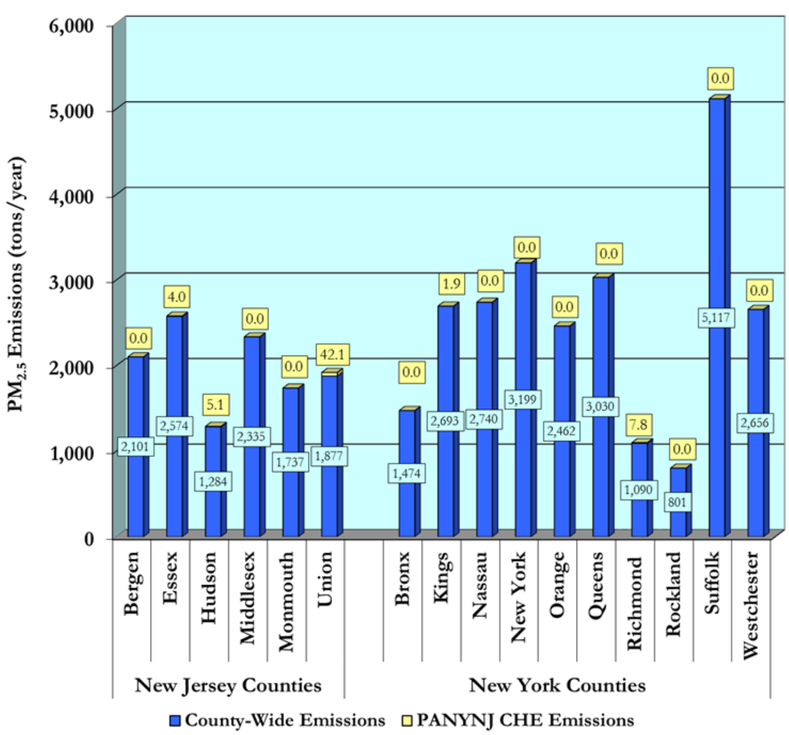


Table 2.7: Comparison of CHE VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	17,028	0.0	0.0%
Essex	NJ	16,814	8.8	0.1%
Hudson	NJ	9,244	7.3	0.1%
Middlesex	NJ	16,653	0.0	0.0%
Monmouth	NJ	12,551	0.0	0.0%
Union	NJ	11,037	61.8	0.6%
New Jersey Subtotal		**83,327**	**78**	**0.1%**
Bronx	NY	14,156	0.0	0.0%
Kings (Brooklyn)	NY	26,367	2.2	0.01%
Nassau	NY	21,541	0.0	0.0%
New York	NY	21,185	0.0	0.0%
Orange	NY	9,654	0.0	0.0%
Queens	NY	27,358	0.0	0.0%
Richmond (Staten Island)	NY	6,576	8.0	0.1%
Rockland	NY	5,701	0.0	0.0%
Suffolk	NY	33,256	0.0	0.0%
Westchester	NY	17,665	0.0	0.0%
New York Subtotal		**183,459**	**10**	**0.006%**
TOTAL		**266,786**	**88**	**0.03%**

Figure 2.6: Comparison of CHE VOC Emissions with Overall VOC Emissions by County, tpy

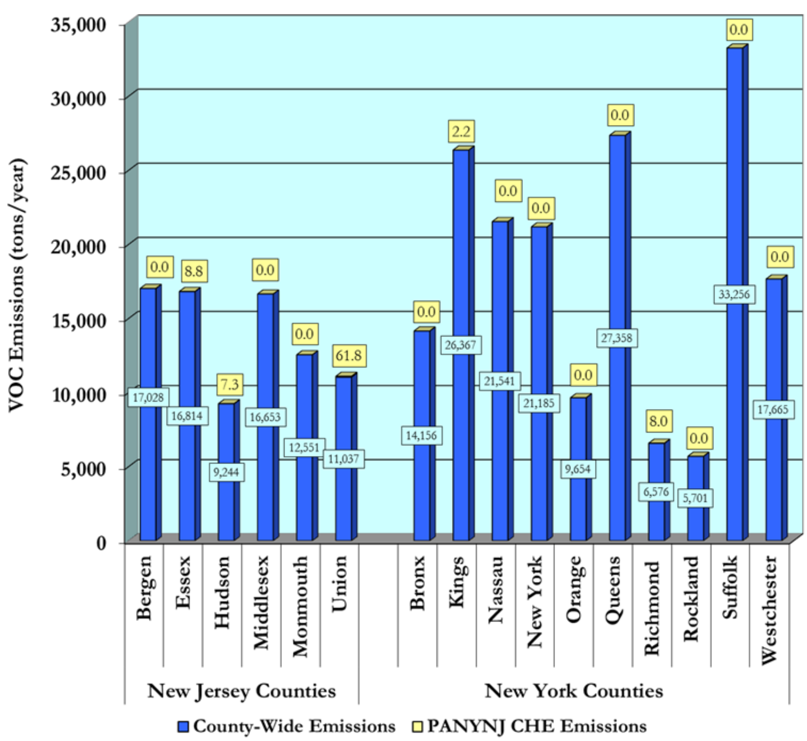


Table 2.8: Comparison of CHE CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	110,855	0.0	0.0%
Essex	NJ	79,450	42.8	0.1%
Hudson	NJ	37,073	32.0	0.1%
Middlesex	NJ	87,617	0.0	0.0%
Monmouth	NJ	74,655	0.0	0.0%
Union	NJ	55,299	234.3	0.4%
New Jersey Subtotal		**444,949**	**309**	**0.1%**
Bronx	NY	52,643	0.0	0.0%
Kings (Brooklyn)	NY	101,980	9.7	0.0%
Nassau	NY	124,041	0.0	0.0%
New York	NY	124,401	0.0	0.0%
Orange	NY	48,412	0.0	0.0%
Queens	NY	123,921	0.0	0.0%
Richmond (Staten Island	NY	33,262	50.8	0.2%
Rockland	NY	32,711	0.0	0.0%
Suffolk	NY	182,114	0.0	0.0%
Westchester	NY	105,117	0.0	0.0%
New York Subtotal		**928,602**	**61**	**0.01%**
TOTAL		**1,373,551**	**371**	**0.03%**

Figure 2.7: Comparison of CHE CO Emissions with Overall CO Emissions by County, tpy

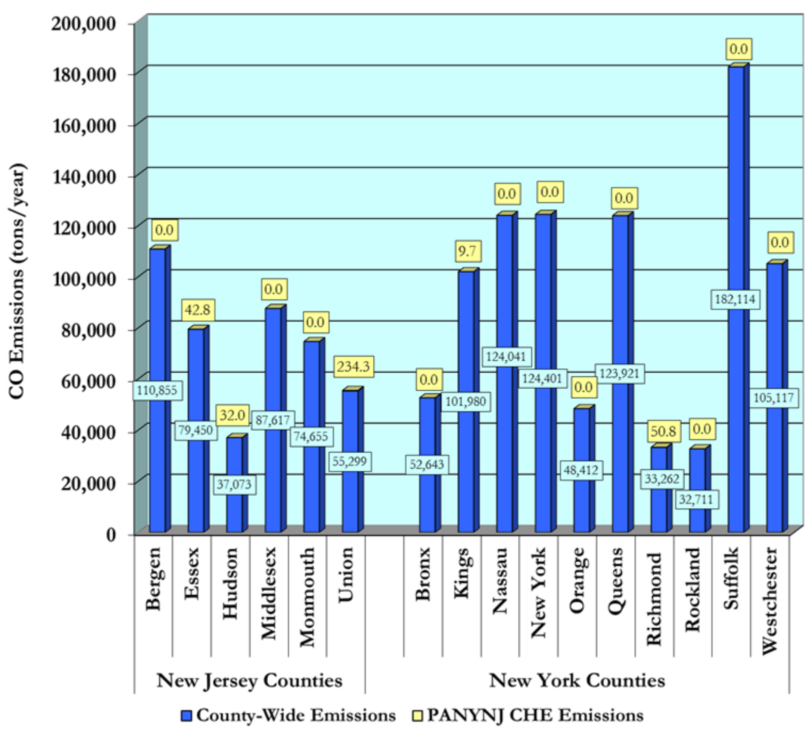


Table 2.9: Comparison of CHE SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	679	0.0	0.000%
Essex	NJ	2,630	0.2	0.006%
Hudson	NJ	1,817	0.1	0.007%
Middlesex	NJ	771	0.0	0.000%
Monmouth	NJ	671	0.0	0.000%
Union	NJ	1,053	0.8	0.072%
New Jersey Subtotal		**7,621**	**1.0**	**0.014%**
Bronx	NY	1,769	0.0	0.000%
Kings (Brooklyn)	NY	2,021	0.0	0.001%
Nassau	NY	3,045	0.0	0.000%
New York	NY	6,776	0.0	0.000%
Orange	NY	10,728	0.0	0.000%
Queens	NY	2,932	0.0	0.000%
Richmond (Staten Island)	NY	383	0.2	0.042%
Rockland	NY	461	0.0	0.000%
Suffolk	NY	11,488	0.0	0.000%
Westchester	NY	2,612	0.0	0.000%
New York Subtotal		**42,215**	**0.2**	**0.000%**
TOTAL		**49,836**	**1.2**	**0.002%**

Figure 2.8: Comparison of CHE SO_2 Emissions with Overall SO_2 Emissions by County, tpy

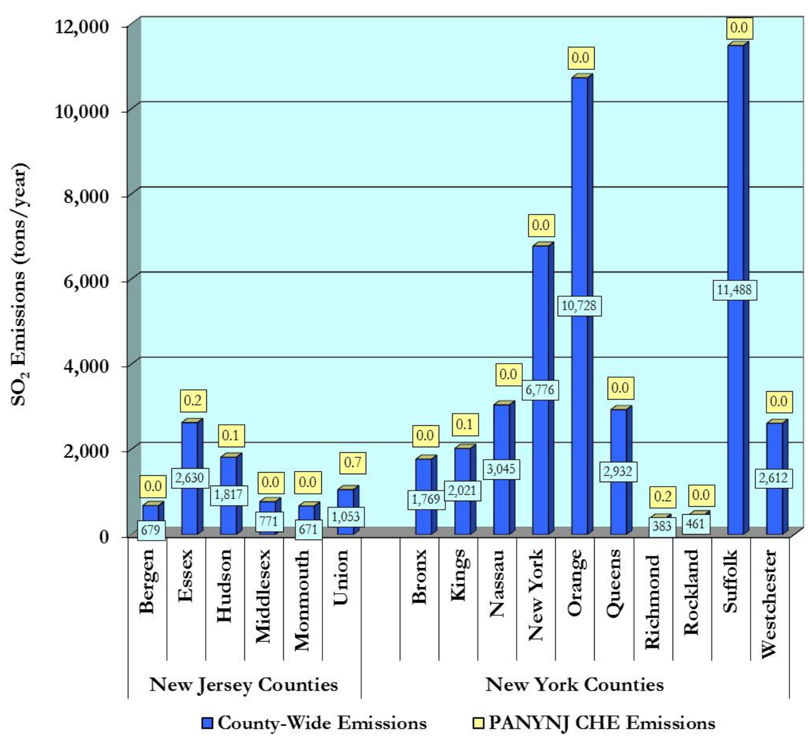
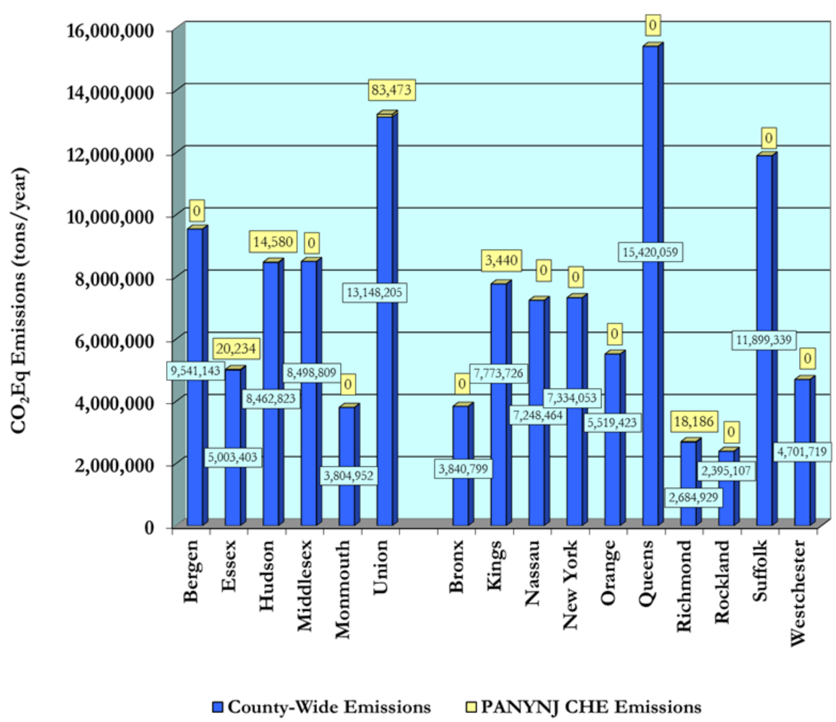


Table 2.10: Comparison of CHE CO_2 Emissions with Overall CO_2 Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	9,541,143	0	0.00%
Essex	NJ	5,003,403	20,234	0.40%
Hudson	NJ	8,462,823	14,580	0.17%
Middlesex	NJ	8,498,809	0	0.00%
Monmouth	NJ	3,804,952	0	0.00%
Union	NJ	13,148,205	83,613	0.64%
New Jersey Subtotal		**48,459,335**	**118,427**	**0.24%**
Bronx	NY	3,840,799	0	0.00%
Kings (Brooklyn)	NY	7,773,726	3,440	0.04%
Nassau	NY	7,248,464	0	0.00%
New York	NY	7,334,053	0	0.00%
Orange	NY	5,519,423	0	0.00%
Queens	NY	15,420,059	0	0.00%
Richmond (Staten Islar	NY	2,684,929	18,186	0.68%
Rockland	NY	2,395,107	0	0.00%
Suffolk	NY	11,899,339	0	0.00%
Westchester	NY	4,701,719	0	0.00%
New York Subtotal		**68,817,618**	**21,626**	**0.03%**
TOTAL		**117,276,953**	**140,054**	**0.12%**

Figure 2.9: Comparison of CHE CO_2 Emissions with Overall CO_2 Emissions by County, tpy



2.2.2 Comparisons with Prior Year Emission Estimates

Overall emissions from cargo handling equipment changed over the years between 2006 and 2013 due to factors such as fleet turnover to newer equipment and increased or decreased utilization of equipment in response to higher or lower terminal throughput. Another factor that influenced total Port Authority emissions from cargo handling equipment was the acquisition of the Global Container Terminal midway through 2010, which increased the amount of equipment attributed to the Port Authority in the port-wide emissions inventories. Table 2.11 presents the annual cargo handling equipment emissions as estimated in the respective emissions inventories, the emissions for each year as adjusted with the addition of the new terminal and for emissions modeling changes, the percentage difference between each prior inventory's adjusted emissions and the 2013 estimates, emissions in tons per million TEUs, and the percentage differences in tons per million TEUs between the prior years and 2013.

Table 2.11: Comparison of 2013 CHE Emissions with Adjusted Prior Year Estimates, tons per year and percent

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq	Million TEUs
Tons per year, as published								
2013	942	63	61	88	371	1.2	139,913	5.467
2012	1,251	79	77	102	406	1.2	133,317	5.530
2010	1,109	67	65	94	380	1.1	123,847	5.007
2008	1,048	66	64	89	355	17	115,014	4.711
2006	1,402	93	86	124	465	219	143,542	4.657
Tons per year, with adjustments								
2013	942	63	61	88	371	1.2	139,913	5.467
2012	983	66	64	89	380	1.2	133,358	5.530
2010	1,155	69	67	98	395	1.2	129,539	5.292
2008	1,162	73	71	99	392	19	128,121	5.265
2006	1,503	100	92	132	495	233	154,184	5.093
Percent change relative to 2013 - tons per year								
2012 - 2013	-4%	-5%	-5%	-1%	-2%	0%	5%	-1%
2010 - 2013	-18%	-9%	-9%	-10%	-6%	0%	8%	3%
2008 - 2013	-19%	-14%	-14%	-11%	-5%	-94%	9%	4%
2006 - 2013	-37%	-37%	-34%	-33%	-25%	-99%	-9%	7%
Tons per million TEU								
2013	172	11	11	16	68	0.2	25,592	
2012	178	12	12	16	69	0.2	24,115	
2010	218	13	13	19	75	0.2	24,478	
2008	221	14	13	19	74	4.0	24,334	
2006	295	20	18	26	97	46	30,274	
Percent change relative to 2013 - tons per million TEU								
2012 - 2013	-3%	-8%	-8%	0%	-1%	0%	6%	
2010 - 2013	-21%	-15%	-15%	-16%	-9%	0%	5%	
2008 - 2013	-22%	-21%	-15%	-16%	-8%	-95%	5%	
2006 - 2013	-42%	-45%	-39%	-38%	-30%	-100%	-15%	

2.3 Methodology

This subsection describes the methods used to collect information and estimate emissions from cargo handling equipment.

2.3.1 Data Collection

Data was collected through queries to the terminal operators requesting updates to the information they had provided for the previous emissions inventories. As in the previous inventories, most container terminal operators provided average activity levels for types of equipment as opposed to reporting specific engine hour data. Thus, in many cases, various pieces of equipment were noted to have the same operating hours. This is not unusual for CHE emissions inventories as many operators do not record operating hours for individual pieces of equipment.

Equipment lists were derived from information maintained by the container terminal operators. Data custody was maintained by a single point of contact outside the Port Authority to allay confidentiality concerns.

2.3.2 Emission Estimating Model

Emissions were estimated using the MOVES2014 emission estimating model.[16] The MOVES2014 model newly incorporates the functions of the NONROAD2008 model that was the standard emissions estimating model for non-road equipment for many years. These models have been designed to accommodate a wide range of off-road equipment types and recognize a defined list of equipment designations. To prepare for model input, the container terminal equipment was stratified into equipment types recognized by the model. For example, a "sweeper" corresponds directly to a single line item for the model, but container handling equipment described by various names by the terminals were grouped together; for example, straddle carriers, empty container handlers and top loaders were categorized under the modeling category "other industrial equipment" because the model does not include a more specific category for these equipment types.

The marine terminal equipment identified by survey was categorized into the most closely corresponding MOVES2014 equipment type, as illustrated in Table 2.12, which presents equipment types by Source Classification Code (SCC), load factor, and MOVES2014 category common name. The earlier categorizations were replicated for purposes of this inventory as much as possible. Table 2.13 then lists the population of equipment identified at port facilities, listed by common name and SCC code.

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

For each calendar year, the model produces emissions factors in grams/ hp-hr for each of the MOVES2014 equipment types by horse power groups and model year. The model year groups are aligned with EPA's nonroad equipment emissions standards. The PANYNJ estimates of CHE emissions from each piece of equipment is based on its model year, horsepower rating, annual hours of operation, and equipment-specific load factor assumptions – summaries of these estimates are presented in the following subsection. A horsepower-hour (hp-hr) represents one horsepower operating for one hour. A 100-horsepower engine operating at its rated 100-horsepower capacity for one hour expends 100-hp-hrs. From this, it is easy to see why horsepower and hours of operation are important components of the emissions inventory data.

Table 2.12: MOVES/NONROAD Engine Source Categories

Equipment Type	SCC	Load Factor	NONROAD Category
Portable light set	2270002027	0.43	Signal board / light plant
Wharf crane	2270002045	0.43	Crane
Non-road vehicle	2270002051	0.59	Off-road truck
Front end loader	2270002060	0.59	Front end loader
Aerial platform	2270003010	0.21	Aerial lift
Diesel Forklift	2270003020	0.59	Forklift
Propane Forklift	226700302	0.30	LPG Forklift
Sweeper	2270003030	0.43	Sweeper / scrubber
Chassis rotator Container top loader Empty container handler	2270003040	0.43	Other industrial equipment
Rubber tired gantry crane Straddle carrier	2270003050	0.21	Other material handling equipment
Terminal tractor	2270003070	0.59	Terminal tractor

Table 2.13: MOVES/NONROAD Equipment Category Population List

NONROAD Category	Source Category Code	2006 Count	2008 Count	2010 Count	2012 Count	2013 Count
Aerial lift	2270003010	11	11	10	11	11
Crane	2270002045	13	7	12	4	4
Diesel forklift	2270003020	0	8	21	105	114
Propane forklift	2267003020	87	108	93	83	83
Front end loader	2270002060	13	7	4	4	0
Other industrial equipment	2270003040	130	143	147	187	186
Other material handling equipment	2270003050	260	293	297	303	307
Offroad truck	2270002051	9	12	5	6	6
Signal board / light plant	2270002027	12	12	12	12	12
Skid-steer Loader	2270002072	0	0	0	0	2
Sweeper / scrubber	2270003030	2	9	9	9	9
Terminal tractor	2270003070	350	403	442	465	446
Totals		**887**	**1,013**	**1,052**	**1,189**	**1,180**

The general form of the equation for estimating CHE emissions is:

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

Where:
E = emissions, grams or tons/year
Power = rated power of the engine, hp or kW
Activity = equipment's engine activity, hr/year
LF = load factor (ratio of average load used during normal operations as compared to full load at maximum rated horsepower, it is an estimate of the average percentage of an engine's rated power output that is required to perform its operating tasks), dimensionless
EF = emission factor, grams of pollutant per unit of work, g/hp-hr or g/kW-hr
FCF = fuel correction factor to reflect changes in fuel properties that have occurred over time on emissions, dimensionless
CF = control factor to reflect changes in emissions due to installation of emission reduction technologies not originally reflected in the emission factors.

The MOVES2014 model contains a load factor for each source category as listed in Table 2.12. The model was run with default condition to obtain emission factors in gm/hp-hr. For calendar year 2013, the default sulfur content used in the model is 32 ppm[17]. Since ULSD fuel with S content of 15 ppm was used for CHE operated at the PANYNJ terminals, PM_{10}, $PM_{2.5}$, DPM and SO_2 emission factors outputted from MOVES2014 were adjusted for lower S content. A control factor was applied to equipment identified as being equipped with on-road engines. Ambient temperatures do not affect diesel exhaust emissions; therefore, they were estimated as ranging from approximately 24 to 86 degrees Fahrenheit.

2.4 Description of Cargo Handling Equipment

The equipment inventoried for the container terminals was limited to landside equipment greater than 25 horsepower (hp) and not designed for highway use. While the equipment is generally termed "cargo handling equipment," the equipment used at these terminals can be separated into primary cargo handling equipment, used directly in handling cargo, and ancillary equipment, which has uses other than directly moving cargo (such as sweepers and fuel trucks).

Table 2.14 summarizes the 2013 fleet characteristics of primary and ancillary non-road equipment, respectively, in terms of equipment count, and averages of model year, horsepower, and annual operating hours. The averages presented are arithmetic means and are included here for comparison. As noted above, emissions were estimated using equipment-specific values for each piece of equipment.

Figures 2.10 and 2.11 illustrate the population distribution of the CHE by equipment type. Equipment is categorized as primary and ancillary equipment. Primary equipment is used directly in the handling of cargo – examples include yard tractors, which move shipping containers around the marine terminals, and top loaders, which lift containers onto stacks for temporary storage. Ancillary equipment refers to equipment not directly used to move cargo but otherwise used to support terminal operations; examples include refueling trucks and yard sweepers. As a group, ancillary equipment makes up 4% of the total equipment population. This equipment is listed separately from primary equipment in Table 2.14 and presented visually in Figure 2.11. In addition to the "Ancillary" category, Figure 2.10 presents an additional category – "Other Primary Equipment" – which makes up 12% of all equipment; this category includes stackers and reach stackers, RORO and empty container hustlers, and chassis flippers. A detailed list of all equipment on which this inventory is based, including model year, horsepower, and annual operating hours, is presented in Appendix A. This information is relevant as engine emissions vary according to these parameters – older engines generally emit more pollutants than new engines, high-horsepower engines typically emit more than lower-power engines. "Primary and "Ancillary" equipment are described in greater detail in the following subsections.

[17] EPA, Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling Compression-Ignition, NR-009d, Table 2

The great majority of equipment is diesel powered, as illustrated in Figure 2.12. The inventory includes 94 propane powered forklifts and 41 electric equipment. The electric equipment is not included in the equipment counts listed below because they do not contribute to emissions at the terminal facilities.

Table 2.14: Primary Cargo Handling Equipment Characteristics

Equipment Type	Count	Percent of Population	Average Model Year	Average hp	Average hrs/year
Primary Equipment					
Terminal Tractor	433	36.7%	2005	200	1,685
Straddle Carrier	258	21.9%	2005	231	3,246
Forklift	197	16.7%	2005	90	669
Empty Container Handler	66	5.6%	2004	196	2,144
Rubber Tired Gantry Crane	49	4.2%	2004	469	2,709
Loaded Container Handler	34	2.9%	2004	305	2,324
Subtotal "Primary Equipment"	1,037	87.9%	2005	203	1,979
Other Primary Equipment					
Reach Stacker	33	2.8%	2007	328	2,942
Stacker	23	1.9%	2004	229	1,042
Top Loader	23	1.9%	2007	362	2,897
RORO Hustler	7	0.6%	2000	215	527
Empty transport hustler	6	0.5%	2007	173	527
Chassis Flipper	5	0.4%	2002	156	1,476
Subtotal "Other Primary Equipment"	97	8.2%	2005	286	2,082
Ancillary Equipment					
Portable Light Set	12	1.0%	2001	50	1,055
Sweeper	9	0.8%	2001	90	660
Aerial Platform	9	0.8%	2003	47	1,055
Crane	4	0.3%	1982	888	250
Diesel Fuel Truck	4	0.3%	2005	243	3,375
Nonroad Vehicle	2	0.2%	1996	288	0
Front End Loader	2	0.2%	1987	125	2,314
Skid Steer Loader	2	0.2%	2004	38	264
Manlift	2	0.2%	2001	162	1,057
Subtotal "Ancillary Equipment"	46	3.9%	1999	165	1,084
Total Population	**1,180**				

Figure 2.10: Population Distribution of Primary CHE, by Number and Percent

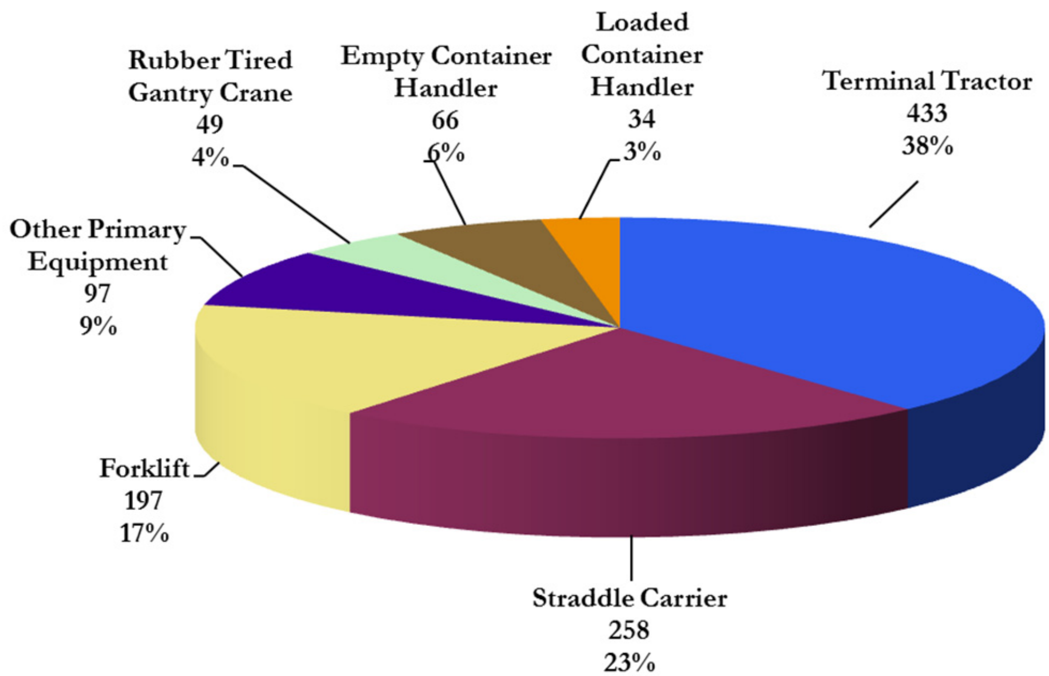


Figure 2.11: Population Distribution of Ancillary Equipment, by Number and Percent

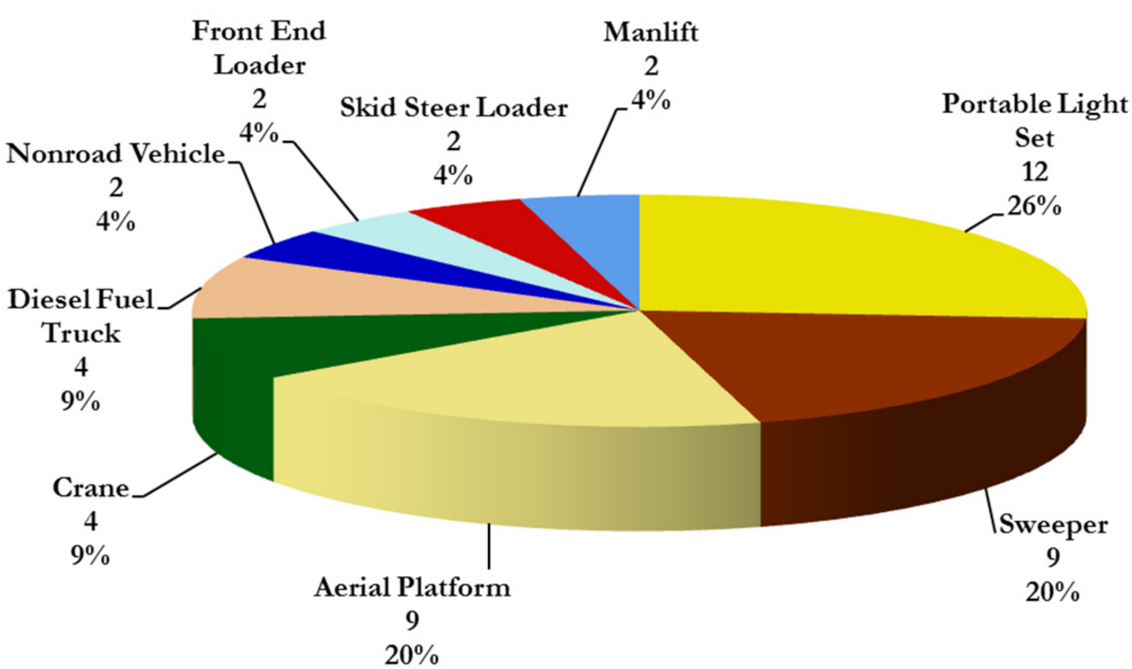
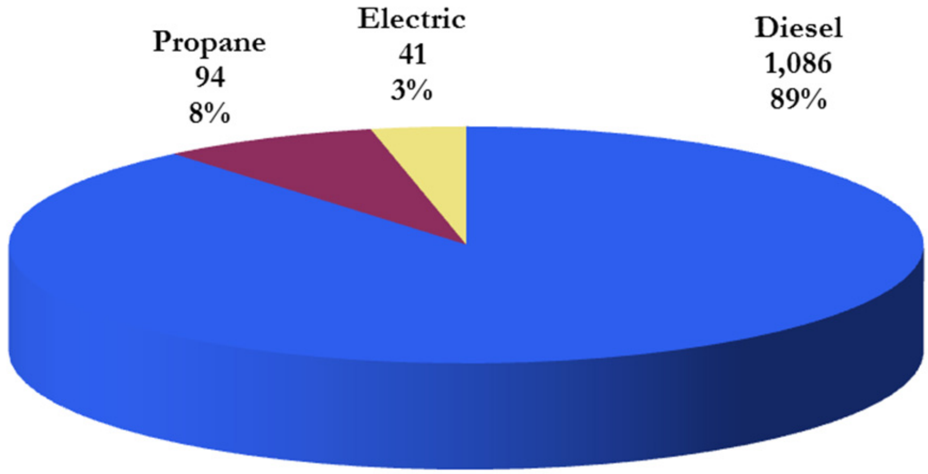


Figure 2.12: Equipment Distribution by Fuel Type



2.4.1 Primary Cargo Handling Equipment

Primary cargo handling equipment is used directly in handling cargo. This equipment consists of terminal tractors, straddle carriers, forklifts, top loaders, empty container handlers, rubber tired gantry cranes, wharf cranes, and chassis rotators. This equipment has been characterized in terms of several characteristics important to estimating emissions, including model year, horsepower, and annual hours of operation.

Table 2.15 presents information on the model years of the various types of primary cargo handling equipment – the average, the earliest (oldest) model year present, and the latest (newest) model year. Figures 2.13 and 2.14 illustrate the model year distributions of terminal tractors and straddle carriers, by far the two most numerous types of equipment in the inventory.

Table 2.15: Model Year Characteristics of Primary CHE

Equipment Type	Average Model Year	Min Model Year	Max Model Year
Chassis Flipper	2002	1998	2006
Empty Container Handler	2007	1996	2013
Empty Transport Hustler	2007	2007	2007
Forklift	2005	1989	2013
Loaded Container Handler	2004	1991	2012
Reach Stacker	2007	1999	2013
RORO Hustler	2000	1999	2000
RTG Crane	2004	2001	2008
Stacker	2004	1999	2014
Straddle Carrier	2005	1998	2013
Terminal Tractor	2005	2000	2013
Top Loader	2007	2004	2011

Figure 2.13: Model Year Distribution of Terminal Tractors

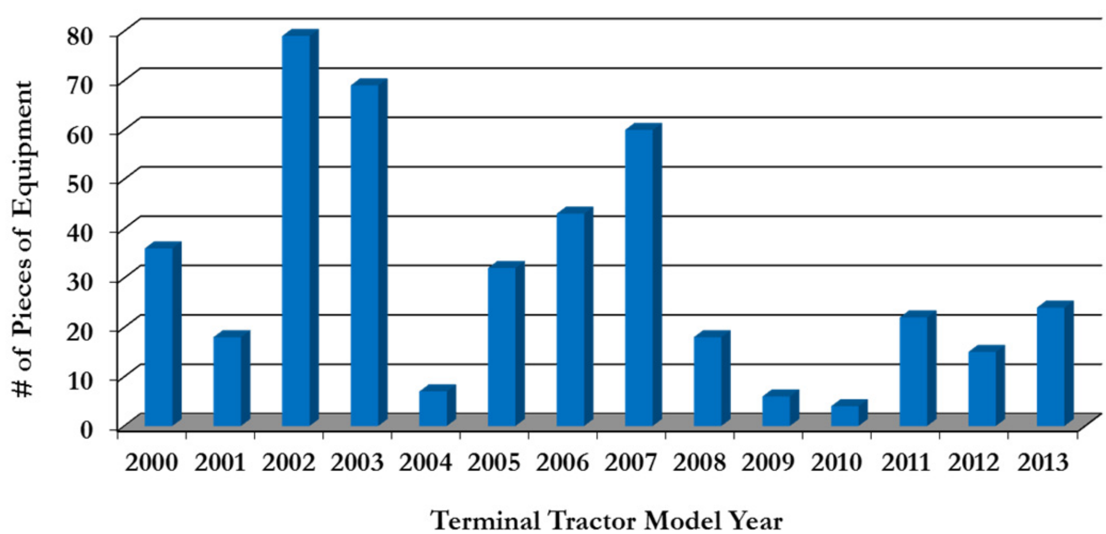


Figure 2.14: Model Year Distribution of Straddle Carriers

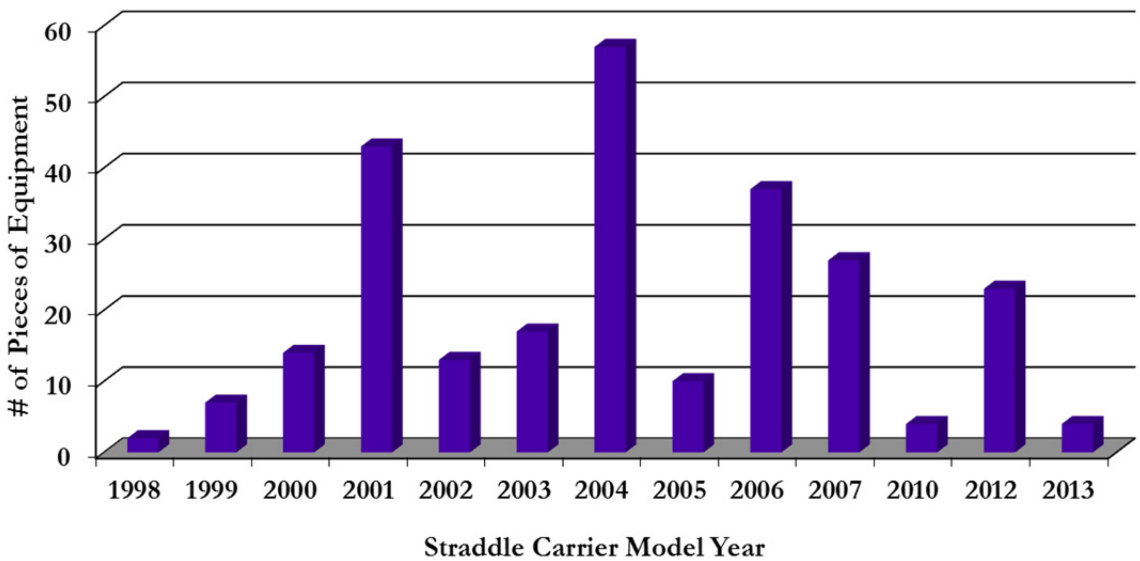


Table 2.16 presents information on the horsepower ratings of the various types of primary cargo handling equipment – the average, the lowest, and the highest.

Table 2.16: Horsepower Characteristics of Primary CHE

Equipment Type	Average hp	Min hp	Max hp
Chassis Flipper	156	152	160
Empty Container Handler	197	160	240
Empty Transport Hustler	173	173	173
Forklift	90	42	300
Loaded Container Handler	305	299	350
Reach Stacker	328	225	365
RORO Hustler	215	215	215
RTG Crane	469	450	475
Stacker	229	152	350
Straddle Carrier	231	184	400
Terminal Tractor	200	165	245
Top Loader	361	330	365

Table 2.17 presents information on the reported annual operating hours of the various types of primary cargo handling equipment – the average, the lowest, and the highest. Figures 2.15 and 2.16 illustrate the variation in reported terminal tractor and straddle carrier operating hours, respectively.

Table 2.17: Reported Operating Hours of Primary CHE

Equipment Type	Average hrs/year	Min hrs/year	Max hrs/year
Chassis Flipper	1,476	1,476	1,476
Empty Container Handler	2,144	0	2,665
Empty Transport Hustler	527	527	527
Forklift	669	0	1,964
Loaded Container Handler	2,324	0	4,605
Reach Stacker	2,942	0	3,797
RORO Hustler	527	527	527
RTG Crane	2,709	1,055	3,197
Stacker	1,042	0	2,912
Straddle Carrier	3,246	0	3,365
Terminal Tractor	1,685	0	3,876
Top Loader	2,897	2,897	2,897

Figure 2.15: Distribution of Annual Operating Hours for Terminal Tractors

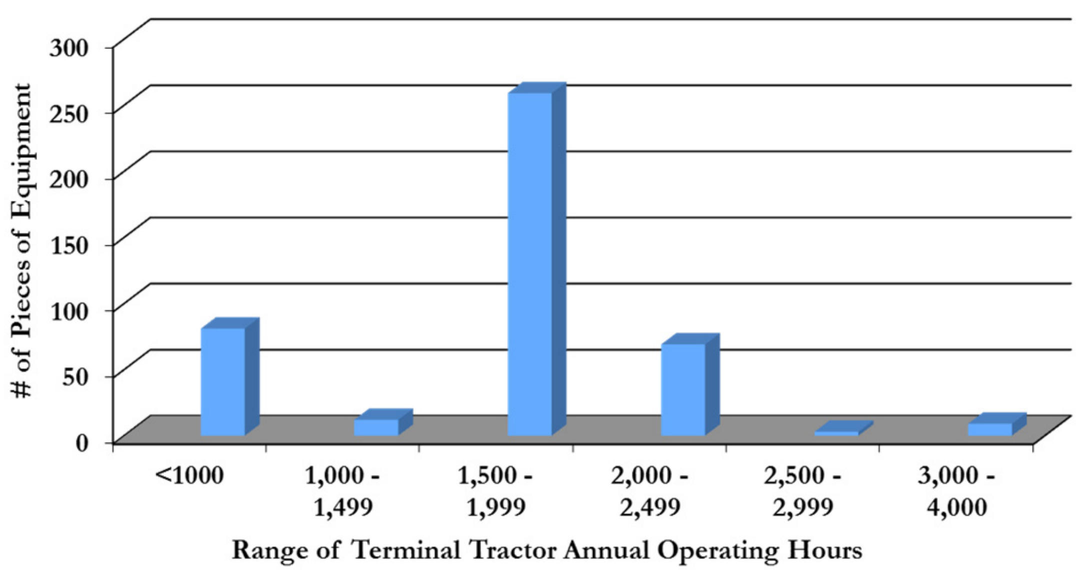
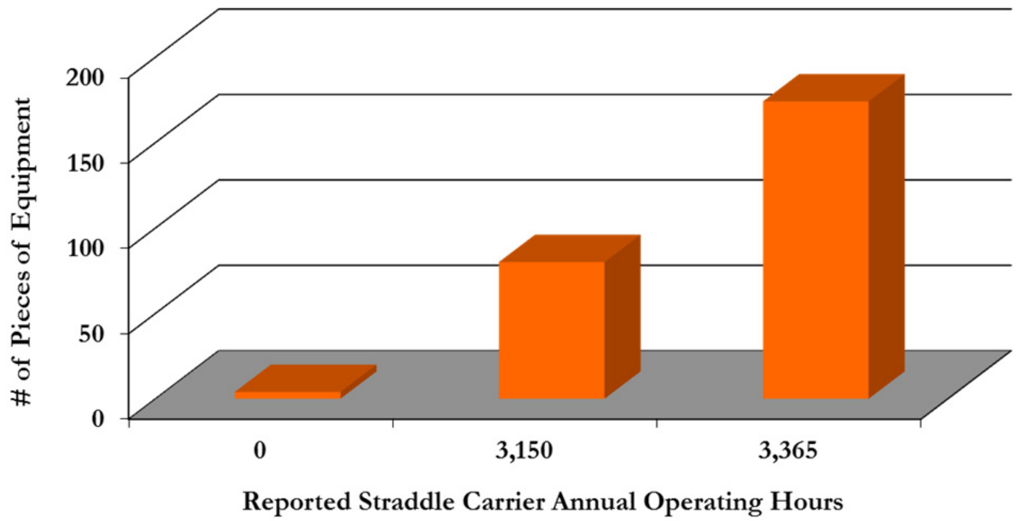


Figure 2.16: Distribution of Annual Operating Hours for Straddle Carriers



2.4.2 Ancillary Equipment

Ancillary equipment, or equipment not directly used to handle cargo, includes non-road vehicles, portable light sets, aerial platforms, front end loaders, sweepers, and generators. Tables 2.18 through 2.20 present the distribution of characteristics of this ancillary equipment in terms of model year, horsepower rating, and annual operating hours, respectively.

Table 2.18: Model Year Characteristics of Ancillary Equipment

Equipment Type	Average Model Year	Min Model Year	Max Model Year
Aerial Platform	2003	1998	2010
Crane	1982	1980	1984
Diesel Fuel Truck	2005	2002	2007
Front End Loader	1987	1987	1987
Manlift	2001	1998	2003
Nonroad Vehicle	1996	1985	2006
Portable Light Set	2001	2001	2001
Skid-steer Loader	2004	2004	2004
Sweeper	2001	1988	2008

Table 2.19: Horsepower Characteristics of Ancillary Equipment

Equipment Type	Average hp	Min hp	Max hp
Aerial Platform	47	42	49
Crane	888	850	950
Diesel Fuel Truck	243	240	250
Front End Loader	125	125	125
Manlift	162	150	174
Nonroad Vehicle	288	250	325
Portable Light Set	50	50	50
Skid-steer Loader	38	38	38
Sweeper	90	38	101

Table 2.20: Reported Operating Hours of Ancillary Equipment

Equipment Type	Average hrs/year	Min hrs/year	Max hrs/year
Aerial Platform	1,055	1,055	1,055
Crane	250	0	500
Diesel Fuel Truck	3,375	3,375	3,375
Front End Loader	2,314	2,314	2,314
Manlift	1,057	1,057	1,057
Nonroad Vehicle	0	0	0
Portable Light Set	1,055	1,055	1,055
Skid-steer Loader	264	264	264
Sweeper	660	659	660

The following Figures 2.17 through 2.21 show examples of the most common types of CHE: yard tractor, straddle carrier, forklift, top loader, and empty container handler (also known as a side handler).

Figure 2.17: Example Yard Tractor

Figure 2.18: Example Straddle Carrier

Figure 2.19: Example Forklift

Figure 2.20: Example Top Loader

Figure 2.21: Example Empty Container Handler

SECTION 3: HEAVY-DUTY DIESEL VEHICLES

This section presents estimated emissions from heavy-duty diesel vehicles (HDDVs) that visit the container terminals, warehouses, and automobile handling facilities within the Port Authority marine terminals. An example of an HDDV is the diesel-powered road truck that calls at a marine terminal to pick up or drop off a container. The following subsections present estimated HDDV emissions, describe the methodologies used to collect information and estimate emissions, and present a description of the equipment types.

Following an Executive Summary that presents an overview of HDDV emissions from PANYNJ sources, the following four subsections focus on:

- 3.1 - Emission Estimates
- 3.2 - Emission Comparisons
- 3.3 - Methodology
- 3.4 - Description of HDDVs

ES3.1 Executive Summary

Table ES3-1 presents the estimated HDDV criteria pollutant and GHG emissions in the context of overall emissions in the states of New York and New Jersey, and in the NYNJLINA counties noted in the Introduction, including emissions in tons per year and the percentage that PANYNJ HDDV emissions make up of overall NYNJLINA emissions, based on EPA's latest National Emissions Inventory numbers.[18]

During the period between development of the 2012 emissions inventory and this 2013 emissions inventory EPA released a revised version of their emission estimating model for HDDVs. MOVES2014, which replaced MOVES2010, incorporates changes that affect the emission estimates produced by the model. The emissions presented in this section, which were estimated using MOVES2014, are not directly comparable to emissions estimated for emissions inventories earlier than this emissions inventory since the earlier inventories were estimated using MOVES2010, MOBILE6.2 or an earlier version of MOBILE. The new MOVES model produces emission estimates that are different from the estimates produced by the MOVES2010 model, preventing a valid direct comparison between estimates made using the two versions of the MOVES model or one of the MOBILE versions. The differences in results include increases and decreases for different pollutants and for different types of activity (e.g., different speeds or running vs. idling). For example, the 2012 short-term idling emission factor for NOx (using MOVES2010) was 79.4 g/hr and the 2013 short-term idling emission factor for NOx (using MOVES2014) is higher at 93.2 g/hr, while the 2012 highway/local-speed emission factor for NOx (using MOVES2010) was 17.3 g/hr and the 2013 highway/local-speed emission factor for NOx (using MOVES2014) is lower at

[18] Criteria pollutant emissions are from the 2011 National Emissions Inventory: *http://www.epa.gov/ttn/chief/net/2011inventory.html*
Greenhouse gas emissions are from the 2011 and 2008 National Emissions Inventories, with stationary and area sources coming from the 2008 Inventory because they are not provided by the 2011 Inventory.
http://www.epa.gov/ttn/chief/net/2008inventory.html

15.4 g/hr. Since the 2012 and 2013 fleets were similar as modeled, these differences do not reflect actual increases and decreases of emissions, rather they reflect the best estimates of emissions based on the latest data available to EPA. Subsection 3.2 below includes a comparison between 2013 HDDV emissions and earlier inventories that has been prepared by adjusting the emissions from inventories earlier than 2013 by the approximate differences in estimates produced by MOVES2014 and MOVES2010.

Table ES3.1: Comparison of PANYNJ HDDV Emissions with State and NYNJLINA Emissions, tpy

Geographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq
New York and New Jersey	590,117	333,133	120,143	601,318	2,994,198	167,504	229,371,430
NYNJLINA	280,279	76,854	37,170	266,786	1,373,551	49,836	117,276,953
Heavy-Duty Diesel Vehicles	2,521	155	147	177	746	2.7	292,960
Percent of NYNJLINA Emissions	0.90%	0.20%	0.40%	0.07%	0.05%	0.005%	0.25%

As noted above, the HDDV emission estimates presented above are not comparable to HDDV emission estimates presented in earlier emissions inventories.

The following figures illustrate the distribution of PANYNJ HDDV emissions by activity and location (on-road driving, on-terminal driving and idling) in terms of tons per year and percent of total HDDV emissions, and in the context of overall NYNJLINA emissions. The NYNJLINA emissions are broken down into on-road mobile sources, other (non-road) mobile sources, and stationary and area sources. Note that the percentages shown in these charts do not always sum to 100% because of rounding. The charts are intended to illustrate the relative magnitude of emission sources at the port and in the region.

Figure ES3.1: Distribution and Comparison of NOx from HDDVs, tpy and percent

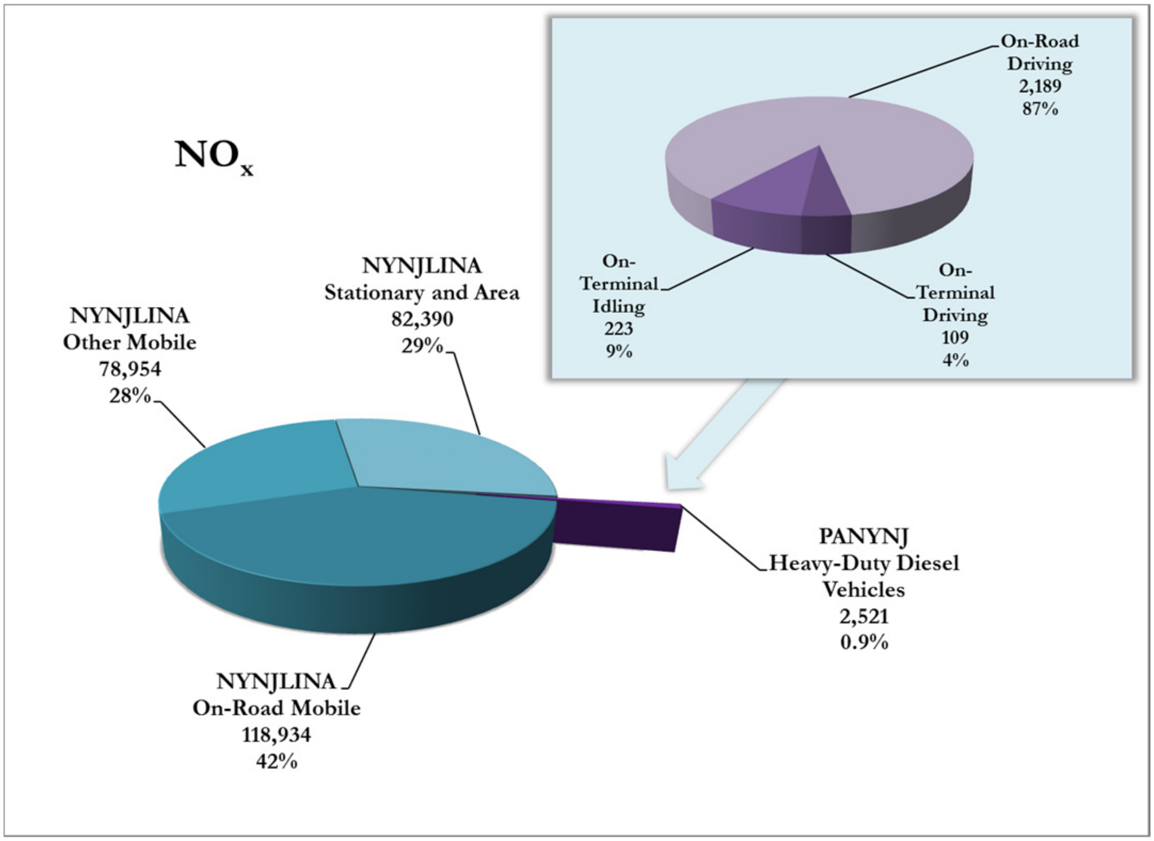


Figure ES3.2: Distribution and Comparison of PM10 from HDDVs, tpy and percent

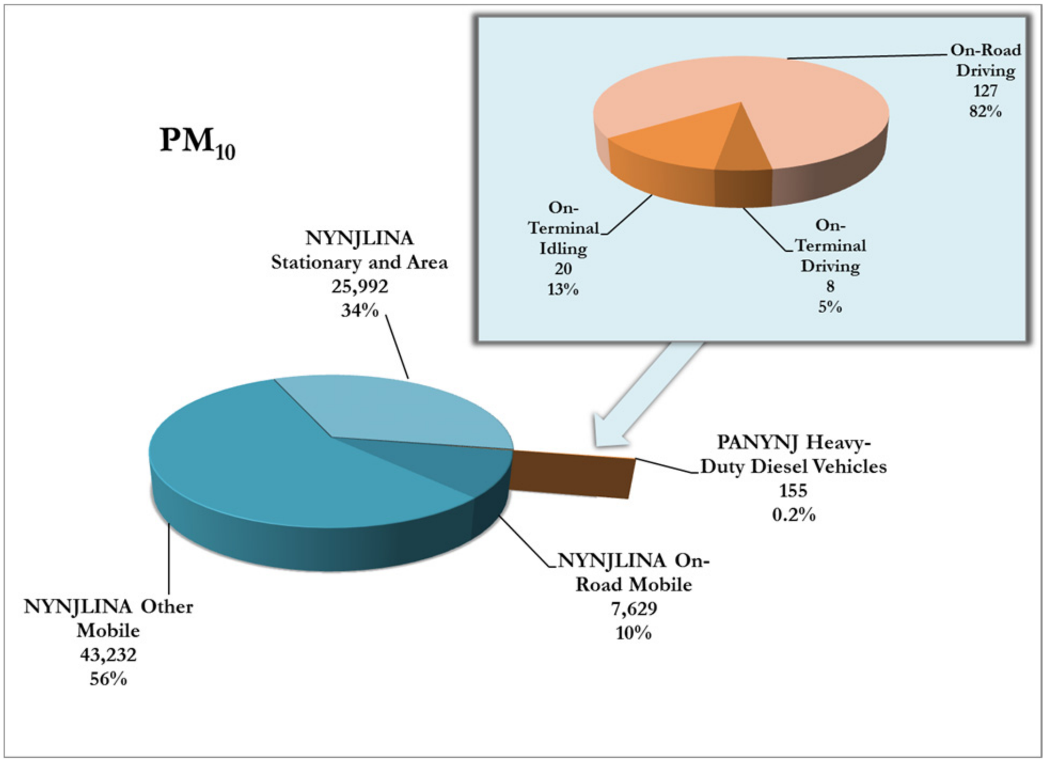


Figure ES3.3: Distribution and Comparison of PM2.5 from HDDVs, tpy and percent

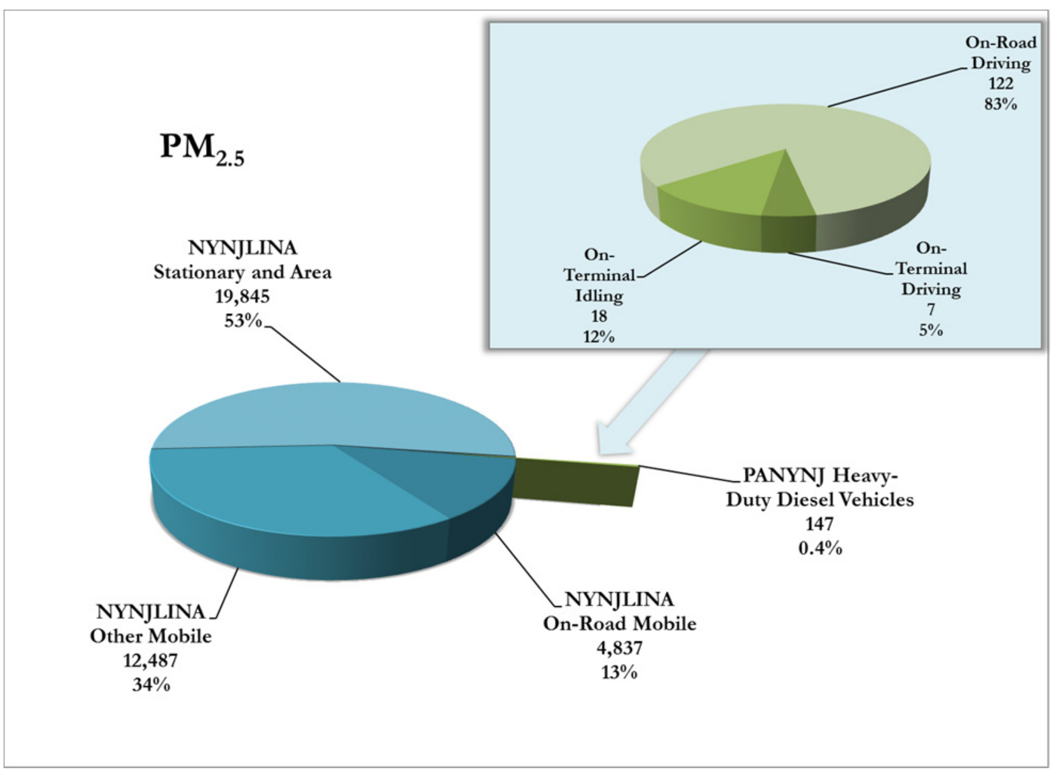


Figure ES3.4: Distribution and Comparison of VOC from HDDVs, tpy and percent

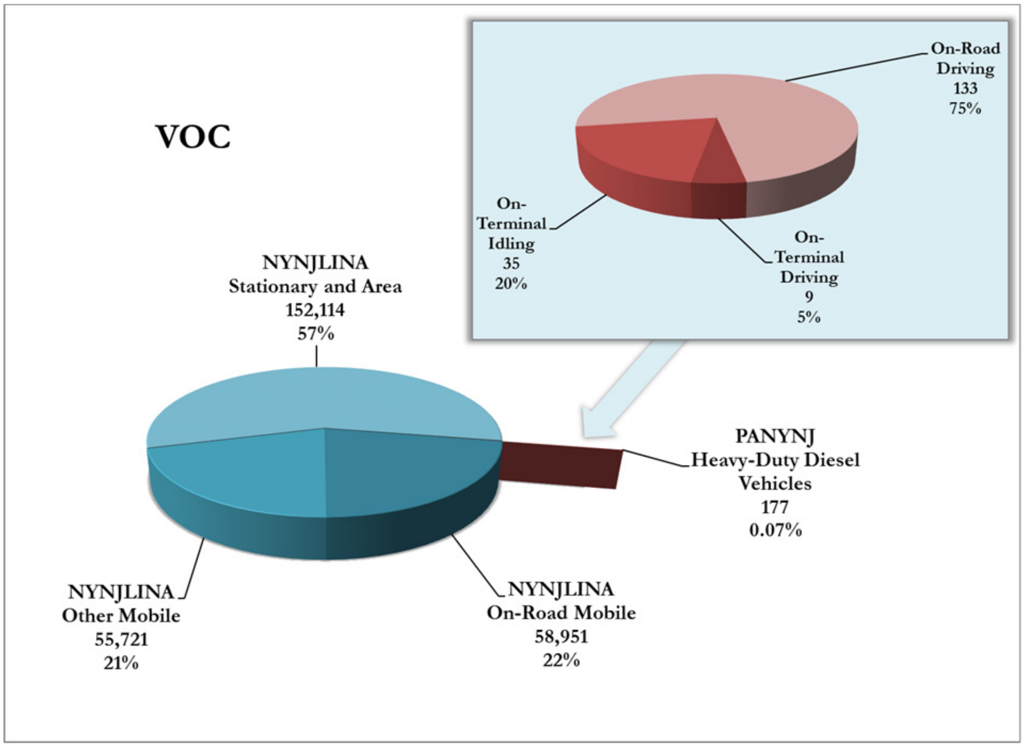


Figure ES3.5: Distribution and Comparison of CO from HDDVs, tpy and percent

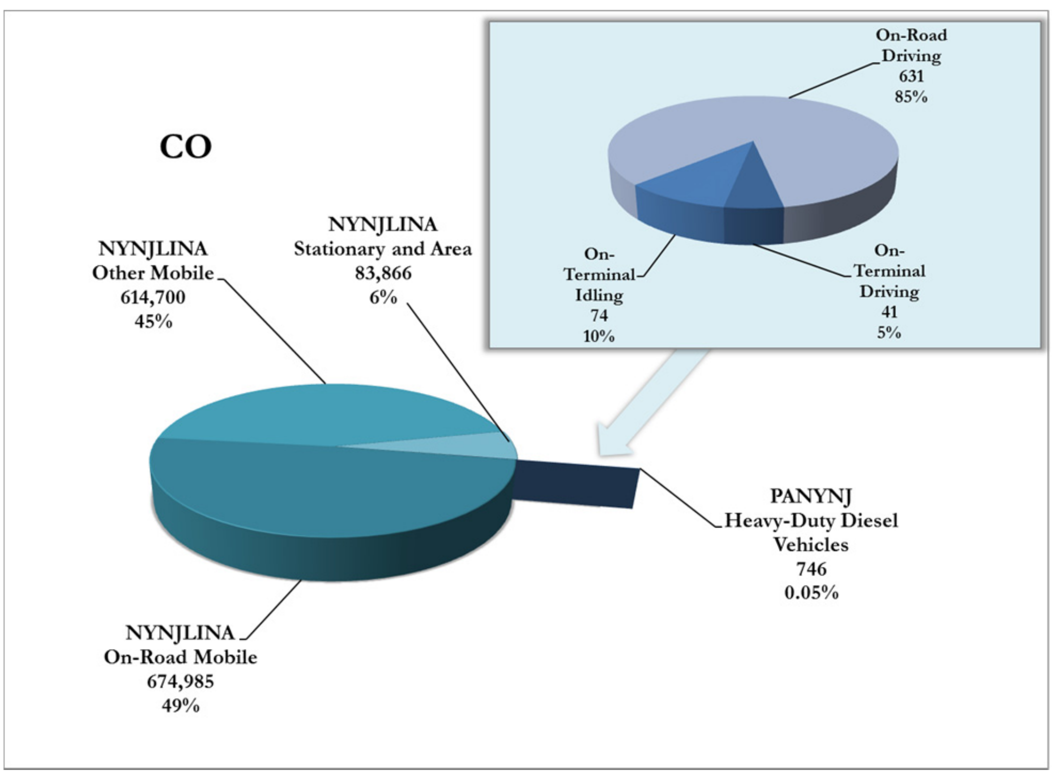


Figure ES3.6: Distribution and Comparison of SO_2 from HDDVs, tpy and percent

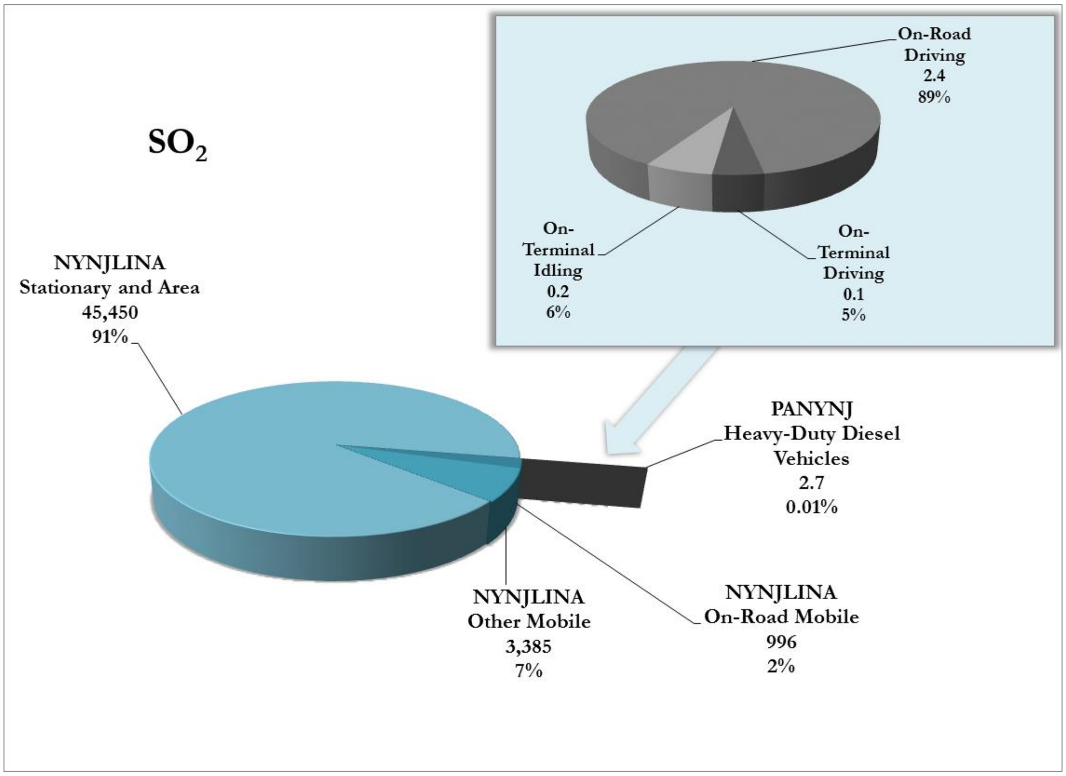
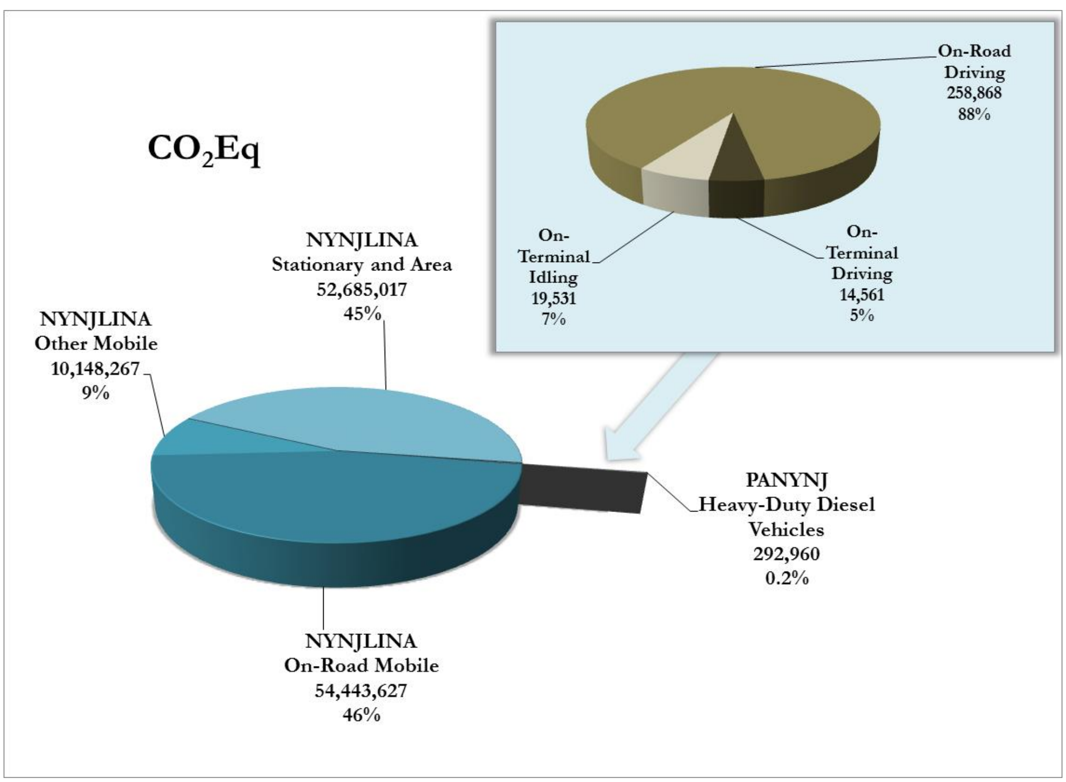


Figure ES3.7: Distribution of CO_2Eq Emissions from HDDVs, tpy and percent



3.1 Heavy-Duty Diesel Vehicle Emission Estimates

On-terminal and on-road emissions have been estimated for HDDV operations associated with the Port Authority marine terminals. The following subsections detail the estimated emissions from these two categories of HDDV activity. On-terminal activity, which includes the operation of trucks while at warehouses as well as within the boundaries of the container and automobile terminals, has been evaluated to include driving emissions and idling emissions from trucks waiting for entry and to be loaded or unloaded. The on-road emission estimates include the idling assumptions built into the emission estimating model used (as described in subsection 3.3.2) so separate idling emissions are not presented for on-road HDDV operation.

The emission estimates presented in this document are listed in several ways to provide as much information to the reader as possible. The emissions are presented by terminal or facility type, by type of activity, and by county and state. Because of these different modes of display, the numerical values must be rounded, displayed, and summed in different ways. Because of this, it is not always possible to display values in a table that sum exactly to the total shown at the bottom of the table. In developing the tables, priority has been given to maintaining consistent totals for each pollutant across table types.

3.1.1 On-Terminal Emissions

Estimates of on-terminal driving emissions of criteria pollutants are presented in Tables 3.1, and of greenhouse gas emissions in Table 3.2. Tables 3.3 and 3.4 present estimates of on-terminal idling emissions of criteria pollutants and greenhouse gases, and summaries of combined driving and idling emissions are presented in Tables 3.5 and 3.6. These estimates were made using the MOVES2014 emission estimating model and, as such, are not comparable with estimates presented in earlier emissions inventories. See section 3.2 below for a comparison of estimated 2013 emissions with earlier estimates.

Table 3.1: Summary of HDDV On-Terminal Driving Criteria Pollutant Emissions (tpy)

Facility Type	VMT	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Auto Terminals	51,067	1.1	0.08	0.08	0.1	0.4	0.001
Container Terminals	4,768,800	105.2	7.69	7.07	8.8	39.2	0.12
Warehouses	122,658	2.7	0.20	0.18	0.2	1.0	0.003
Overall Total	**4,942,525**	**109.1**	**7.97**	**7.33**	**9.2**	**40.6**	**0.13**

Table 3.2: Summary of HDDV On-Terminal Driving Greenhouse Gas Emissions (tpy)

Facility Type	VMT	CO_2	N_2O	CH_4	CO_2 Eq
Auto Terminals	51,067	150	0.000	0.002	150
Container Terminals	4,768,800	14,046	0.000	0.167	14,049
Warehouses	122,658	361	0.000	0.004	361
Overall Total	**4,942,525**	**14,557**	**0.000**	**0.173**	**14,561**

Table 3.3: Summary of HDDV On-Terminal Idling Criteria Pollutant Emissions (tpy)

Facility Type	Idling Hours	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Auto Terminals	92,568	23.2	0.6	0.6	5.8	9.2	0.01
Container Terminals	1,799,016	185	18	16	27	60	0.15
Warehouses	144,371	14.8	1.4	1.3	2.2	4.8	0.01
Overall Total	**2,035,955**	**222.8**	**19.6**	**18.0**	**35.5**	**74.2**	**0.17**

Table 3.4: Summary of HDDV On-Terminal Idling Greenhouse Gas Emissions (tpy)

Facility Type	Idling Hours	CO_2	N_2O	CH_4	CO_2 Equivalent
Auto Terminals	92,568	940	0.000	0.605	953
Container Terminals	1,799,016	17,190	0.000	0.413	17,198
Warehouses	144,371	1,380	0.000	0.033	1,380
Overall Total	**2,035,955**	**19,509**	**0.000**	**1.051**	**19,531**

Table 3.5: Summary of Total HDDV On-Terminal Criteria Pollutant Emissions (tpy)

Facility Type	VMT	Idling Hours	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Auto Terminals	51,067	92,568	24.4	0.7	0.6	5.9	9.6	0.01
Container Terminals	4,768,800	1,799,016	290	25	23	36	99	0.27
Warehouses	122,658	144,371	17.5	1.6	1.5	2.4	5.8	0.02
Overall Total	**4,942,525**	**2,035,955**	**331.9**	**27.6**	**25.4**	**44.6**	**114.8**	**0.30**

Table 3.6: Summary of Total HDDV On-Terminal Greenhouse Gas Emissions (tpy)

Facility Type	VMT	Idling Hours	CO_2	N_2O	CH_4	CO_2 Equivalent
Auto Terminals	51,067	92,568	1,090	0.000	0.606	1,103
Container Terminals	4,768,800	1,799,016	31,235	0.000	0.580	31,248
Warehouses	122,658	144,371	1,741	0.000	0.037	1,742
Overall Total	**4,942,525**	**2,035,955**	**34,066**	**0.000**	**1.224**	**34,093**

3.1.2 On-Road Emissions

Table 3.7 presents estimates of on-road, off-terminal criteria pollutant emissions by state (tpy) for the container terminal truck calls, and Table 3.8 presents the greenhouse gas emission estimates for the same facilities. These estimates were made using the MOVES2014 emission estimating model and, as such, are not comparable with estimates presented in earlier emissions inventories. See section 3.2 below for a comparison of estimated 2013 emissions with earlier estimates. The geographical breakdown of these emissions by county is also presented in Section 3.2.

Table 3.7: Summary of HDDV On-Road Criteria Pollutant Emissions by State (tpy)

State	VMT (thousands)	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
New Jersey	105,425	1,792	104.0	99.6	108.5	516.9	2.0
New York	23,323	397	23.0	22.0	24.0	114.4	0.4
Total	**128,748**	**2,189**	**127.0**	**121.6**	**132.6**	**631.3**	**2.4**

Table 3.8: Summary of HDDV On-Road Greenhouse Gas Emissions by State (tpy)

State	VMT (thousands)	CO_2	N_2O	CH_4	CO_2 Eq
New Jersey	105,425	211,966	0.23	1.74	211,974
New York	23,323	46,893	0.05	0.39	46,893
Total	**128,748**	**258,859**	**0.28**	**2.13**	**258,868**

3.1.3 Total HDDV On-Terminal and On-Road Related Emissions

The totals of on-terminal and on-road, emissions (for container, auto and warehouse facilities) are presented in Table 3.9 (criteria pollutants) and Table 3.10 (greenhouse gases). These estimates were made using the new MOVES2014 emission estimating model and, as such, are not comparable with estimates presented in earlier emissions inventories. See section 3.2 below for a comparison of estimated 2013 emissions with earlier estimates.

Table 3.9: Total Marine Terminal Criteria Pollutant Emission Estimates, tpy

Activity Component	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
On-Terminal Driving	109	8	7	9	41	0.1
On-Terminal Idling	223	20	18	35	74	0.2
On-Road Driving	2,189	127	122	133	631	2.4
Totals	**2,521**	**155**	**147**	**177**	**746**	**2.7**

Table 3.10: Total Marine Terminal Greenhouse Gas Emission Estimates, tpy

Activity Component	CO_2	N_2O	CH_4	CO_2 Eq
On-Terminal Driving	14,557	0.00	0.17	14,561
On-Terminal Idling	19,509	0.00	1.05	19,531
On-Road Driving	258,859	0.28	2.13	258,868
Totals	**292,925**	**0.28**	**3.35**	**292,960**

3.2 Heavy-Duty Diesel Vehicle Emission Comparisons

This section presents the heavy-duty truck emission estimates prepared using the MOVES2014 model detailed in section 3.1 in the context of countywide and area-wide emissions. Port Authority marine terminal-related truck emissions are compared with all emissions in the NYNJLINA on a county-by-county basis. Overall county-level emissions were excerpted from the most recent National Emissions Inventory numbers.[19] The extent to which the National Emissions Inventory estimates of on-road emissions were prepared using either the MOVES2014 or MOVES2010 model or the previous-generation model, MOBILE6.2, is not known, so the percentage comparisons should be considered as approximate.

[19] See: 2008 and 2011 National Emission Inventory versions, as noted above.

This section also presents a comparison of 2013 heavy-duty truck emission estimates, prepared using the MOVES2014 model, with the results of earlier emissions inventories, prepared using the now-outdated MOVES2010 and MOBILE6.2 models for calendar year 2012 and earlier, that have been adjusted to reflect the relative differences in outputs between the two models. As noted in the Introduction to this emissions inventory report, the MOVES2014 model version estimates different emission rates than did the MOVES2010 version.[20] The differences in results include increases and decreases for different pollutants and for different types of activity (e.g., different speeds or running vs. idling) while the MOVES2010 model estimated generally higher emissions than the MOBILE6.2 model.[21] For example, the 2012 short-term idling emission factor for NOx (using MOVES2010) was 79.4 g/hr and the 2013 short-term idling emission factor for NOx (using MOVES2014) is higher at 93.2 g/hr, while the 2012 highway/local-speed emission factor for NOx (using MOVES2010) was 17.3 g/hr and the 2013 highway/local-speed emission factor for NOx (using MOVES2014) is lower at 15.4 g/hr. Since the 2012 and 2013 fleets were similar as modeled, these differences do not reflect actual increases and decreases of emissions, rather they reflect the best estimates of emissions based on the latest data available to EPA. With the "state-of-the-art" in emission estimating models occasionally being advanced as in these cases, adjustments are necessary to assess progress to date in reducing emissions from the heavy-duty truck fleet serving the Port Authority's tenants. The earlier emission estimates have also been adjusted to include HDDV emissions associated with the Global Container Terminal during those earlier years, as discussed in the Introduction.

3.2.1 Comparisons with County and Regional Emissions

Table 3.11 summarizes estimated criteria pollutant emissions from the Port Authority marine terminal heavy-duty truck related activities reported in this current inventory, at the county level. Subsequent Tables 3.12 through 3.18 examine each pollutant individually, comparing Port Authority marine terminal-related truck activity with total county level emissions. Figures 3.1 through 3.7 summarize the same information visually on an individual county basis. Each column displays the countywide emissions, and the Port Authority marine terminal truck contribution to total emissions is shown on top of the countywide column.

[20] *http://www.epa.gov/otaq/models/moves/documents/420f14049.pdf*

[21] *http://www.epa.gov/otaq/models/moves/420f09073.pdf*

Table 3.11: Summary of Heavy-Duty Diesel Vehicle Criteria Pollutant Emissions by County (on-terminal and on-road), tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2Eq
Bergen	NJ	145	8.4	8.1	8.8	41.9	0.16	17,194
Essex	NJ	696	41.9	39.9	48.5	205.9	0.75	80,874
Hudson	NJ	332	20.1	19.1	23.2	98.1	0.36	38,533
Middlesex	NJ	475	27.6	26.4	28.8	137.0	0.52	56,195
Monmouth	NJ	32	1.8	1.8	1.9	9.2	0.04	3,770
Union	NJ	426	30.1	28.2	39.4	133.8	0.43	47,810
New Jersey subtotal		**2,107**	**129.9**	**123.4**	**150.6**	**625.9**	**2.26**	**244,375**
Bronx	NY	43	2.5	2.4	2.6	12.3	0.05	5,034
Kings (Brooklyn)	NY	108	6.4	6.1	6.8	31.2	0.12	12,667
Nassau	NY	73	4.3	4.1	4.4	21.2	0.08	8,684
New York	NY	19	1.1	1.0	1.1	5.4	0.02	2,207
Orange	NY	42	2.5	2.4	2.6	12.2	0.05	5,011
Queens	NY	36	2.1	2.0	2.2	10.3	0.04	4,223
Richmond (Staten Island)	NY	21	1.7	1.6	2.4	6.5	0.02	2,122
Rockland	NY	6	0.3	0.3	0.3	1.6	0.01	672
Suffolk	NY	26	1.5	1.5	1.6	7.6	0.03	3,102
Westchester	NY	41	2.4	2.3	2.5	11.9	0.05	4,864
New York subtotal		**414**	**24.6**	**23.5**	**26.5**	**120.1**	**0.45**	**48,585**
TOTAL		**2,521**	**155**	**147**	**177**	**746**	**2.7**	**292,960**

Table 3.12: Comparison of Heavy-Duty Diesel Vehicle NO_x Emissions with Overall NO_x Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	14,798	145	0.98%
Essex	NJ	17,195	696	4.05%
Hudson	NJ	9,585	332	3.46%
Middlesex	NJ	14,766	475	3.22%
Monmouth	NJ	10,366	32	0.31%
Union	NJ	12,325	426	3.45%
New Jersey Subtotal		**79,035**	**2,107**	**2.67%**
Bronx	NY	13,195	43	0.32%
Kings (Brooklyn)	NY	25,190	108	0.43%
Nassau	NY	21,973	73	0.33%
New York	NY	33,432	19	0.06%
Orange	NY	11,854	42	0.36%
Queens	NY	31,678	36	0.11%
Richmond (Staten Island)	NY	10,793	21	0.19%
Rockland	NY	5,622	6	0.10%
Suffolk	NY	30,558	26	0.09%
Westchester	NY	16,949	41	0.24%
New York Subtotal		**201,244**	**414**	**0.2%**
TOTAL		**280,279**	**2,521**	**0.90%**

Figure 3.1: Comparison of Heavy-Duty Diesel Vehicle NO_x Emissions with Overall NO_x Emissions by County, tpy

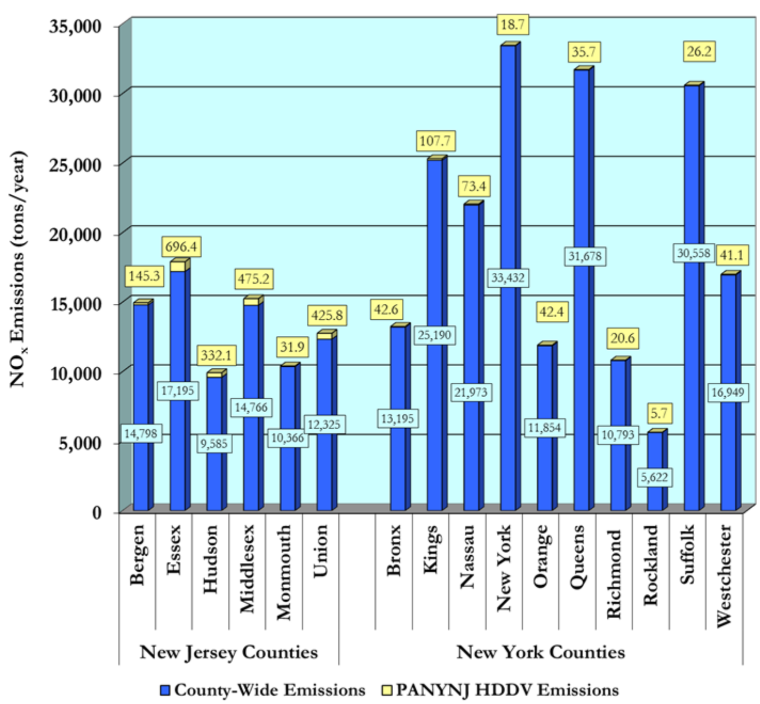


Table 3.13: Comparison of Heavy-Duty Diesel Vehicle PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	3,565	8.4	0.24%
Essex	NJ	5,233	41.9	0.80%
Hudson	NJ	1,732	20.1	1.16%
Middlesex	NJ	4,288	27.6	0.64%
Monmouth	NJ	3,334	1.8	0.055%
Union	NJ	2,787	30.1	1.1%
New Jersey Subtotal		**20,939**	**130**	**0.62%**
Bronx	NY	2,605	2.5	0.09%
Kings (Brooklyn)	NY	4,779	6.4	0.13%
Nassau	NY	5,840	4.3	0.073%
New York	NY	6,363	1.1	0.017%
Orange	NY	7,595	2.5	0.032%
Queens	NY	5,244	2.1	0.040%
Richmond (Staten Island)	NY	1,885	1.7	0.09%
Rockland	NY	1,993	0.3	0.017%
Suffolk	NY	12,931	1.5	0.012%
Westchester	NY	6,680	2.4	0.036%
New York Subtotal		**55,915**	**25**	**0.04%**
TOTAL		**76,854**	**155**	**0.20%**

Figure 3.2: Comparison of Heavy-Duty Diesel Vehicle PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

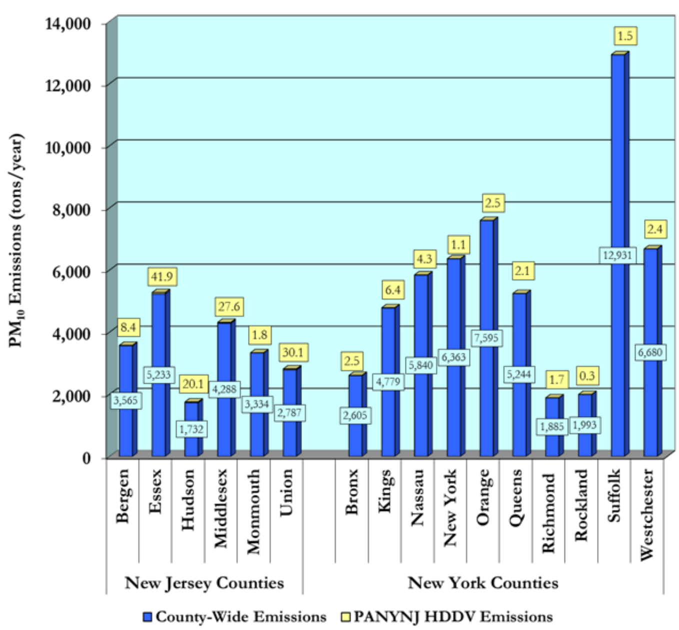


Table 3.14: Comparison of Heavy-Duty Diesel Vehicle $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	2,101	8.1	0.38%
Essex	NJ	2,574	39.9	1.55%
Hudson	NJ	1,284	19.1	1.49%
Middlesex	NJ	2,335	26.4	1.13%
Monmouth	NJ	1,737	1.8	0.10%
Union	NJ	1,877	28.2	1.50%
New Jersey Subtotal		**11,908**	**123**	**1.0%**
Bronx	NY	1,474	2.4	0.16%
Kings (Brooklyn)	NY	2,693	6.1	0.23%
Nassau	NY	2,740	4.1	0.15%
New York	NY	3,199	1.0	0.032%
Orange	NY	2,462	2.4	0.10%
Queens	NY	3,030	2.0	0.07%
Richmond (Staten Island)	NY	1,090	1.6	0.14%
Rockland	NY	801	0.3	0.039%
Suffolk	NY	5,117	1.5	0.03%
Westchester	NY	2,656	2.3	0.09%
New York Subtotal		**25,262**	**24**	**0.09%**
TOTAL		**37,170**	**147**	**0.40%**

Figure 3.3: Comparison of Heavy-Duty Diesel Vehicle $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by county, tpy

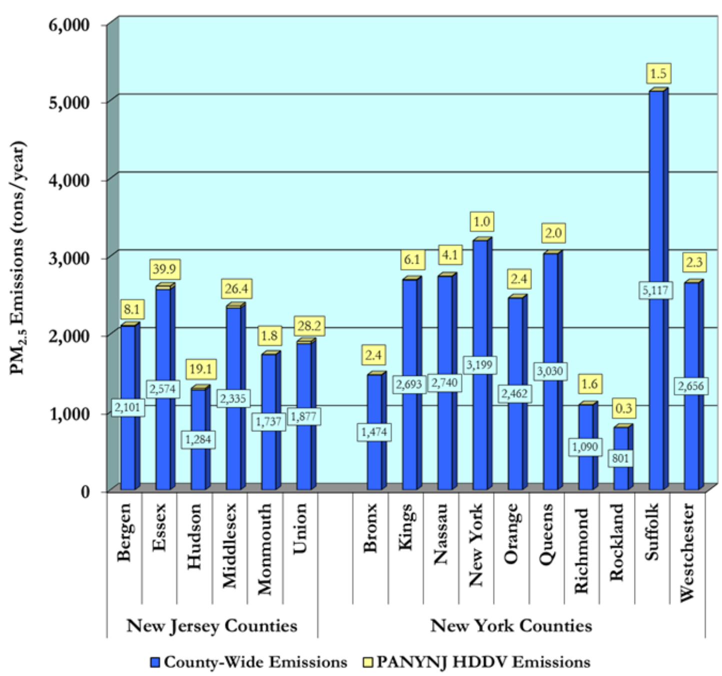


Table 3.15: Comparison of Heavy-Duty Diesel Vehicle VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	17,028	8.8	0.05%
Essex	NJ	16,814	48.5	0.29%
Hudson	NJ	9,244	23.2	0.25%
Middlesex	NJ	16,653	28.8	0.17%
Monmouth	NJ	12,551	1.9	0.015%
Union	NJ	11,037	39.4	0.36%
New Jersey Subtotal		**83,327**	**151**	**0.18%**
Bronx	NY	14,156	2.6	0.018%
Kings (Brooklyn)	NY	26,367	6.8	0.026%
Nassau	NY	21,541	4.4	0.021%
New York	NY	21,185	1.1	0.005%
Orange	NY	9,654	2.6	0.027%
Queens	NY	27,358	2.2	0.008%
Richmond (Staten Island)	NY	6,576	2.4	0.037%
Rockland	NY	5,701	0.3	0.006%
Suffolk	NY	33,256	1.6	0.005%
Westchester	NY	17,665	2.5	0.014%
New York Subtotal		**183,459**	**27**	**0.014%**
TOTAL		**266,786**	**177**	**0.07%**

Figure 3.4: Comparison of Heavy-Duty Diesel Vehicle VOC Emissions with Overall VOC Emissions by County, tpy

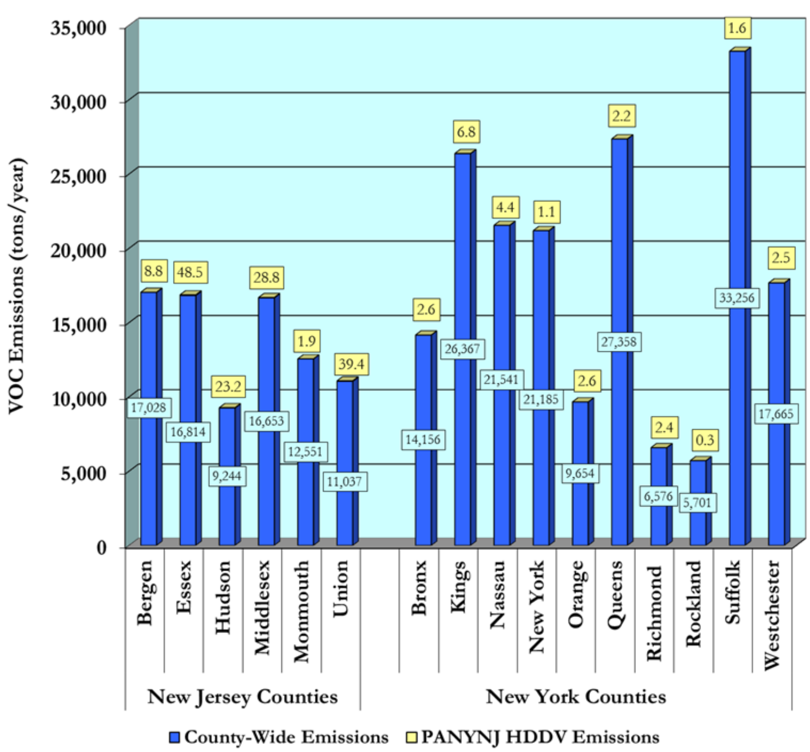


Table 3.16: Comparison of Heavy-Duty Diesel Vehicle CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	110,855	41.9	0.038%
Essex	NJ	79,450	205.9	0.259%
Hudson	NJ	37,073	98.1	0.265%
Middlesex	NJ	87,617	137.0	0.156%
Monmouth	NJ	74,655	9.2	0.012%
Union	NJ	55,299	133.8	0.242%
New Jersey Subtotal		**444,949**	**626**	**0.14%**
Bronx	NY	52,643	12.3	0.023%
Kings (Brooklyn)	NY	101,980	31.2	0.031%
Nassau	NY	124,041	21.2	0.017%
New York	NY	124,401	5.4	0.004%
Orange	NY	48,412	12.2	0.025%
Queens	NY	123,921	10.3	0.008%
Richmond (Staten Island)	NY	33,262	6.5	0.019%
Rockland	NY	32,711	1.6	0.005%
Suffolk	NY	182,114	7.6	0.004%
Westchester	NY	105,117	11.9	0.011%
New York Subtotal		**928,602**	**120**	**0.013%**
TOTAL		**1,373,551**	**746**	**0.05%**

Figure 3.5: Comparison of Heavy-Duty Diesel Vehicle CO Emissions with Overall CO Emissions by County, tpy

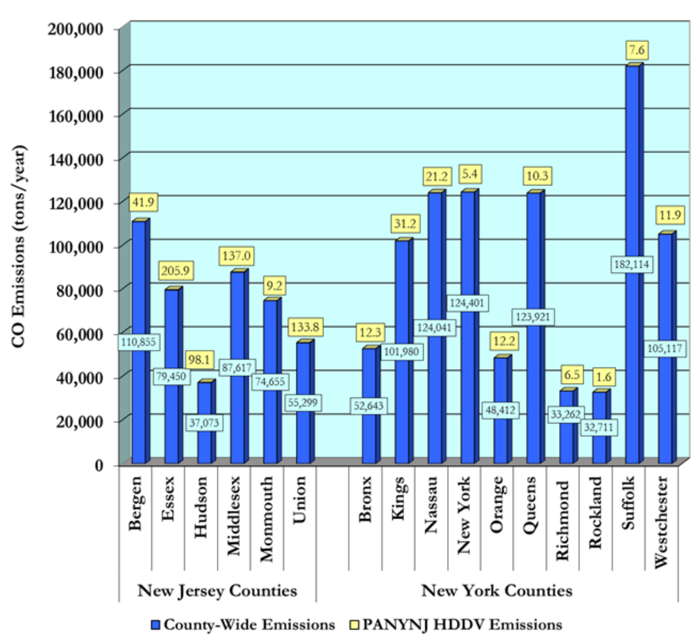


Table 3.17: Comparison of Heavy-Duty Diesel Vehicle SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	679	0.2	0.024%
Essex	NJ	2,630	0.7	0.028%
Hudson	NJ	1,817	0.4	0.020%
Middlesex	NJ	771	0.5	0.068%
Monmouth	NJ	671	0.0	0.005%
Union	NJ	1,053	0.4	0.041%
New Jersey Subtotal		**7,621**	**2.3**	**0.030%**
Bronx	NY	1,769	0.0	0.003%
Kings (Brooklyn)	NY	2,021	0.1	0.006%
Nassau	NY	3,045	0.1	0.003%
New York	NY	6,776	0.0	0.000%
Orange	NY	10,728	0.0	0.000%
Queens	NY	2,932	0.0	0.001%
Richmond (Staten Islar	NY	383	0.0	0.005%
Rockland	NY	461	0.0	0.001%
Suffolk	NY	11,488	0.0	0.000%
Westchester	NY	2,612	0.0	0.002%
New York Subtotal		**42,215**	**0.5**	**0.001%**
TOTAL		**49,836**	**2.7**	**0.005%**

Figure 3.6: Comparison of Heavy-Duty Diesel Vehicle SO_2 Emissions with Overall SO_2 Emissions by County, tpy

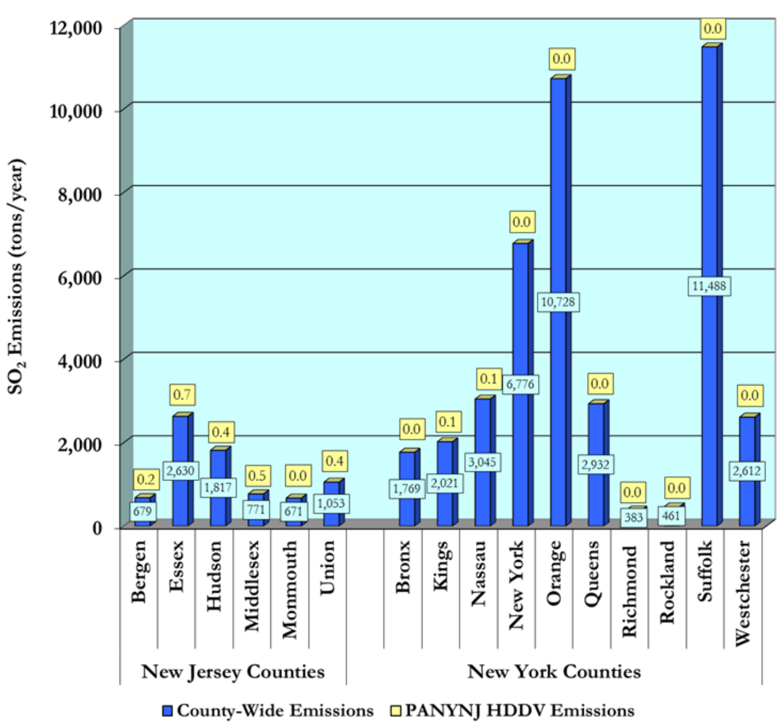
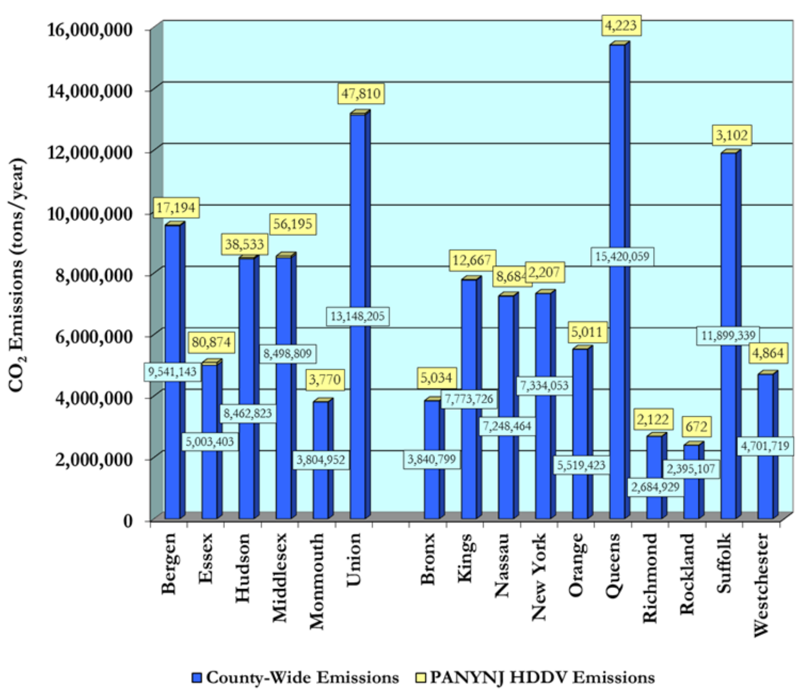


Table 3.18: Comparison of Heavy-Duty Diesel Vehicle CO_2Eq Emissions with Overall CO_2Eq Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	9,541,143	17,194	0.2%
Essex	NJ	5,003,403	80,874	1.6%
Hudson	NJ	8,462,823	38,533	0.5%
Middlesex	NJ	8,498,809	56,195	0.7%
Monmouth	NJ	3,804,952	3,770	0.1%
Union	NJ	13,148,205	47,810	0.4%
New Jersey Subtotal		**48,459,335**	**244,375**	**0.50%**
Bronx	NY	3,840,799	5,034	0.1%
Kings (Brooklyn)	NY	7,773,726	12,667	0.2%
Nassau	NY	7,248,464	8,684	0.1%
New York	NY	7,334,053	2,207	0.0%
Orange	NY	5,519,423	5,011	0.1%
Queens	NY	15,420,059	4,223	0.0%
Richmond (Staten Island)	NY	2,684,929	2,122	0.1%
Rockland	NY	2,395,107	672	0.0%
Suffolk	NY	11,899,339	3,102	0.0%
Westchester	NY	4,701,719	4,864	0.1%
New York Subtotal		**68,817,618**	**48,585**	**0.07%**
TOTAL		**117,276,953**	**292,960**	**0.25%**

Figure 3.7: Comparison of Heavy-Duty Diesel Vehicle CO_2Eq Emissions with Overall CO_2Eq Emissions by County, tpy



3.2.2 Comparisons with Prior Year Emission Estimates

The HDDV emission estimates published in emissions inventories prior to the previous 2012 inventory were prepared using the MOBILE6.2 model, which was replaced as EPA's accepted emissions model by the MOVES2010 model, which in turn has been superseded by the MOVES2014 version of the MOVES model. In order to illustrate the trends in emissions between inventory years over time, the emission estimates for 2012 and prior years were adjusted by factors representing the approximate differences among the models for each pollutant, since each update incorporates new information on engine emissions and other factors that can change the emission estimates produced by the model. The adjustment factors were developed using the relative difference between the 2012 MOVES2010 emission factors and the 2013 MOVES2014 emission factors for running (on-terminal and on-road) and idling (low idle and extended idle). These factors allow the approximation of the effect of MOVES-based emission factors on the prior year estimates.

Another change that has been made to the earlier years' emission estimates (prior to 2012) is to include emissions from the Global Container Terminal in the prior year estimates. The Global Container Terminal was acquired in 2010 by the Port Authority and the emissions associated with the terminal were included for the second half of the year in the 2010 emissions inventory and for the full year in the 2012 and this 2013 emissions inventory. HDDV emissions associated with this terminal during the first half of 2010 as well as 2008 and 2006 were estimated and included first in the 2012 emissions inventory and now in the comparisons presented in Table 3.19. This table presents annual HDDV emissions as estimated in the respective emissions inventories, the emissions for each year as adjusted for the MOBILE6.2 to MOVES modeling change and for the addition of the new terminal, the percentage difference between each prior inventory's adjusted emissions and the 2013 estimates, emissions in tons per million TEUs, and the percentage differences in tons per million TEUs between the prior years and 2013.

The effects of the newer fleet in 2012 and 2013 than in earlier years, discussed later in this section, show up in the decreases of NO_x and PM compared with 2010 and earlier inventories. Despite the slight decrease in overall TEU throughput, total miles travelled increased by a similar degree because of the specific throughput changes at each of the marine terminals, resulting in a modest increase in emissions across all pollutants. Continued renewal of the drayage truck fleet as a result of the Port Authority's truck program is expected to reverse the increases, and the enhanced model year data collection discussed below will provide up-to-date model year distributions that will reflect the effectiveness of the program. Subsequent emissions inventories, which will be developed using the MOVES model as were the 2012 and 2013 inventories, will provide a clearer picture of changes in emissions as a result of the changing drayage truck fleet.

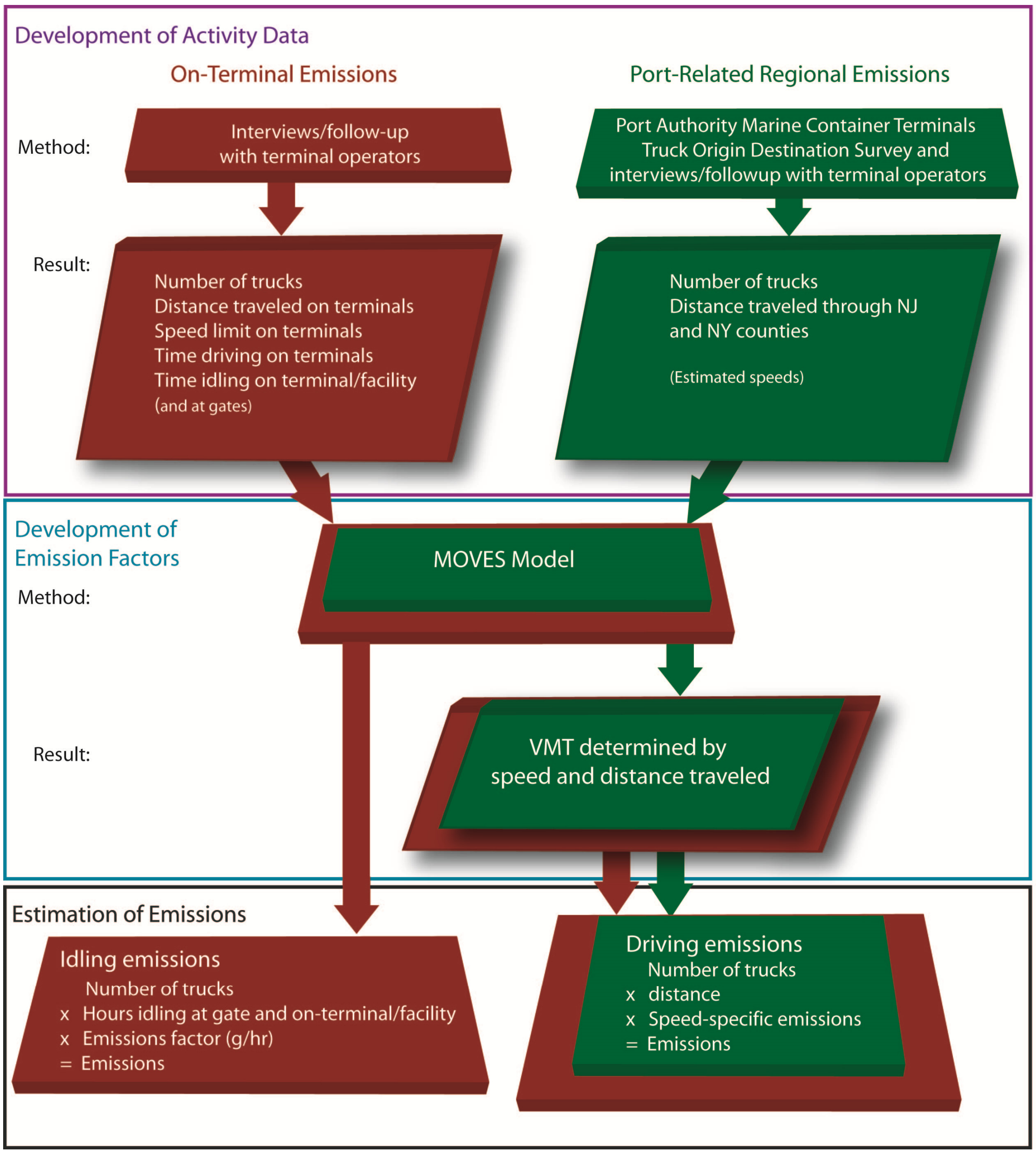
Table 3.19: Comparison of 2013 HDDV Emissions with Adjusted Prior Year Estimates, tons per year and percent

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq	Million TEUs
Tons per year, as published								
2013	2,521	155	147	177	746	3	292,960	5.467
2012	2,664	141	137	151	876	3	316,348	5.530
2010	2,104	46	42	96	477	2	229,000	5.007
2008	2,331	59	54	105	603	2	211,042	4.711
2006	1,935	59	54	87	564	26	208,446	4.657
Tons per year, with adjustments								
2013	2,521	155	147	177	746	3	292,960	5.467
2012	2,442	150	142	172	723	2.6	283,545	5.530
2010	2,588	192	173	138	636	2.4	286,033	5.292
2008	2,998	259	234	157	838	2.3	278,131	5.265
2006	2,431	254	229	127	768	29	268,189	5.093
Percent change relative to 2013 - tons per year (adjusted)								
2012 - 2013	3%	3%	4%	3%	3%	4%	3%	-1%
2010 - 2013	-3%	-19%	-15%	28%	17%	13%	2%	3%
2008 - 2013	-16%	-40%	-37%	13%	-11%	18%	5%	4%
2006 - 2013	4%	-39%	-36%	40%	-3%	-91%	9%	7%
Tons per million TEU (adjusted)								
2013	461	28	27	32	136	0.50	53,587	
2012	442	27	26	31	131	0.47	51,274	
2010	489	36	33	26	120	0.45	54,050	
2008	569	49	44	30	159	0.44	52,826	
2006	477	50	45	25	151	5.7	52,658	
Percent change relative to 2013 - tons per million TEU (adjusted)								
2012 - 2013	4%	4%	4%	3%	4%	6%	5%	
2010 - 2013	-6%	-22%	-18%	23%	13%	11%	-1%	
2008 - 2013	-19%	-43%	-39%	7%	-14%	14%	1%	
2006 - 2013	-3%	-44%	-40%	28%	-10%	-91%	2%	

3.3 Heavy-Duty Diesel Vehicle Emission Calculation Methodology

This section contains a description of the methodology used to collect data and the process in which emission estimates were developed. Figure 3.8 illustrates this process in a flow diagram for on-terminal and off-terminal activity.

Figure 3.8: HDDV Emission Estimating Process



3.3.1 Data Acquisition

Data for the HDDV emission estimates came from contacting the operator of each facility and requesting an update of the information provided for the previous inventory. Table 3.20 illustrates the range and average of reported characteristics of on-terminal HDDV activities at Port Authority marine terminals, which are leased to private operators for auto handling, container terminal, and warehouse operations.

Table 3.20: Summary of Reported On-Terminal Operating Characteristics

Maritime Operation	Annual Trips	Vehicle Miles Traveled	Average Speed (mph)	Average Idling Time (hours)
Auto-Handling Facilities	66,720	51,067	5	1.4
Container Terminals	3,943,709	4,768,800	15	0.5
Warehouses	221,240	122,658	15	0.7

The average idling times were based on information provided by the terminals. In addition, the prevalence of idling by trucks waiting at warehouses was evaluated by site observations made on two different days, to account for the fact that not all trucks idle while they are being unloaded or loaded at the warehouses. On average, 35% of trucks were observed to be idling while at the warehouses – the idling time figure in the table above reflects a weighted average idling time for all trucks, idling or not (i.e., the average was calculated by dividing total idling hours by total number of truck calls). The average idling time for an individual truck that does idle is 1.7 hours, according to survey responses.

On-Road

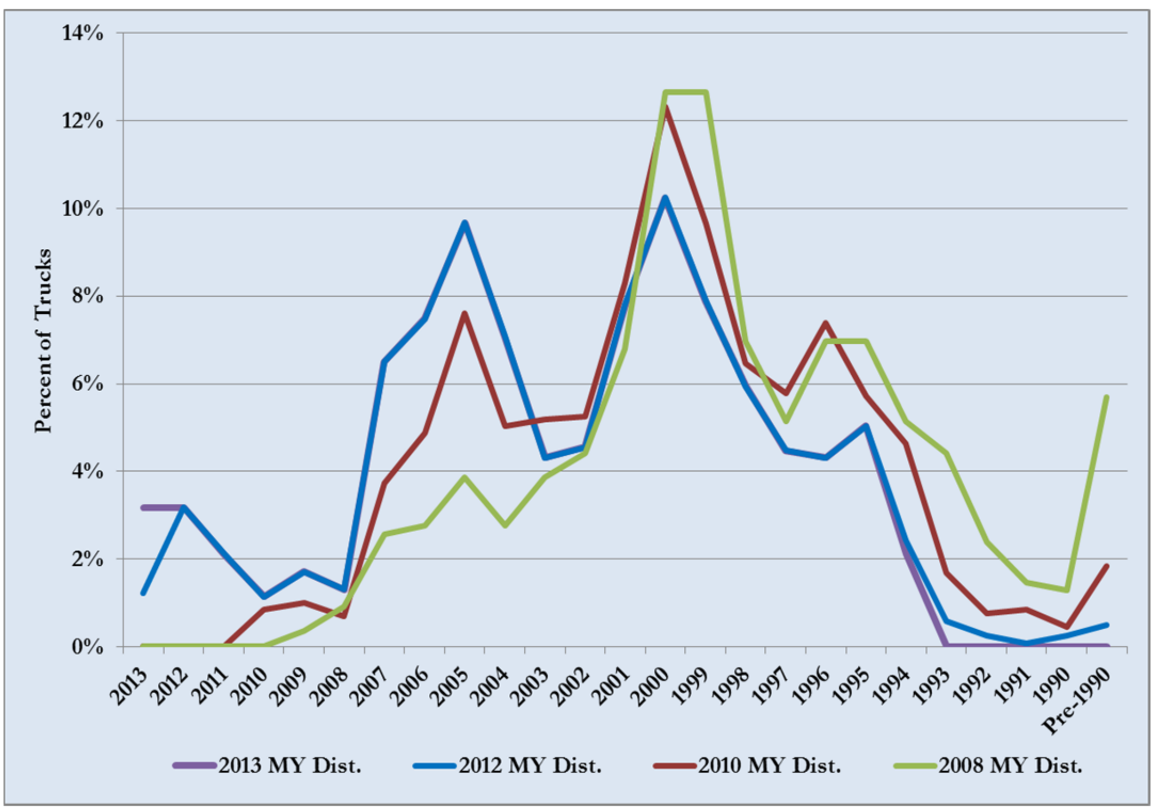
As used in previous HDDV Emissions Inventories, Vollmer's draft origin/destination study[22] was used for the 2012 emissions inventory update to determine travel distance characteristics in developing the on-road emission estimates. Since annual gate counts, truck characteristics, and on-terminal activity information were collected for each of the six container terminals through the Container Truck Survey, the origin/destination study was referred to for its information on the percentages of trucks traveling to and from each of the counties. Based on this information, vehicle miles of travel (VMT) were estimated for regional HDDV activity by estimating the average distances from the terminals to the counties in the NYNJLINA. These VMT estimates were used with appropriate emission factors to estimate on-road emissions. On-road transport associated with on-terminal warehouses and auto marine terminals, which follow processing of the marine cargo with freight from other sources, are secondary in nature and are considered part of the regional traffic structure and are therefore not included in this inventory

[22] Port Authority Marine Container Terminals – Truck Origin-Destination Survey 2005. Vollmer, November 2005 draft report, revised 2/27/2006

Model Year Distribution

The Port Authority conducted a model year survey of the drayage trucks calling on Port Authority marine container terminals in December 2012. This survey was an update to similar surveys conducted in 2008 and 2010 to collect information on the distribution of model years of the drayage trucks calling at the terminals, and other information. The information derived from the 2008, 2010, and 2012 surveys includes the model year distribution illustrated in Figure 3.9 for the trucks serving the Port Authority terminals. Model year is an important characteristic of drayage trucks because emission standards are applicable on a model year basis and newer trucks are generally subject to stricter (lower) emission standards than older trucks and, therefore, exhibit lower emissions. The 2012 model year distribution shows, in general, lower percentages of older model year trucks and higher percentages of newer model year trucks compared with the results of the previous two surveys. Since the 2012 drayage truck survey was conducted late in 2012, a repeat survey was not conducted in 2013. However, minor changes were made to the 2012 distribution to represent the addition of new trucks to the fleet, and the removal of the oldest trucks. While virtually identical to the distribution used for the 2012 emissions inventory the differences can be seen at the newer and older ends of the distribution shown in Figure 3.9. To the extent that more modernization of the fleet occurred than is reflected in the 2013 distribution shown below, fleet emissions may have been slightly overestimated. This may have contributed to the modest increase in emissions discussed in the comparison above.

Figure 3.9: Model Year Distribution



The container terminals at the Port Authority marine terminals are in the process of installing gate systems that make use of radio frequency identification (RFID) technology to identify and record drayage trucks that are registered as eligible to access the terminals. This is a potentially valuable source of information about the distribution of truck model years in Port goods movement service that may replace the periodic surveys that have been conducted. The RFID system, combined with the drayage truck registry, can provide an essentially complete picture of truck calls in a calendar year, providing for a robust model year distribution for a given year. While a drayage truck registry has been established, the RFID system was not operational in 2013 so there is no way of knowing which of the registered trucks actually called at a terminal, or how many times – which are essential components of developing a call-based model year distribution. The combination of RFID and registry information will be evaluated for upcoming inventories, and will be used to establish a model year distribution when sufficient data is available.

3.3.2 Emission Estimating Methodology

The general form of the equation for estimating vehicle emissions is:

E = EF * A

Where:

E = Emissions
EF = Emission Factor
A = Activity

Two types of activity are considered in estimating drayage truck emissions: engine running with vehicle moving at a given speed, and engine idling with vehicle at rest. Running emission factors are expressed in terms of grams per mile (g/mi) while idling emission factors are expressed in terms of grams per hour (g/hr). Therefore, the activity measure used for estimating running emissions is miles and the activity measure used for estimating idling emissions is hours. The emission factor (g/mi or g/hr) is multiplied by the activity measure vehicle miles traveled (VMT) or hours to estimate grams of emissions, which are then converted to pounds or tons as appropriate. The time period covered by the emission estimate corresponds to the time period of the activity measure. For example, an annual VMT figure multiplied by a gram per mile emission factor results in a gram per year emission estimate.

The emission factors have been developed using MOVES2014, which is the latest mobile source emissions model developed by EPA. Vehicle types, time periods, geographical areas, pollutants, vehicle operating characteristics, and road types are supplied by the user. MOVES2014 estimates emission factors for the pollutants included in this emission inventory, in grams per mile and grams per hour, for combination short-haul trucks. The emission factors developed by the model were adjusted to reflect the actual vehicle age distribution for trucks used at the Port Authority marine terminals. The model provides default information on operating parameters of the vehicle type specified. Combination short-haul truck is the vehicle type in MOVES2014 most closely associated with serving the marine terminals. They are defined in the model as combination tractor/trailer trucks with more than four tires with a range of operation up to 200 miles.

MOVES2014 running emission factors include the idle emissions associated with the drive cycle travel. The road types in MOVES2014 most closely associated with port drayage trucks are "urban unrestricted access," representing the activity of the trucks on marine terminal shared roadways and open public roads in the inventory area, and "urban restricted access," representing the activity of the trucks on the controlled access highways in the area. The emission factors developed for these two road types were averaged to obtain the emission factors used to estimate on-road emissions. The MOVES2014 model was also used to develop emission factors for the very slow-speed driving within the tenanted terminal boundaries, which averages a reported 15 miles per hour, and for on-terminal idling, both the low-idle experienced during the short-term idling of trucks in normal operation on the container terminals, and high idle rates utilized by automobile transport trucks to load vehicles at the auto terminals.

On-terminal and on-road emissions were calculated in a similar manner, by multiplying the activity value by the relevant emission factor. As an example, a mileage total of 100,000 VMT would be multiplied by the relevant NO_x emission factor (e.g., 17.271 g/mi for on-road travel):

$$\frac{100{,}000 \text{ miles/yr} \times 17.271 \text{ g/mi}}{453.6 \text{ g/lb} \times 2{,}000 \text{ lb/ton}} = 1.9 \text{ tons/yr}$$

Similarly, for on-terminal idling emissions, total idling hours per year would be multiplied by the NOx emission factor for idling. As an example:

$$\frac{100{,}000 \text{ hours/yr} \times 79.448 \text{ g/hour}}{453.6 \text{g/lb} \times 2{,}000 \text{ lb/ton}} = 8.8 \text{ tons/yr}$$

The MOVES2014-derived driving and idling emission factors for Class 8 HDDVs used in the emission estimates are presented in Table 3.21.

Table 3.21: HDDV Emission Factors (g/hr and g/mi)

Component of Operation	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2	N_2O	CH_4
Short-Term Idle (g/hr)	93.163	8.859	8.150	13.858	30.324	0.075	8,668	0.000	0.208
Extended Idle (g/hr)	227.86	6.114	5.625	56.782	90.165	0.079	9,212	0.000	5.926
On-Terminal (g/mi) (15 mph avg. speed)	20.016	1.463	1.346	1.680	7.461	0.023	2,672	0.000	0.032
On-Road (g/mi) MOVES highway/local	15.423	0.895	0.857	0.934	4.448	0.017	1,824	0.002	0.015

The extended idling emission rates shown in Table 3.21 are applicable for periods of idling above normal engine idling speeds to run equipment needed for safety, comfort, or operation of ancillary equipment. Container and warehouse trucks are not believed to idle for extended periods due to increased anti-idling signage and reported verbal warnings from terminal operators. This is supported by observations made by surveyors (including a primary author of this emissions inventory report) during the 2012 drayage truck survey at New Jersey and New York container terminals, when it was observed that drayage trucks were often shut off while not in actual use within or adjacent to the terminals. Automobile transport trucks reportedly operate at increased idle while loading vehicles to run equipment needed for the operation. Feedback on the surveys from the container, warehouse and auto handling facilities provided annual activity information for the on-terminal analysis.

Emissions were calculated as tons per year for each maritime operation, with idling and transit activities estimated separately. Table 3.22 summarizes the terminal operating characteristics by terminal/facility type. On-road emissions have been calculated in the same manner as on-terminal emissions, the VMT multiplied by the appropriate emission factor, as listed above. Vehicle miles traveled within each county of the NYNJLINA have been estimated using the Vollmer origin-destination study for HDDVs servicing the container terminals.

Table 3.22: On-Terminal HDDV Operating Characteristics

Terminal Type	Number Truck Calls (annual)	Distance on Facility (miles)	Average Idle Time Per Visit	Total Distance (miles)	Total Idle Time (hours)	Extended Idling? (>15 mins)
Automobile	32,956	0.25	1.45	8,239	47,786	Yes
Automobile	20,764	2.00	1.18	41,528	24,502	Yes
Automobile	13,000	0.10	1.56	1,300	20,280	Yes
Container	1,375,113	1.50	0.47	2,062,670	639,428	No
Container	976,524	1.00	0.54	976,524	522,440	No
Container	705,724	1.60	0.39	1,129,158	275,232	No
Container	537,677	1.00	0.38	537,677	204,317	No
Container	278,911	0.10	0.46	27,891	126,905	No
Container	69,760	0.50	0.44	34,880	30,694	No
Warehouse	80,000	0.25	0.81	20,000	64,800	No
Warehouse	52,000	0.05	0.61	2,600	31,720	No
Warehouse	40,000	1.50	0.88	60,000	35,200	No
Warehouse	22,500	0.20	0.35	4,500	7,875	No
Warehouse	10,000	2.00	0.13	20,000	1,300	No
Warehouse	7,800	1.50	0.08	11,700	624	No
Warehouse	3,120	0.25	0.17	780	530	No
Warehouse	3,120	0.90	0.45	2,808	1,404	No
Warehouse	2,700	0.10	0.34	270	918	No

3.4 Description of Heavy-Duty Diesel Vehicles

This section contains a description of HDDVs including their modes of operation in Port service, and the general types of vehicles. This emissions inventory includes emission estimates from HDDV operations at the following facilities in operation during 2012:

Table 3.23: Maritime Facilities by Type of HDDV Operation

Type of Operation	Marine Facility
Container Terminals	1. Port Newark Container Terminal (PNCT) at Port Newark 2. Maher Terminal at the Elizabeth PA Marine Terminal (EPAMT) 3. APM Terminal at EPAMT 4. New York Container Terminal at Howland Hook Marine Terminal 5. Red Hook Container Terminal, LLC secondary barge depot at Port Newark 6. Global Marine Terminal at the Port Jersey Port Authority Marine Terminal
Auto Marine Terminals	1. Toyota Logistics at Port Newark 2. Foreign Auto Preparation Services (FAPS) at Port Newark 3. BMW at the Port Jersey Port Authority Auto Marine Terminal
On-Terminal Warehouses at Port Newark/EPAMT/BPAMT	1. Phoenix Beverage 2. Harbor Freight Transport 3. Eastern Warehouse 4. Export Transport Co. 5. ASA Apple Inc. 6. Courier Systems 7. TRT International Ltd. 8. East Coast Warehouse & Distribution Corp. 9. P. Judge and Sons

3.4.1 Operational Modes

HDDVs are used extensively to move goods, particularly containerized cargo, to and from the marine terminals that serve as a bridge between land and sea transportation. HDDVs deliver goods to local, regional, and national destinations. Over the course of the day, HDDVs are driven onto and through these container, warehouse and/or auto-handling facilities where they deliver and/or pick up goods. They are also driven on the marine terminal roadways, which are roads situated within the boundaries of major, multi-facility terminals such as Port Newark/EPAMT, and on the public roads outside these complexes.

Areas of activity for which emissions have been estimated include on-terminal (dropping off or picking up cargo) and on the public roads throughout the counties discussed in Section 1.

- On-terminal operations include driving through the terminal to drop off and/or pick up cargo, and idling while queuing, loading / unloading, and departing the terminal.
- On-road operations consist of HDDV origin/destination moves from/to the first point of rest within, or out to the limits of, the NYNJLINA region.

The "first point of rest" is the location at which import cargo (received from ships) is transferred from the first means of transport out of the arrival terminal to the ground or to another mode of transportation (such as truck-to-rail transfer). This occurs, for example, at the warehouse facilities when a container is moved from ship-side to a warehouse for transloading, which is the process of unloading import shipping containers and repacking them into other containers or enclosed trailers for transport to multiple destinations. Some warehouses are located in the vicinity of the Port Authority marine terminals while others are located within 100 miles of the Port. For example, HDDVs transport cargo from the port area to warehouses located in the lower Hudson Valley, New York, northeastern Pennsylvania, the Philadelphia area, and northern Baltimore /Delaware area.

3.4.2 Vehicle Types

This inventory deals exclusively with diesel-fueled HDDVs because these are the types of vehicles reported by the terminal operators and are by far the most prevalent type of vehicle in this service. The most common configuration of HDDV is the articulated tractor-trailer (truck and semi-trailer) having five axles, including the trailer axles. The most common type of trailer in this study area is the container trailer (known as a chassis), built to accommodate standard sized cargo containers. Another common configuration is the bobtail, which is a tractor traveling without an attached trailer. Other types include auto-carriers and flatbeds. These vehicles are all classified as HDDVs regardless of their actual weight because their classification is based on GVWR. The emissions estimates developed by the current regulatory model (discussed in subsection 3.3) do not distinguish among different configurations (e.g., whether loaded or unloaded). In the 2008, 2010, and 2012 HDDV model year surveys, most of the HDDVs were in the heaviest category, 60,000 - 80,000 pounds GVWR, with the remainder being in the 33,000 – 60,000-pound category.

Figure 3.10 is an illustration of a container truck transporting a container in a container terminal, while Figure 3.11 illustrates a truck without an attached trailer, known as a bobtail. These are typical of trucks in use at Port Authority marine terminals and are provided for illustrative purposes.

Figure 3.10: HDDV with Container

Figure 3.11: HDDV - Bobtail

SECTION 4: RAIL LOCOMOTIVES

This section presents estimated emissions from the locomotives that visit and serve the Port Authority's marine container terminals and discusses the methodologies used in developing the estimates. For the purpose of developing the emissions estimates, locomotive activity has been considered in two general categories, line haul and switching activity. Line haul activity refers to the movement of import and export cargo from and to these Port Authority marine terminals to and from locations outside the boundary of the Port Authority facilities but within the NYNJLINA, or to and from the boundary of the NYNJLINA for trains that travel beyond the area. Switching locomotive activity includes activity related to movement of cargo within the boundaries of the following Port Authority marine terminals:

- Port Newark
- The Elizabeth Port Authority Marine Terminal
- The Port Jersey Port Authority Marine Terminal
- ExpressRail at Howland Hook, Staten Island

In addition, one container terminal operates a single switching locomotive to move rail cars on their terminal., Also, the Port Authority operates a service that uses switching locomotives to move rail cars onto and off of barges in a service that runs between the Greenville Yard in Jersey City (in Hudson Co., NJ) and the 65th St. Yard in Brooklyn (in Kings Co., NY). These switching operations are also included in the emission estimates.

After an executive summary, the following four subsections focus on:

- 4.1 - Locomotive Emission Estimates
- 4.2 - Locomotive Emission Comparisons
- 4.3 - Methodology
- 4.4 - Description of Train Activity and Locomotives

ES4.1 Executive Summary

Table ES4-1 presents the estimated locomotive criteria pollutant and CO_2 emissions in the context of overall emissions in the states of New York and New Jersey, and in the NYNJLINA, including emissions in tons per year and the percentage that PANYNJ locomotive emissions make up of overall NYNJLINA emissions.[23]

Table ES4.1: Comparison of PANYNJ Locomotive Emissions with State and NYNJLINA Emissions, tpy

Geographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq
New York and New Jersey	590,117	333,133	120,143	601,318	2,994,198	167,504	229,371,430
NYNJLINA	280,279	76,854	37,170	266,786	1,373,551	49,836	117,276,953
Railroad Locomotives	257	9	9	19	49	0.2	18,382
Percent of NYNJLINA Emissions	0.09%	0.01%	0.02%	0.007%	0.004%	0.000%	0.02%

The following figures illustrate the distribution of PANYNJ switching and line haul locomotive emissions in terms of tons per year and percent of total locomotive emissions, and in the context of overall NYNJLINA emissions. The NYNJLINA emissions are broken down into on-road mobile sources, other (non-road) mobile sources, and stationary and area sources. Note that the percentages shown in these charts do not always sum to 100% because of rounding. The charts are intended to illustrate the relative magnitude of emission sources at the port and in the region.

[23] 2011 and 2008 National Emission Inventory Databases, US EPA, as cited above.

Figure ES4.1: Distribution and Comparison of NO_x from Locomotives, tpy and %

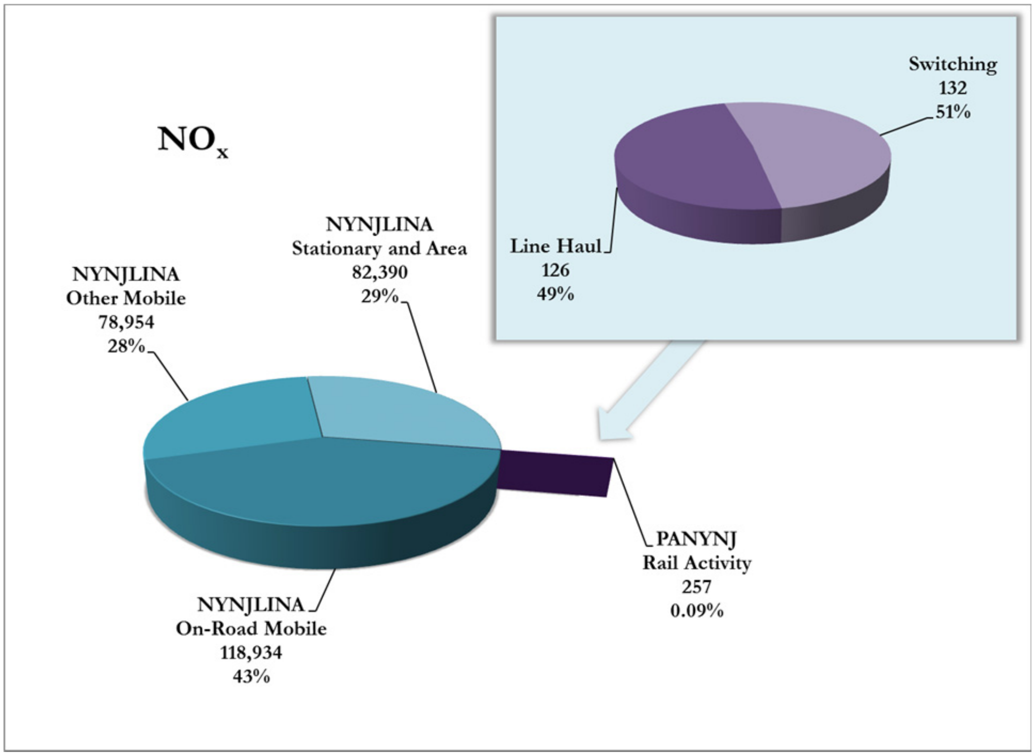


Figure ES4.2: Distribution and Comparison of PM_{10} from Locomotives, tpy and %

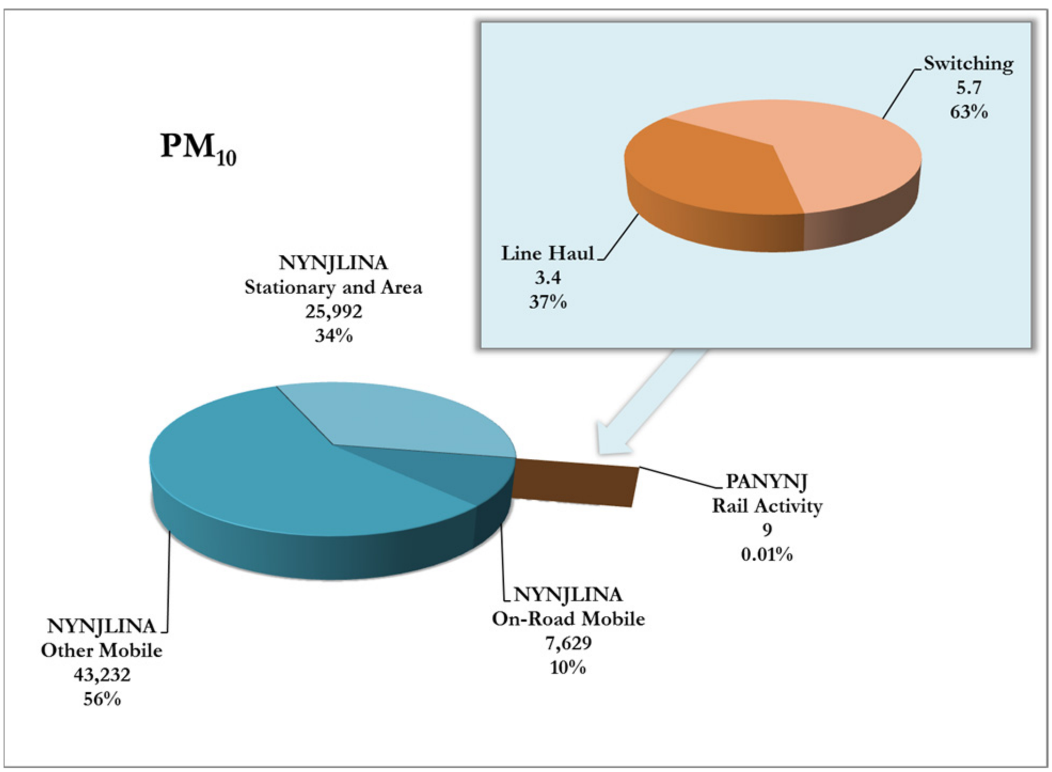


Figure ES4.3: Distribution and Comparison of $PM_{2.5}$ from Locomotives, tpy and %

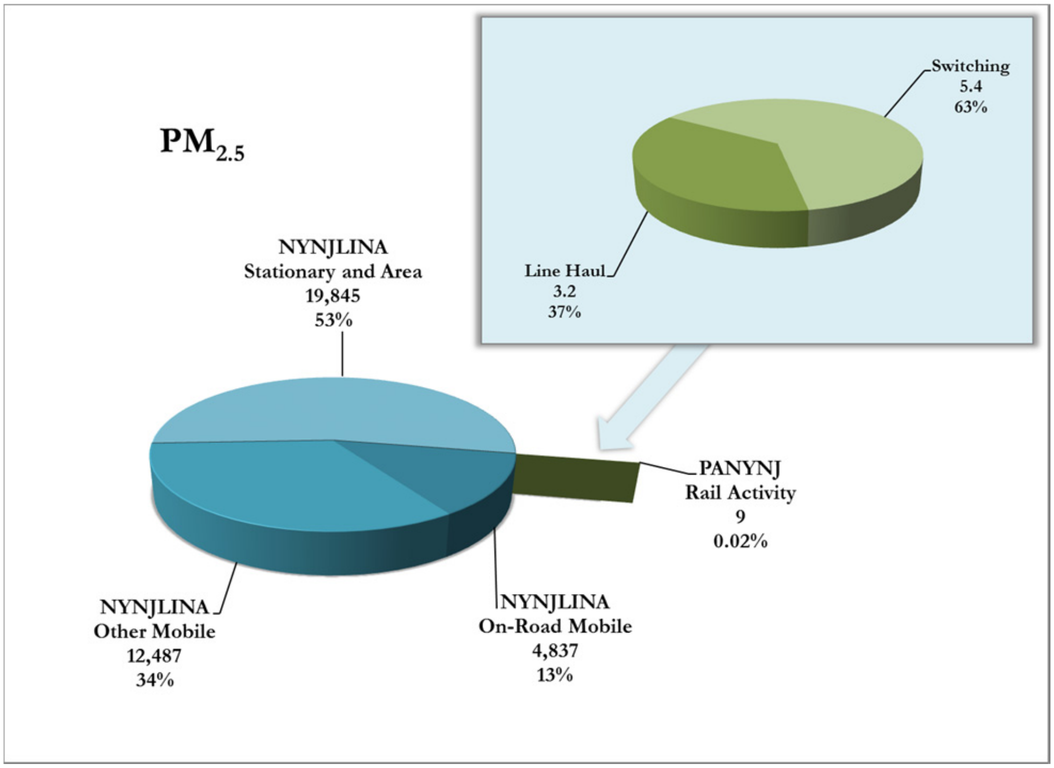


Figure ES4.4: Distribution and Comparison of VOC from Locomotives, tpy and %

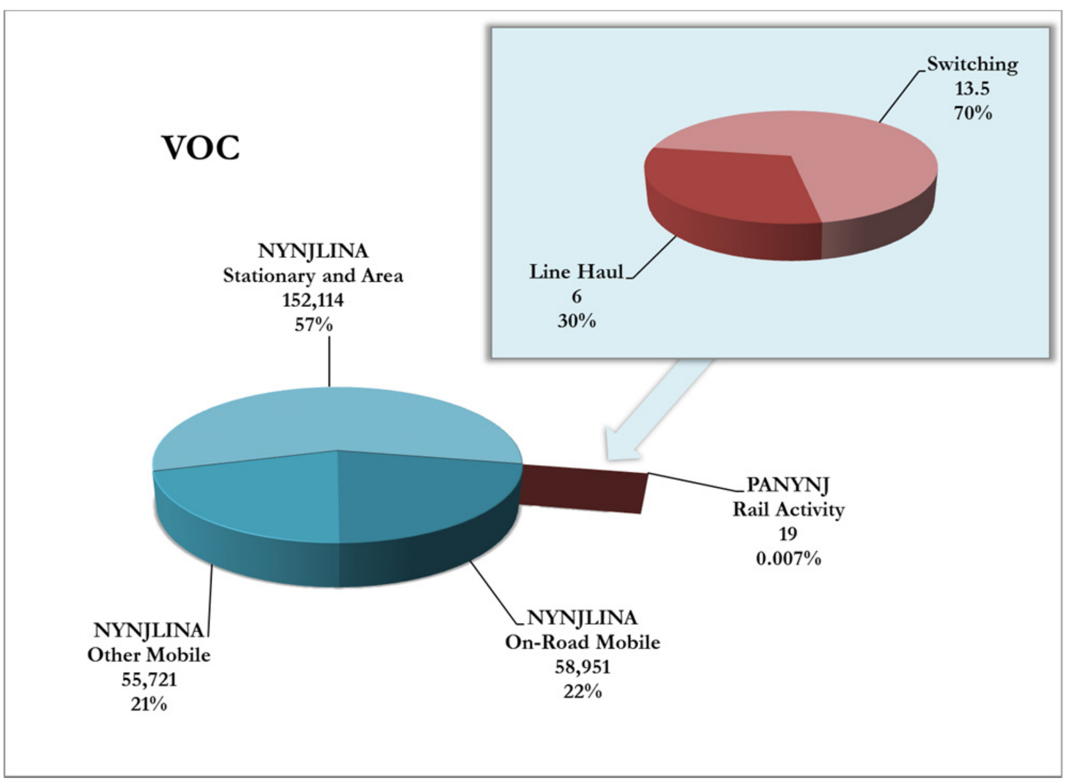


Figure ES4.5: Distribution and Comparison of CO from Locomotives, tpy and %

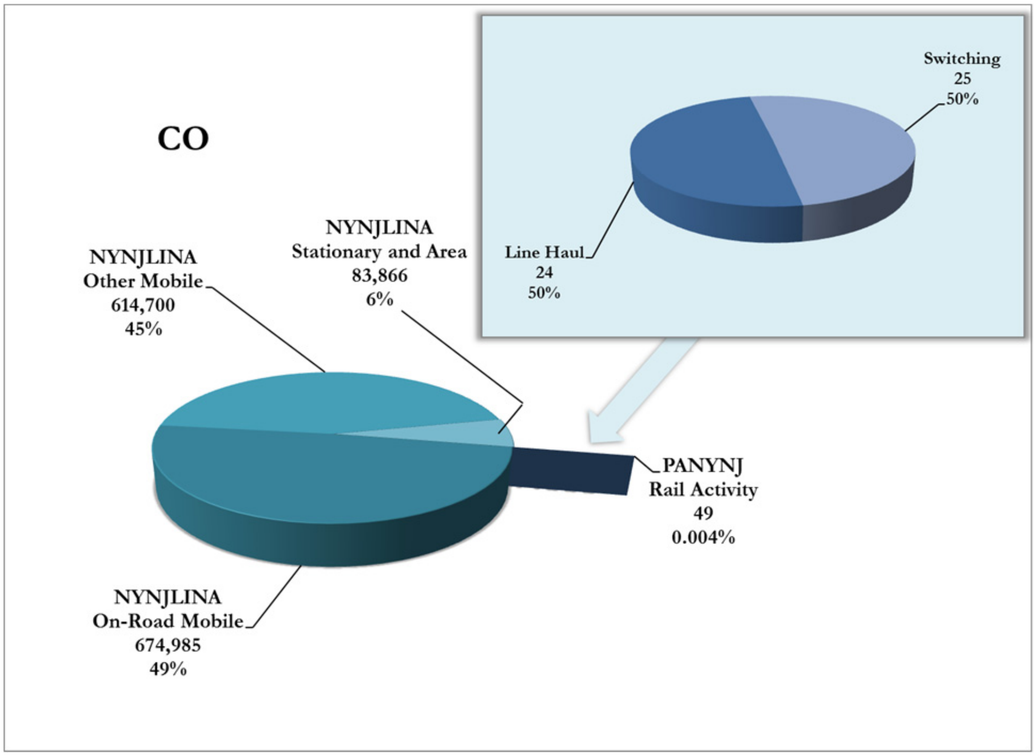


Figure ES4.6: Distribution and Comparison of SO_2 from Locomotives, tpy and %

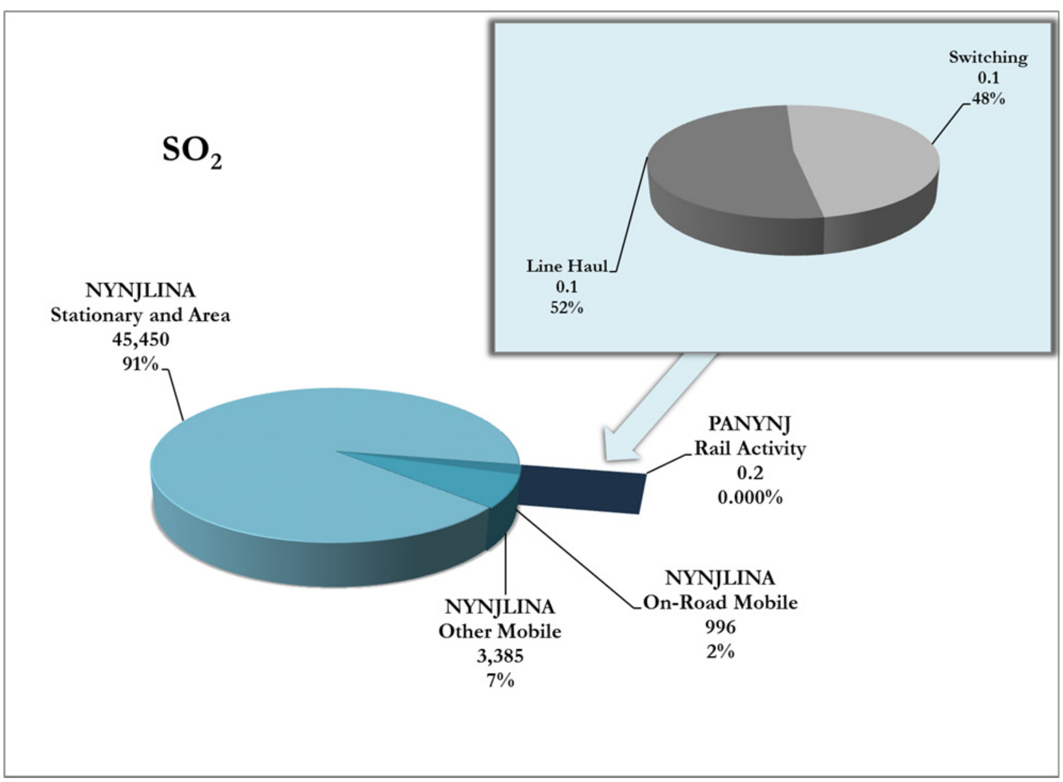
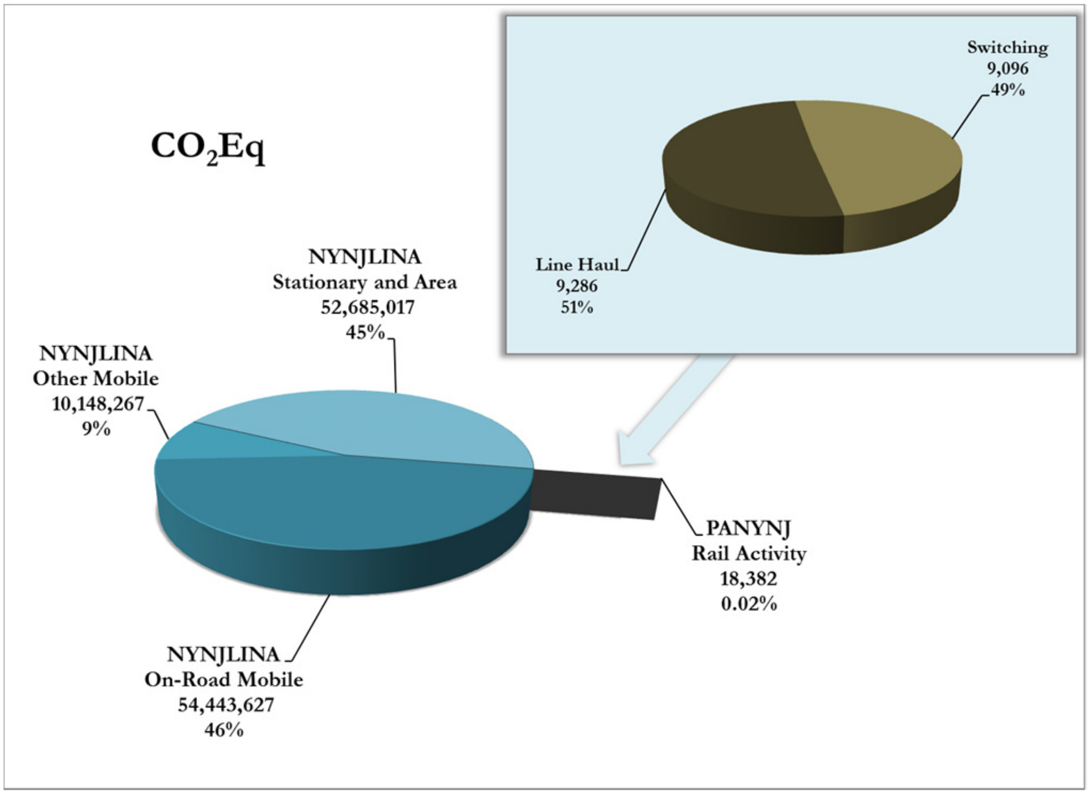


Figure ES4.7: Distribution of CO_2 Eq from Locomotives, tpy and %



4.1 Locomotive Emission Estimates

This subsection presents the estimated emissions from line haul and switching activities associated with the Port Authority marine terminals. The relationships between these emissions and overall county and state emissions are presented and discussed in Section 4.2.

The emission estimates presented in this document are listed in several ways to provide as much information to the reader as possible. The emissions are presented by terminal or facility type, by type of activity, and by county and state. Because of these different modes of display, the numerical values must be rounded, displayed, and summed in different ways. Because of this, it is not always possible to display values in a table that sum exactly to the total shown at the bottom of the table. In developing the tables, priority has been given to maintaining consistent totals for each pollutant across table types.

Table 4.1 summarizes the line haul and criteria pollutant emissions, and Table 4.2 summarizes greenhouse gas emissions.

Table 4.1: Locomotive Criteria Pollutant Emission Estimates, tons per year

Activity Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Line Haul	126	3.4	3.2	5.9	24.1	0.1
Switching	132	5.7	5.4	13.5	24.5	0.1
Totals	**257.2**	**9.2**	**8.6**	**19.4**	**48.6**	**0.2**

Table 4.2: Locomotive Greenhouse Gas Emission Estimates, tons per year

Activity Type	CO_2	N_2O	CH_4	CO_2 Eq
Line Haul	9,202	0.22	0.73	9,286
Switching	9,011	0.21	0.63	9,096
Totals	**18,213**	**0.43**	**1.36**	**18,382**

4.2 Locomotive Emission Comparisons

This subsection presents locomotive emission estimates detailed in section 4.1 in the context of county-wide and non-attainment area-wide emissions, and also presents a comparison of 2013 locomotive emissions with the results of earlier emissions inventories.

4.2.1 Comparisons with County and Regional Emissions

Port Authority marine terminal-related locomotive emissions are compared with all emissions in the NYNJLINA counties on a county-by-county basis. Overall county-level emissions were excerpted from the most recent National Emissions Inventory database.[24] Locomotive emissions are apportioned to the county level through a determination of the percentage of railroad track transiting individual counties vs. the regional track length. Thus emissions were calculated for rail trips at the county level, and were summed to yield the regional total. A more detailed discussion of the rail emission calculation methodology is presented in Section 4.3.

[24] See: 2008 and 2011 National Emission Inventory Database, U.S. EPA, *http://www.epa.gov/ttn/chief/net/2008inventory.html#inventorydata*

Table 4.3 presents estimated criteria pollutant emissions from the Port Authority marine terminal-related locomotive activity reported in this current inventory, at the county level. Subsequent Tables 4.4 through 4.10 present each pollutant individually, comparing Port related locomotive emissions with total county level emissions. Figures 4.1 through 4.7 summarize the same information visually on an individual county basis. Each column displays the county-wide emissions, and the Port Authority marine terminal locomotive contribution to total emissions is shown on top of the county-wide column.

Table 4.3: Summary of Locomotive Criteria Pollutant Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2Eq
Bergen	NJ	28.2	0.8	0.7	1.3	5.4	0.0	2,088
Essex	NJ	100.3	4.2	4.0	9.9	19.0	0.1	7,055
Hudson	NJ	25.9	0.7	0.7	1.2	4.9	0.0	1,882
Middlesex	NJ	4.4	0.1	0.1	0.2	0.9	0.0	327
Monmouth	NJ	0.0	0.0	0.0	0.0	0.0	0.0	0
Union	NJ	41.2	1.6	1.5	3.5	7.8	0.0	2,933
New Jersey subtotal		**199.9**	**7.4**	**7.0**	**16.2**	**38.0**	**0.2**	**14,285**
Bronx	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Kings (Brooklyn)	NY	1.6	0.1	0.1	0.1	0.2	0.0	86
Nassau	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
New York	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Orange	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Queens	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Richmond (Staten Isld)	NY	10.5	0.4	0.4	1.0	1.8	0.0	670
Rockland	NY	45.2	1.2	1.1	2.1	8.7	0.0	3,341
Suffolk	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Westchester	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
New York subtotal		**57.3**	**1.7**	**1.6**	**3.2**	**10.6**	**0.0**	**4,097**
TOTAL		**257**	**9**	**9**	**19**	**49**	**0.2**	**18,382**

Table 4.4: Comparison of Locomotive NO_x Emissions with Overall NO_x Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	14,798	28	0.19%
Essex	NJ	17,195	100	0.58%
Hudson	NJ	9,585	26	0.27%
Middlesex	NJ	14,766	4.4	0.03%
Monmouth	NJ	10,366	0.0	0.00%
Union	NJ	12,325	41	0.33%
New Jersey Subtotal		**79,035**	**200**	**0.25%**
Bronx	NY	13,195	0.0	0.00%
Kings (Brooklyn)	NY	25,190	1.6	0.01%
Nassau	NY	21,973	0.0	0.00%
New York	NY	33,432	0.0	0.00%
Orange	NY	11,854	0.0	0.00%
Queens	NY	31,678	0.0	0.00%
Richmond (Staten Isld)	NY	10,793	10.5	0.10%
Rockland	NY	5,622	45	0.80%
Suffolk	NY	30,558	0.0	0.00%
Westchester	NY	16,949	0.0	0.00%
New York Subtotal		**201,244**	**57**	**0.03%**
TOTAL		**280,279**	**257**	**0.09%**

Figure 4.1: Comparison of Locomotive NO_x Emissions with Overall NO_x Emissions by County, tpy

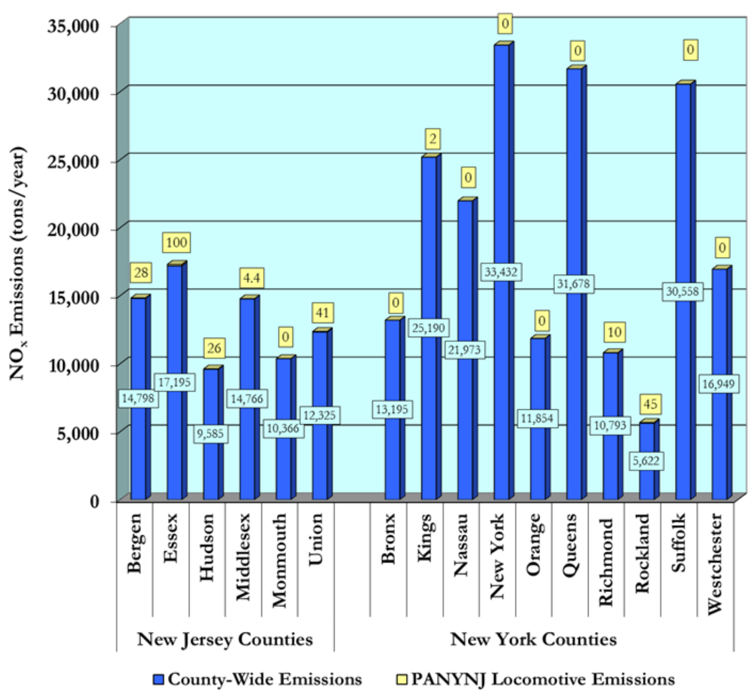


Table 4.5: Comparison of Locomotive PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	3,565	0.8	0.02%
Essex	NJ	5,233	4.2	0.08%
Hudson	NJ	1,732	0.7	0.04%
Middlesex	NJ	4,288	0.1	0.003%
Monmouth	NJ	3,334	0	0%
Union	NJ	2,787	1.6	0.06%
New Jersey Subtotal		**20,939**	**7**	**0.04%**
Bronx	NY	2,605	0	0%
Kings (Brooklyn)	NY	4,779	0	0%
Nassau	NY	5,840	0	0%
New York	NY	6,363	0	0%
Orange	NY	7,595	0	0%
Queens	NY	5,244	0	0%
Richmond (Staten Isld)	NY	1,885	0	0%
Rockland	NY	1,993	1.2	0.06%
Suffolk	NY	12,931	0	0%
Westchester	NY	6,680	0	0%
New York Subtotal		**55,915**	**2**	**0.003%**
TOTAL		**76,854**	**9**	**0.01%**

Figure 4.2: Comparison of Locomotive PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

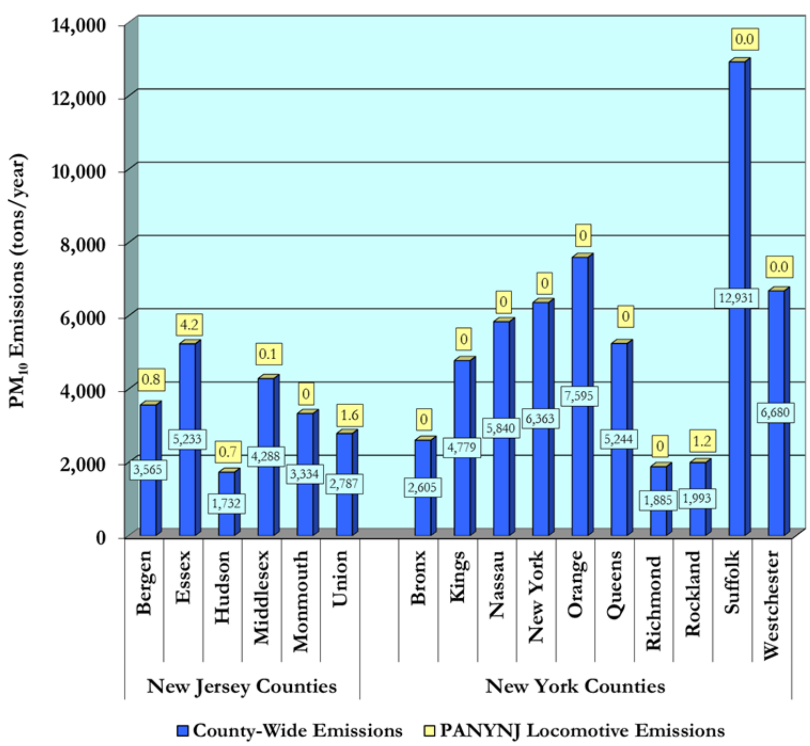


Table 4.6: Comparison of Locomotive $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	2,101	0.7	0.03%
Essex	NJ	2,574	4.0	0.16%
Hudson	NJ	1,284	0.7	0.05%
Middlesex	NJ	2,335	0.1	0.00%
Monmouth	NJ	1,737	0	0%
Union	NJ	1,877	1.5	0.08%
New Jersey Subtotal		**11,908**	**7**	**0.1%**
Bronx	NY	1,474	0	0%
Kings (Brooklyn)	NY	2,693	0	0%
Nassau	NY	2,740	0	0%
New York	NY	3,199	0	0%
Orange	NY	2,462	0	0%
Queens	NY	3,030	0	0%
Richmond (Staten Isld)	NY	1,090	0	0%
Rockland	NY	801	1.1	0.14%
Suffolk	NY	5,117	0	0%
Westchester	NY	2,656	0	0%
New York Subtotal		**25,262**	**2**	**0.01%**
TOTAL		**37,170**	**9**	**0.02%**

Figure 4.3: Comparison of Locomotive $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

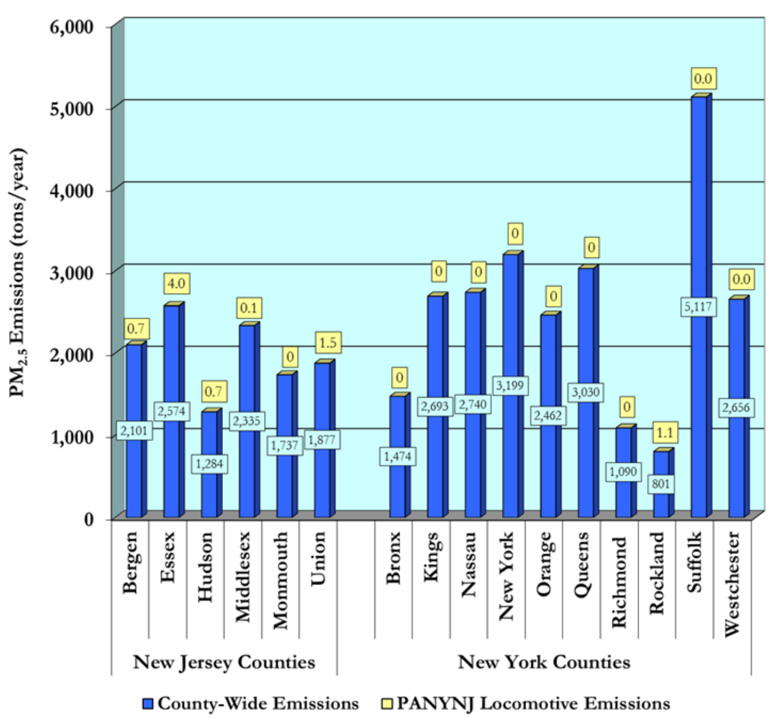


Table 4.7: Comparison of Locomotive VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	17,028	1.3	0.008%
Essex	NJ	16,814	9.9	0.059%
Hudson	NJ	9,244	1.2	0.013%
Middlesex	NJ	16,653	0.2	0.001%
Monmouth	NJ	12,551	0	0%
Union	NJ	11,037	3.5	0.03%
New Jersey Subtotal		**83,327**	**16**	**0.02%**
Bronx	NY	14,156	0	0%
Kings (Brooklyn)	NY	26,367	0	0%
Nassau	NY	21,541	0	0%
New York	NY	21,185	0	0%
Orange	NY	9,654	0	0%
Queens	NY	27,358	0	0%
Richmond (Staten Isld)	NY	6,576	1	0%
Rockland	NY	5,701	2.1	0.037%
Suffolk	NY	33,256	0	0%
Westchester	NY	17,665	0	0%
New York Subtotal		**183,459**	**3**	**0.002%**
TOTAL		**266,786**	**19**	**0.007%**

Figure 4.4: Comparison of Locomotive VOC Emissions with Overall VOC Emissions by County, tpy

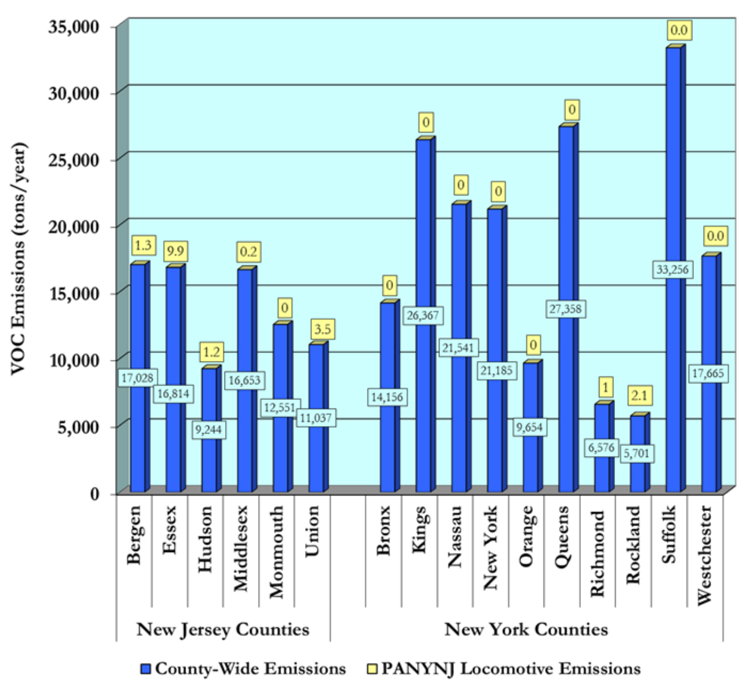


Table 4.8: Comparison of Locomotive CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	110,855	5.4	0.005%
Essex	NJ	79,450	19.0	0.024%
Hudson	NJ	37,073	4.9	0.013%
Middlesex	NJ	87,617	0.9	0.0010%
Monmouth	NJ	74,655	0.0	0.00%
Union	NJ	55,299	7.8	0.01%
New Jersey Subtotal		**444,949**	**38**	**0.009%**
Bronx	NY	52,643	0.0	0.000%
Kings (Brooklyn)	NY	101,980	0.2	0.000%
Nassau	NY	124,041	0.0	0.000%
New York	NY	124,401	0.0	0.000%
Orange	NY	48,412	0.0	0.000%
Queens	NY	123,921	0.0	0.000%
Richmond (Staten Isld)	NY	33,262	1.8	0.005%
Rockland	NY	32,711	8.7	0.027%
Suffolk	NY	182,114	0.0	0.000%
Westchester	NY	105,117	0.0	0.000%
New York Subtotal		**928,602**	**11**	**0.0011%**
TOTAL		**1,373,551**	**49**	**0.004%**

Figure 4.5: Comparison of Locomotive CO Emissions with Overall CO Emissions by County, tpy

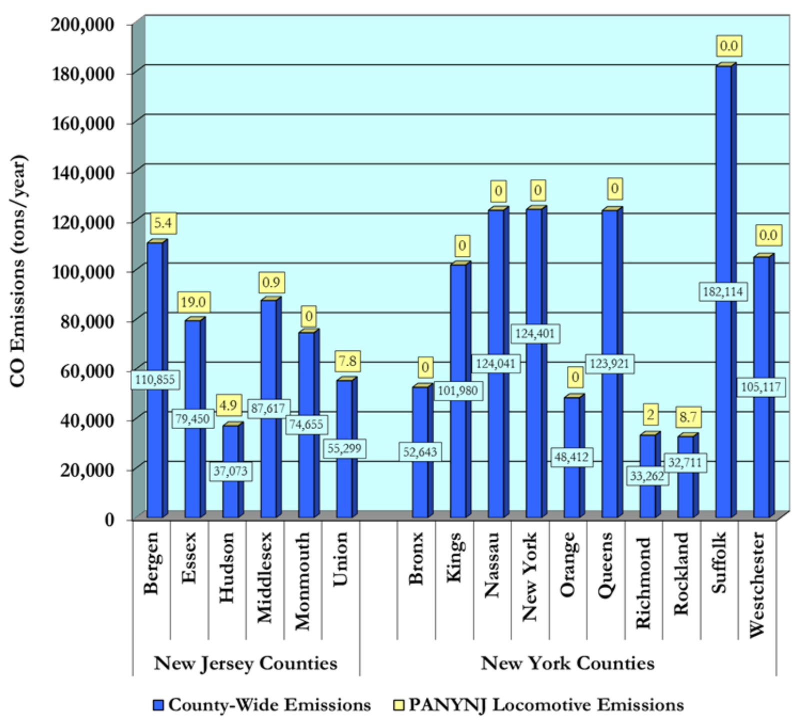


Table 4.9: Comparison of Locomotive SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	679	0.0	0.004%
Essex	NJ	2,630	0.1	0.003%
Hudson	NJ	1,817	0.0	0.001%
Middlesex	NJ	771	0.0	0.001%
Monmouth	NJ	671	0.0	0.000%
Union	NJ	1,053	0.0	0.003%
New Jersey Subtotal		**7,621**	**0.2**	**0.002%**
Bronx	NY	1,769	0.0	0.000%
Kings (Brooklyn)	NY	2,021	0.0	0.000%
Nassau	NY	3,045	0.0	0.000%
New York	NY	6,776	0.0	0.000%
Orange	NY	10,728	0.0	0.000%
Queens	NY	2,932	0.0	0.000%
Richmond (Staten Isld)	NY	383	0.0	0.001%
Rockland	NY	461	0.0	0.008%
Suffolk	NY	11,488	0.0	0.000%
Westchester	NY	2,612	0.0	0.000%
New York Subtotal		**42,215**	**0.0**	**0.000%**
TOTAL		**49,836**	**0.2**	**0.0004%**

Figure 4.6: Comparison of Locomotive SO_2 Emissions with Overall SO_2 Emissions by County, tpy

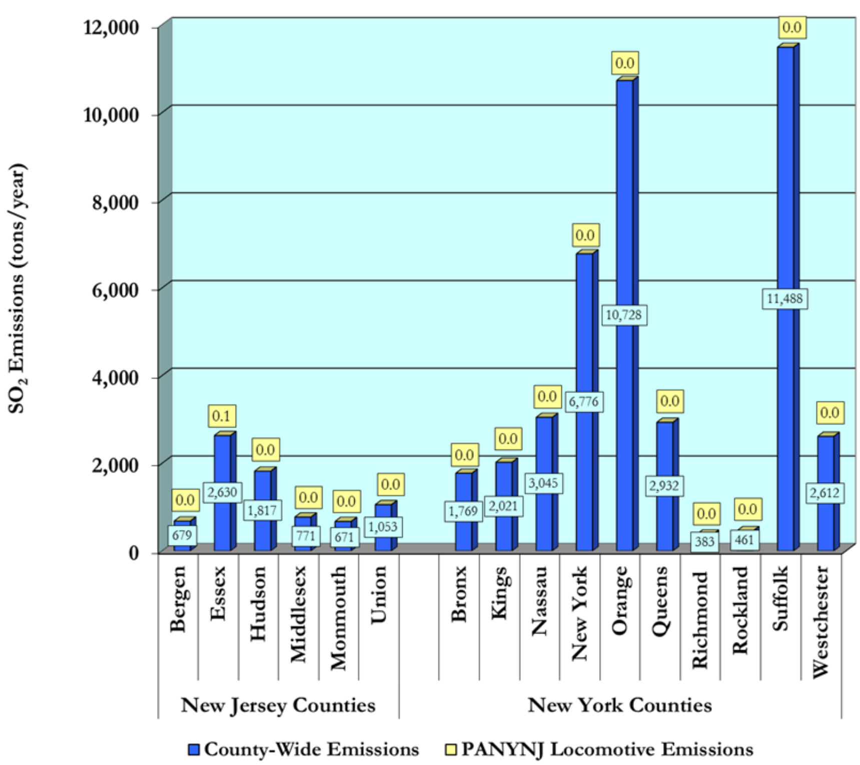
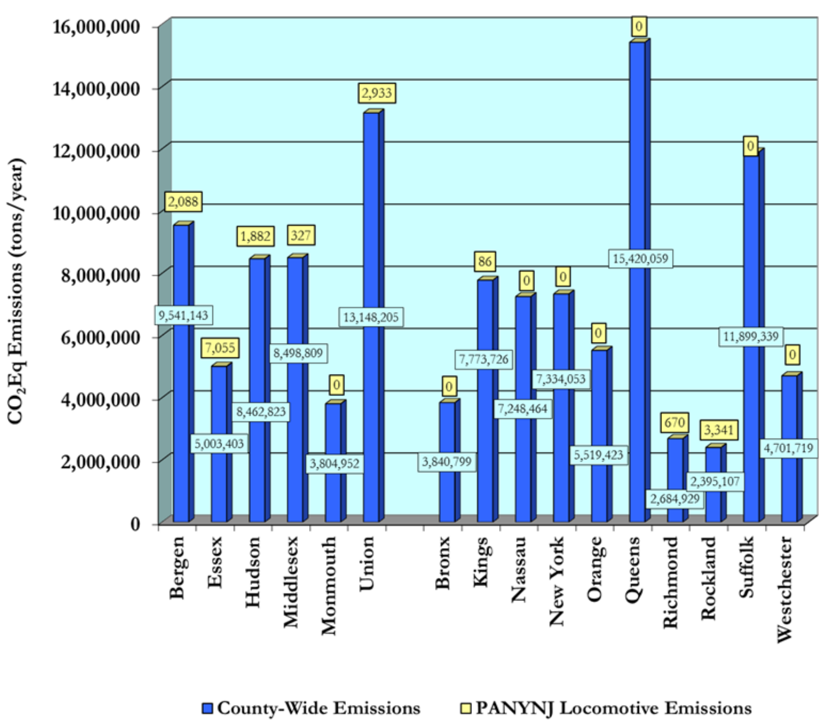


Table 4.10: Comparison of Locomotive CO_2 Emissions with Overall CO_2 Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	9,541,143	2,088	0.02%
Essex	NJ	5,003,403	7,055	0.14%
Hudson	NJ	8,462,823	1,882	0.02%
Middlesex	NJ	8,498,809	327	0.00%
Monmouth	NJ	3,804,952	0	0.00%
Union	NJ	13,148,205	2,933	0.02%
New Jersey Subtotal		**48,459,335**	**14,285**	**0.03%**
Bronx	NY	3,840,799	0	0.00%
Kings (Brooklyn)	NY	7,773,726	86	0.00%
Nassau	NY	7,248,464	0	0.00%
New York	NY	7,334,053	0	0.00%
Orange	NY	5,519,423	0	0.00%
Queens	NY	15,420,059	0	0.00%
Richmond (Staten Isld)	NY	2,684,929	670	0.02%
Rockland	NY	2,395,107	3,341	0.14%
Suffolk	NY	11,899,339	0	0.00%
Westchester	NY	4,701,719	0	0.00%
New York Subtotal		**68,817,618**	**4,097**	**0.01%**
TOTAL		**117,276,953**	**18,382**	**0.02%**

Figure 4.7: Comparison of Locomotive CO_2 Emissions with Overall CO_2 Emissions by County, tpy



4.2.2 Comparisons with Prior Year Emission Estimates

Table 4.11 presents the annual locomotive emissions as estimated in the respective emissions inventories, the percentage difference between each prior inventory's adjusted emissions and the 2013 estimates, emissions in tons per million TEUs, and the percentage differences in tons per million TEUs between the prior years and 2013. Since the addition of the container terminal and cruise terminal did not affect rail transport of cargo and hence did not affect locomotive emissions no adjustments have been made to this source category's prior year emission estimates.

Table 4.11: Comparison of 2013 Locomotive Emissions with Prior year Estimates, tons per year and percent

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq	Million TEUs
Tons per year, as published								
2013	257	9.2	8.6	19	49	0.2	18,382	5.467
2012	266	9.4	9.0	20	49	1.3	18,458	5.530
2010	261	9.2	8.7	20	46	3.8	17,364	5.007
2008	268	9.7	9.0	20	45	3.8	17,183	4.711
2006	286	10.2	9.4	20	44	32	14,710	4.657
Percent change relative to 2013 - tons per year								
2012 - 2013	-3%	-2%	-5%	-5%	0%	-84%	0%	-1%
2010 - 2013	-1%	0%	-1%	-5%	7%	-95%	6%	9%
2008 - 2013	-4%	-5%	-5%	-5%	9%	-95%	7%	16%
2006 - 2013	-10%	-10%	-9%	-5%	11%	-99%	25%	17%
Tons per million TEU								
2013	47	1.7	1.6	3.5	9.0	0.04	3,362	
2012	48	1.7	1.6	3.6	8.9	0.24	3,338	
2010	52	1.8	1.7	4.0	9.2	0.76	3,468	
2008	57	2.1	1.9	4.2	9.6	0.81	3,647	
2006	61	2.2	2.0	4.3	9.4	6.87	3,159	
Percent change relative to 2013 - tons per million TEU								
2012 - 2013	-2%	0%	0%	-3%	1%	-83%	1%	
2010 - 2013	-10%	-6%	-6%	-13%	-2%	-95%	-3%	
2008 - 2013	-18%	-19%	-16%	-17%	-6%	-95%	-8%	
2006 - 2013	-23%	-23%	-20%	-19%	-4%	-99%	6%	

4.3 Locomotive Emission Calculation Methodology

There is no regulatory model available for determining rail emissions (such as the MOVES2014 model used for CHE and HDDVs); therefore, emissions from locomotives have been estimated using available information and emission factors published by EPA. The following subsections detail the methodology used to develop line haul and switching emission estimates.

4.3.1 Line Haul Emissions

The information obtained regarding line haul rail service includes the total number of containers moved into and out of the Port Authority's marine terminals via rail,[25] the rail line routes used to transport these goods, an approximate schedule for these trains, and the average length of primary scheduled trains. This data has been used to estimate the total amount of fuel used by the locomotives and hence the associated emissions.

The basis of the line haul emission estimates is the amount of fuel used in the transport of cargo to and from the Port Authority marine terminals – fuel usage has been estimated using the number of train trips, train weights, and distance. Step one in this process estimates the number and lengths of trains used to transport this cargo. Step 2 estimates the weight of each of these trains (gross tons, the weight of cargo, rail cars, and locomotives); the final calculation of emissions from these trains is based on multiplying the weight moved by the distance over which the trains traveled, and multiplying the resulting estimate of gross ton-miles (GTM) by a conversion factor to estimate gallons of fuel and by fuel-based emission factors expressed as grams of emissions per million gross ton-miles (g/MMGTM)..

The emission factors for most pollutants (NO_x, PM, HC, CO) come from an EPA publication[26] issued in support of locomotive rulemaking. The EPA factors are published as energy-based factors, in units of grams per horsepower-hour. These factors have been converted to fuel-based factors using a conversion factor of 20.8 horsepower-hours per gallon of fuel, published in the same EPA document cited above. Emission factors for SO_2 and CO_2 have been developed using a mass balance approach (based on the typical amounts of sulfur and carbon in diesel fuel). The SO_2 emission factor was calculated using a mass-balance method with an assumed diesel fuel sulfur content of 19 ppm in 2013. The average 19 ppm is based on EPA's Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder.[27] The emission factors for N_2O and CH_4 were obtained from an EPA publication on greenhouse gases.[28] The emission factors for line haul locomotives are presented in Table 4.12.

Table 4.12: Line-Haul Locomotive Emission Factors

Units	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
g/gal	139	3.8	3.5	6.5	26.7	0.12	10,186	0.25	0.79
g/hp-hr	6.7	0.18	0.17	0.31	1.28	0.01	489	0.012	0.038

[25] Information provided by PANYNJ by email 3 December 2013.

[26] "Emission Factors for Locomotives," EPA-420-F-09-025, Office of Transportation and Air Quality, April 2009

[27] *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder,* EPA420-R-08-001, March 2008.

[28] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2009; April 2011; Table A- 129: Emission Factors for CH4 and N2O Emissions from Non-Highway Mobile Combustion (g gas/kg fuel).

Gross weights of the primary scheduled trains servicing the marine terminals have been estimated through the average number of containers carried by each train, an average weight value provided by the Port Authority, and the average length of the trains. Each railroad serving the marine terminals operates one inbound and one outbound primary train per day. Because the balance of trade favors imports, there is a need for an additional outbound train that carries fewer containers than the primary train. The process involves balancing the annual number and average capacity of the scheduled trains with the total number of containers moved by rail during the year. The starting point is the average length and schedule of primary trains servicing each marine terminal from the 2005 Port Authority rail utilization study.[29]

Using the nominal length of the scheduled trains as a starting point, the average length and capacity of the secondary trains was estimated for each of the two railroads. Table 4.13 presents the parameters and estimated average lengths of the inbound and outbound trains of both railroads. The terms in the column headings are the railroads' designations for the train service.

Table 4.13: Line-Haul Train Length Assumptions

Parameters	Q159 Outbound	Q162 Outbound	Q112 Inbound	25V Outbound	23M Outbound	24V Inbound
# of 5-platform cars per train	28	16	28	8	18	14
Length of 5-platform car, feet	300	300	300	300	300	300 feet
Length of cargo, feet	8,400	4,800	8,400	2,400	5,400	4,200 feet
Length of 1 locomotive, feet	70	70	70	70	70	70 feet
# of locomotives per train	2	2	2	1	2	2
Total locomotive length, feet	140	140	140	140	140	140 feet
Total train length	**8,540**	**4,940**	**8,540**	**2,540**	**5,540**	**4,340 feet**

The total train length is calculated by multiplying the number of railcars by each car's length, and adding the number and length of locomotives, as listed in the table. In order to validate the length assumptions, the number of containers that would be carried by each length of train was calculated and annual volumes were estimated and compared with reported annual container throughputs for each railroad. These steps are illustrated in Tables 4.13 and 4.14.

[29] "New Jersey Marine Terminal Rail Facility 2005 Comparison Study," CH2MHILL, Port Authority of NY&NJ, February 2006.

Table 4.14 illustrates the estimated number of containers each average train would carry, based on 5-platform railcars, each platform capable of holding up to four TEUs (maximum load consisting of two 40-ft containers). In this table, the potential number of TEUs per train is estimated by multiplying the number of cars per train shown in the previous table by the number of platforms per car and the capacity number of TEUs per platform. Not all platforms are filled with 4 TEUs, however, and the term "density" is used to describe the percentage of potential capacity that is actually filled. The density assumptions are shown in Table 4.14. Multiplying the potential TEU capacity of the train by the density value estimates the actual TEU content of the typical train, and dividing by the average number of TEUs per container (most, but not all, containers are 40 feet, so the average is less than 2) estimates the number of containers that can be carried by the train sizes shown in the table.

Table 4.14: Line-Haul Train Container Capacities

Parameters	Q159 Outbound	Q162 Outbound	Q112 Inbound	25V Outbound	23M Outbound	24V Inbound
Platforms/car	5	5	5	5	5	5
TEUs/platform (capacity)	4	4	4	4	4	4
TEUs per train (potential)	560	320	560	160	360	280
Average "density"	95%	95%	95%	95%	95%	95%
TEUs per train (adjusted)	532	304	532	152	342	266 TEUs
Average TEUs per container:	1.72	1.72	1.72	1.72	1.72	1.72
Containers per train (average)	**309**	**177**	**309**	**88**	**199**	**155**

Table 4.15 lists the train schedule assumptions, most of which are described in the rail utilization study. The secondary train schedule assumptions have been chosen to balance the total container throughputs estimated using the methods described in these paragraphs with the actual reported throughputs. The annual number of containers estimated for each railroad is the product of the number of trains per day, the days per week those trains run, and the number of containers each train can carry (from Table 4.14). The total estimated number of containers moved by the train configurations described above (and shown below in Table 4.15) corresponds to the reported actual 2013 on-dock rail throughput to within approximately two tenths of a percent (estimated 424,996, actual 425,784). While not exact, the degree of correspondence between estimated and reported throughput provides a degree of confidence in the estimated train parameters on which the emission estimates are based.

Table 4.15: Line-Haul Train Schedules and Throughput

Parameters	Q159 Outbound	Q162 Outbound	Q112 Inbound	25V Outbound	23M Outbound	24V Inbound
Trains/day	1	1	1	1	1	1
Days/week	7	7	7	5	7	5
Trains per year	364	364	364	260	364	260
Containers/year	112,476	64,428	112,476	22,880	72,436	40,300 containers
Total estimated containers:	**289,380**			**135,616**		

The next step in estimating fuel usage is estimating the gross weight of each of the train sizes described by the previous tables. Information for these estimates was obtained from information reported by the Norfolk Southern and CSX railroads to the U.S. Surface Transportation Board in the 2012 submittals of an annual report known as the "R-1."[30] Among the details in this report are the total gross ton-miles moved by locomotives in freight service and the total freight moved in railcar-miles. Dividing gross ton-miles by car-miles provides an estimate of the average weight of a railcar in normal service (gross ton-miles / car-miles = gross tons/car). The average railcar weight estimated in this manner is shown in Table 4.16. In addition to average car weight, Table 4.16 lists the average number of railcars per train, estimated by multiplying the number of 5-platfom cars (shown in Table 4.16) by 5 (the railcars listed in the R-1 reports are analogous to a platform rather than the 5-platform railcar commonly used in container service). The average gross weight of each train type is the number of railcars multiplied by the average gross weight per car, as shown in Table 4.16.

Table 4.16: Line-Haul Train Gross Weight

Parameters	Q159 Outbound	Q162 Outbound	Q112 Inbound	25V Outbound	23M Outbound	24V Inbound
Platforms per train (average)	140	80	140	40	90	70
Gross tons per platform	82					
Gross weight of train	**11,505**	**6,574**	**11,505**	**3,287**	**7,396**	**5,753**

Overall annual gross tonnage for each railroad is the gross weight of each train multiplied by the number of trains per year (shown in Table 4.14). These figures total approximately **10.77 million gross tons** for the railroad whose trains are represented by the left three columns in the previous tables, and approximately **5.04 million gross tons** for the railroad whose trains are represented by the three columns to the right.

Since fuel use and emissions depend not only on the weight of the trains but also on the distance the trains travel, the primary routes taken by the two railroads were evaluated for distance within each county included in this inventory, and the annual number of gross tons for each railroad was multiplied by the distance. The result of this calculation is an estimate of the number of gross ton-miles associated with each county, as shown in Table 4.17. Fuel consumption in each county was estimated by multiplying the ton-miles by the factor of 1.15 gallons of fuel per thousand gross ton-miles, derived from information in the R-1 reports on fuel consumption as well as gross ton-miles. The result of this calculation step is also shown in the table below.

[30] *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2012* (Norfolk Southern Railroad) and *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2012* (CSX Transportation, Inc.).

Table 4.17: Line Haul Locomotive Ton-Mile and Fuel Use Estimates

County	Track Mileage	Thousand Gross Ton-Miles	Gallons Fuel
North Route			
Essex	3	32,306,150	36,858
Hudson	13	139,993,318	159,717
Bergen	15	161,530,752	184,289
Rockland	24	258,449,203	294,862
South Route			
Essex	5	25,212,472	28,765
Union	15	75,637,416	86,294
Middlesex	5	25,212,472	28,765
Total	80	718,341,783	819,549

The last step is to apply the emission factors (Table 4.12) to the fuel use estimate to estimate the total locomotive emissions.

4.3.2 Switching Emissions

Switching emission estimates have been based primarily on the activity information developed for the previous Port Authority inventories of cargo handling equipment and rail emissions, and the change in Port Newark and Elizabeth PA Marine Terminal cargo throughputs between 2012 and 2013. The scaling of activity with growth in container throughput by rail should provide a reasonable estimate of activity growth. The 2002 emission estimates were based on the number and duration of daily shift operations, and the later estimates have been made using the ratios of container throughputs by rail. For example, 426,000 containers moved by rail in 2013 divided by 433,000 containers moved by rail in 2012 results in a negative growth factor of 0.98 or a 2% reduction in throughput; this was multiplied by the 2012 operating hours estimate of 44,303 for a 2013 estimate of 43,417 hours.

A variety of switchers operate in ExpressRail service at various times, including ultra-low emission locomotives powered by two or three generator sets (genset locomotives) rather than one large locomotive engine. These genset locomotives emit lower levels of most pollutants than typical switchers and have been estimated to reduce particulate emissions within the NYNJLINA by as much as 3.22 tons per year and NO_x emissions by as much as 64.0 tons per year compared with the locomotives they replaced.[31] These reductions have been projected for the non-attainment area as a whole and operational information has not been available to differentiate the reductions that have been achieved within the Port domain of this emissions inventory.

[31] M.J. Bradley & Associates, LLC. *Reducing Emissions from Diesel Locomotives CSXT / NESCAUM - DPF Genset Locomotive Pilot Project.* October 8, 2010 and M.J. Bradley & Associates, LLC. *CSXT, NJTPA, NJDOT and PANYNJ - Congestion Mitigation and Air Quality - Diesel Emission Reduction Project - Locomotive Repower Project Oak Island — Newark, NJ.* May 2012.

Estimates of locomotive engine emissions are based on their regulatory "Tier level," which is based on when they were built or rebuilt. The ExpressRail switchers are assumed to emit at an average of Tier 1 rates, which are applicable to locomotives built between approximately 2002 and 2004. Older locomotives emit higher rates of most pollutants, while newer locomotives, including the gensets discussed above, emit at lower rates; in the absence of specific information on how much work each type of locomotive performed within the inventory domain, the Tier 1 rates represent a reasonably conservative approach to estimating overall switching emissions. Emission factors for most pollutants are from the 2009 EPA publication cited above. Emission factors for SO_2 and CO_2 have been developed using a mass balance approach (based on the typical amounts of sulfur and carbon in diesel fuel) and emission factors for N_2O and CH_4 were obtained from the EPA publication on greenhouse gases cited previously. The emission factors are listed in Table 4.18. The switching locomotives operated by the container terminal and by the rail-to-barge cross-harbor service pre-date the Tier 1 emission levels (they were manufactured in the 1960s and 1970s), so Tier 0 emission factors have been used for these locomotives.

Table 4.18: Switching Locomotive Emission Factors

Units	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
Tier 0 emission factors									
g/gal	191	6.1	6.1	15.2	27.3	0.12	10,182	0.00	1.52
g/hp-hr	12.6	0.40	0.40	1.00	1.80	0.01	672	0.000	0.100
Tier 1 emission factors									
g/gal	150	6.5	6.1	15.3	27.7	0.12	10,182	0.26	0.76
g/hp-hr	9.9	0.43	0.40	1.01	1.83	0.01	672	0.017	0.050

The emission factors are in units of grams per horsepower-hour. An estimate of annual horsepower-hours was developed from the adjusted operating hour estimate discussed above using data contained in an EPA dataset that lists average switching duty in-use horsepower for 20 locomotive models rated between 1,500 and 4,100 horsepower, averaging 3,030 horsepower. The in-use horsepower varies from 159 to 349 horsepower, with an average of 264 horsepower. Multiplying the estimate of 43,417 hours by the average in-use horsepower of 264 results in a horsepower-hour estimate of 11,453,435 for the year. The emission factors were multiplied by this total to estimate annual switching emissions. For the container terminal switching locomotive the horsepower-hours were estimated from the reported number of operating hours multiplied by the average in-use horsepower. The horsepower-hours of the rail-to-barge cross-harbor service switchers were estimated by converting the annual fuel consumption (in gallons) of these locomotives to horsepower-hours using a brake-specific fuel consumption factor, which represents the number of gallons of fuel consumed per horsepower-hour.

4.4 Description of Locomotives

This subsection describes the rail system as it served the Port Authority marine terminals in 2012 and the locomotives that were in service.

4.4.1 Operational Modes

Locomotives are used in two general modes of operation, terminal switching and line haul. Switching activities take place within a limited geographical area and are the activities related to preparing trains for transport to distant locations and to breaking up and distributing railcars from trains arriving from distant origins. Line haul refers to the movement of rail freight over long distances, between local rail yards and distant locations.

The rail activities associated with the Port Authority marine terminals covered by this 2013 emissions inventory consist primarily of intermodal (containerized cargo) service associated with the container terminals at Port Newark and the Elizabeth PA Marine Terminal (i.e., Port Newark Container Terminal, Maher Terminal, APM Terminal), and at the Howland Hook Marine Terminal on Staten Island, New York. Switching takes place adjacent to the Port Newark Container Terminal (an operation known as ExpressRail Port Newark), at a rail facility between the APM and Maher Terminals (known as ExpressRail Elizabeth), and at the New York Container Terminal at Howland Hook (ExpressRail Staten Island). ExpressRail is operated by Consolidated Rail Corporation (Conrail), a jointly owned, private subsidiary of the Norfolk Southern and CSX Railroads, using switching locomotives owned by either Norfolk Southern or CSX.

Beyond the Port Authority marine terminals, container trains are transported to and from ExpressRail by Norfolk Southern and CSX. The primary route for CSX is north/south parallel to the Hudson River, while Norfolk Southern trains run east/west. Approximately 55 miles of the CSX route is within the counties covered by this emissions inventory, while the Norfolk Southern route includes approximately 25 miles within the area.

4.4.2 Locomotives

The locomotives used in these activities are essentially similar, although switching locomotives are usually smaller than the locomotives used in line haul service. Locomotives in switching service are often older line haul locomotives that are no longer suitable for the longer and heavier trains that are common in present-day train transport. Figure 4.8 illustrates a typical older switching locomotive, while Figure 4.9 presents a newer model switcher. These specific switch engines do not necessarily work on Port Authority marine terminals – the illustrations are provided as examples. Line haul locomotives, especially those in intermodal service (used in transporting containerized cargo) are typically in the range of 4,000 horsepower, while locomotives in switching use are smaller, typically under 3,000 horsepower. Figure 4.10 shows a typical line haul locomotive.

Locomotives operate somewhat differently than other types of land-based mobile sources in that their engines are not directly coupled to their wheels via a transmission and drive shaft; instead, the locomotive engine powers a generator or alternator that generates electricity which, in turn, powers an electric motor that turns the drive wheels. This method of operation means that locomotive engines operate under more steady-state operating conditions than more typical mobile source engines, which undergo frequent changes in speed and load during normal operation. By contrast, locomotives have been designed to operate in a series of discrete throttle positions, called notches, typically one through eight plus an idle position. Many locomotives also have an operating condition known as dynamic braking, in which the electric engine operates as a generator to help slow the train, with the generated power being dissipated as heat.

Because line haul locomotives are used to transport cargo across large areas of the country, they are dispatched by the railroads that own and operate them on the basis of where they are needed and not on the basis of any discrete operating area. Therefore, there are no "local fleets" of line haul locomotives. To a large extent this is also true of switching locomotives, which can be moved among several rail yards in the area, most of which are not directly associated with Port Authority marine terminals. For this reason, the emission estimates discussed in the previous subsections are based on activity patterns and general locomotive and train characteristics rather than locomotive-specific information.

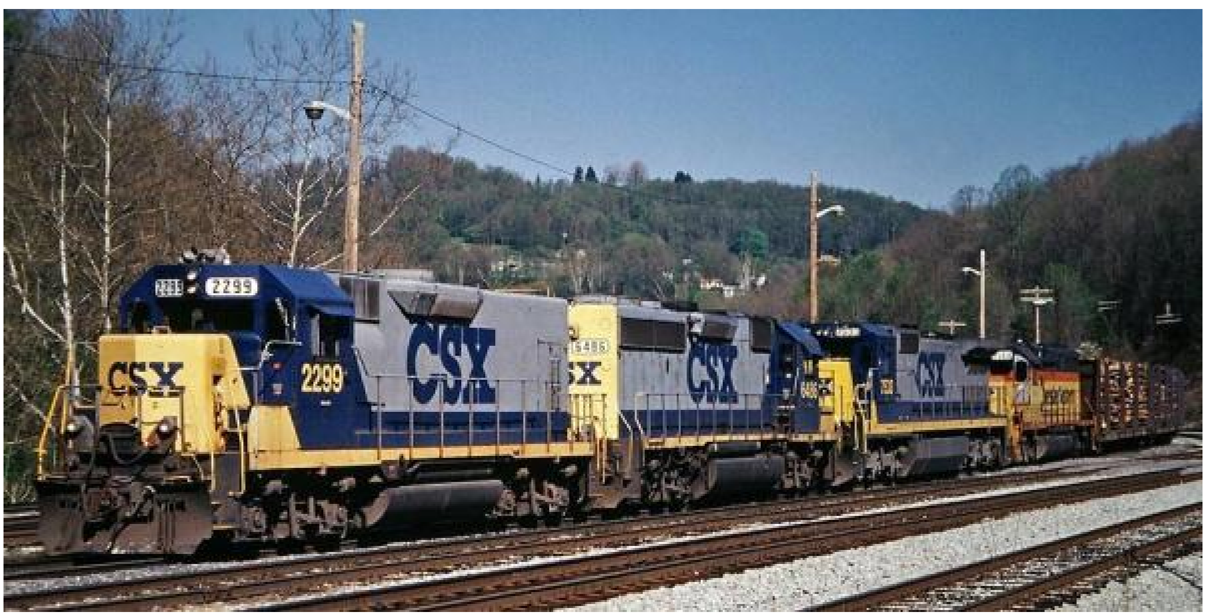
Figure 4.8: Example Switching Locomotives at On-Dock Rail Facility

Photo courtesy of PANYNJ

Figure 4.9: Example Switching Locomotive

Photo courtesy of PANYNJ

Figure 4.10: Example Line Haul Locomotive



Photograph courtesy of Richard C. Borkowski, Pittsburgh, PA
http://www.railpictures.net/viewphoto.php?id=259556

SECTION 5: COMMERCIAL MARINE VESSELS

This section presents estimated emissions from ocean-going vessels and harbor craft, collectively known as commercial marine vessels (CMVs), calling at the following Port Authority marine terminals. These include:

- Port Newark
- Elizabeth Port Authority Marine Terminal
- Port Jersey Port Authority Marine Terminal
- Howland Hook Marine Terminal
- Brooklyn Port Authority Marine Terminal

The Port of New York and New Jersey also includes many marine terminals that are privately owned and operated, which do not come under the aegis of the Port Authority of New York and New Jersey – such as the various fuel and oil depots situated along the Arthur Kill/Kill Van Kull waterways. The emissions from vessels calling at these terminals are not included in this inventory.

The geographic area covered by this inventory remains unchanged from the commercial marine vessel emissions inventories developed for 2000, 2006, 2008, 2010 and 2012. It includes the counties within the New York New Jersey Long Island Non-Attainment Area (NYNJLINA) in which Port Authority marine terminal related CMV activity occurs, and is bounded on the ocean side by the three-nautical-mile demarcation line off the eastern coast of the U.S. This line (shown in Figure 5.1) is also the boundary of the New York – New Jersey Harbor System (NYNJHS), as designated by the U.S. Army Corps of Engineers. The NYNJHS encompasses the predominant CMV activity area within the region. The counties within this area that include marine vessel activity include the New York counties Bronx, Kings, Queens, Richmond, Nassau, New York, Orange, Rockland, Suffolk, Westchester; and the New Jersey counties Bergen, Monmouth, Ocean, Middlesex, Hudson, Essex, and Union. However, Ocean County, New Jersey, has not been included with the NYNJLINA counties listed in various tables in this report because there are no identified Port Authority marine terminal related CMV activities or emissions within the county.

In many cases, vessel travel lanes do not fall neatly within one or another county. Best efforts have been made to reasonably allocate emissions to the relevant counties (and states).

Following an Executive Summary that presents an overview of commercial marine vessel emissions from the PANYNJ activity compared with overall emissions in the NYNJLINA and New York/New Jersey, the following four subsections focus on:

- 5.1 - Emission Estimates
- 5.2 - Emission Comparisons
- 5.3 - Methodology
- 5.4 - Description of Vessels

ES5.1 Executive Summary

Table ES5.1 presents the estimated commercial marine vessel (CMV) criteria pollutant and CO_2 equivalent emissions in the context of overall emissions in the states of New York and New Jersey, and in the NYNJLINA, including emissions in tons per year and the percentage that PANYNJ CMV emissions make up of overall NYNJLINA emissions.[32]

Table ES5.1: Comparison of PANYNJ CMV Emissions with State and NYNJLINA Emissions, tpy

Geographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2 Eq
New York and New Jersey	590,117	333,133	120,143	601,318	2,994,198	167,504	229,371,430
NYNJLINA	280,279	76,854	37,170	266,786	1,373,551	49,836	117,276,953
OGVs	2,495	158	127	149	262	652	139,772
Harbor Craft	384	19	18	15	50	0.5	21,534
Total Commercial Marine Vessels	2,880	176	145	164	312	653	161,306
% of NYNJLINA Emissions	**1.0%**	**0.2%**	**0.4%**	**0.1%**	**0.02%**	**1.3%**	**0.1%**

The following figures illustrate the distribution of PANYNJ CMV emissions by vessel type in terms of tons per year and percent of total CMV emissions, and in the context of overall NYNJLINA emissions. The NYNJLINA emissions are broken down into on-road mobile sources, other (non-road) mobile sources, and stationary and area sources. Note that the percentages shown in these charts do not always sum to 100% because of rounding. The charts are intended to illustrate the relative magnitude of emission sources at the port and in the region.

[32] 2011 and 2008 National Emission Inventory Databases, US EPA, as cited above.

Figure ES5.1: Distribution and Comparison of NO_x from CMVs, tpy and percent

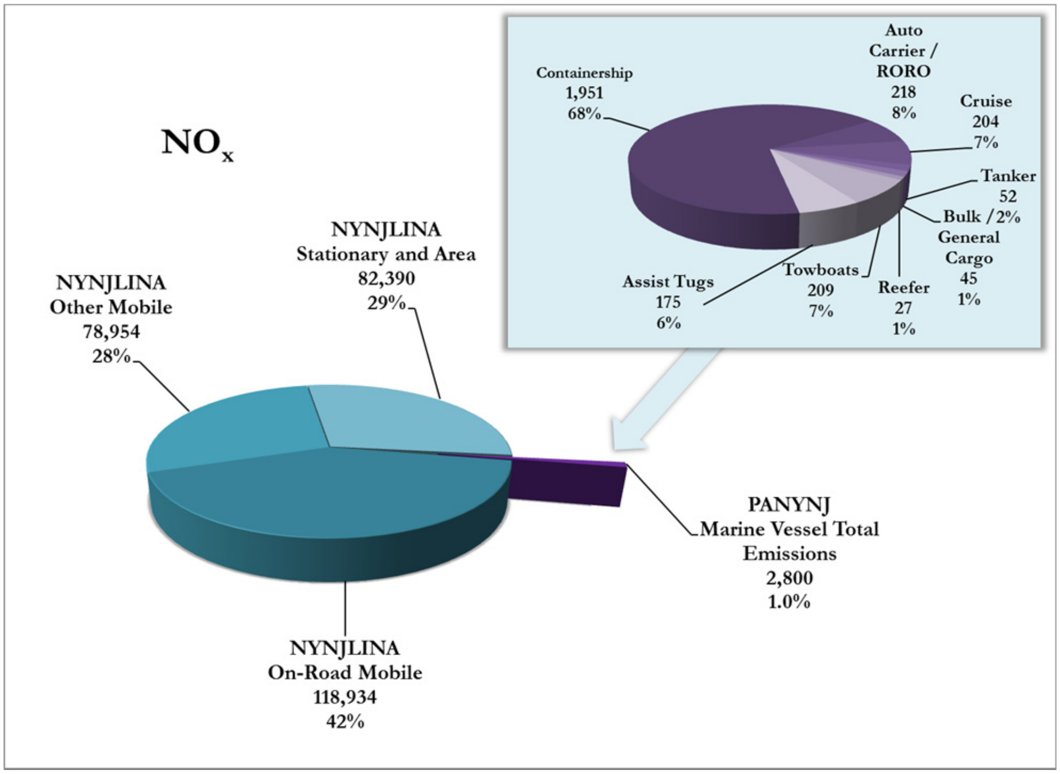


Figure ES5.2: Distribution and Comparison of PM_{10} from CMVs, tpy and percent

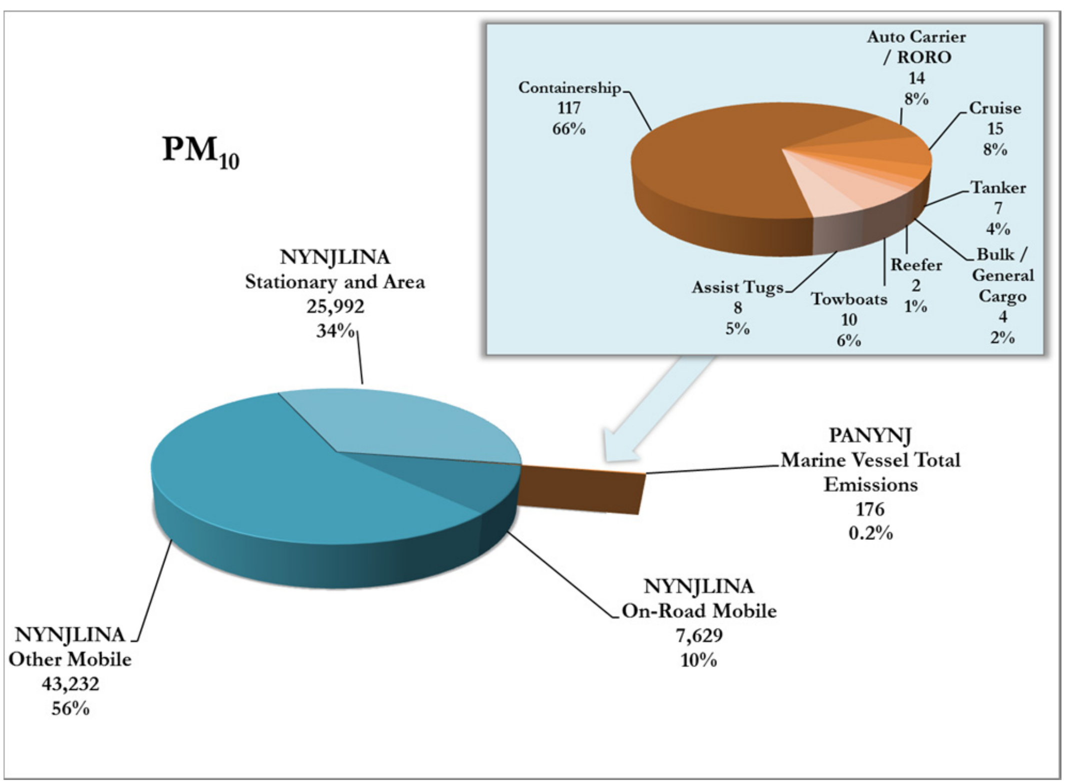


Figure ES5.3: Distribution and Comparison of $PM_{2.5}$ from CMVs, tpy and percent

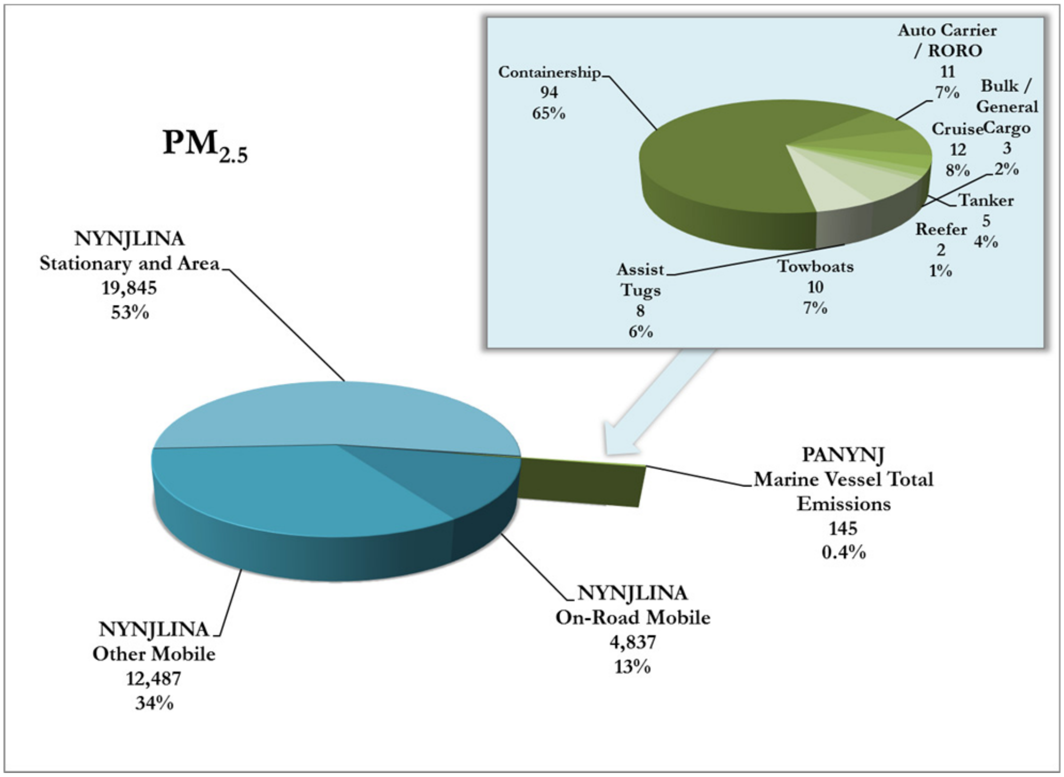


Figure ES5.4: Distribution and Comparison of VOC from CMVs, tpy and percent

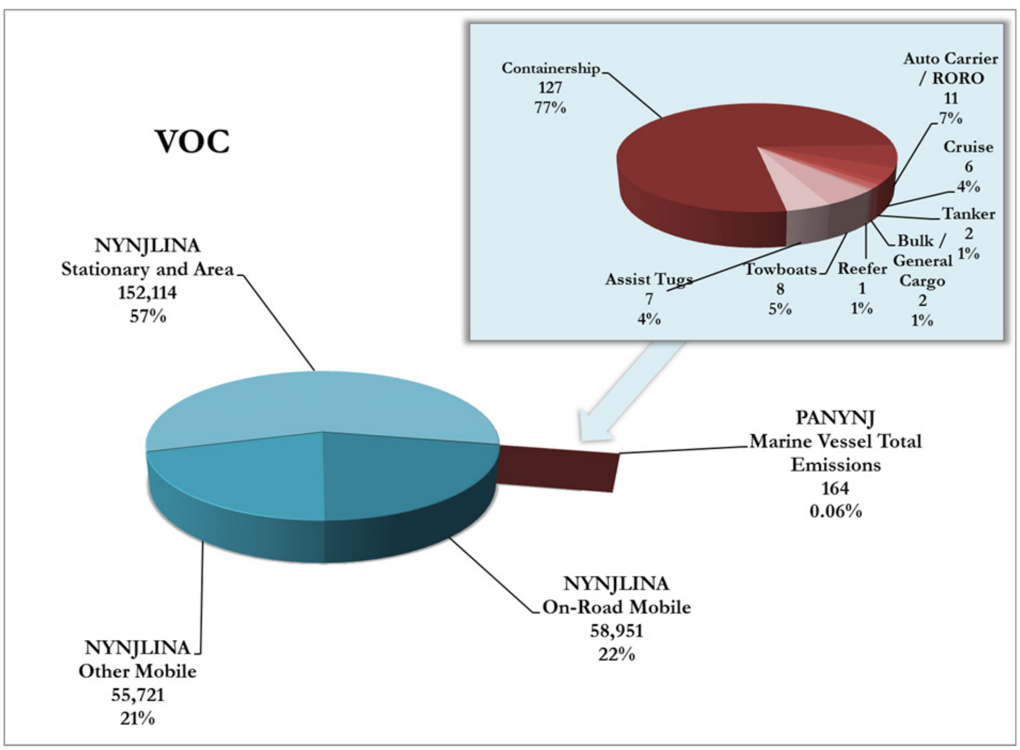


Figure ES5.5: Distribution and Comparison of CO from CMVs, tpy and percent

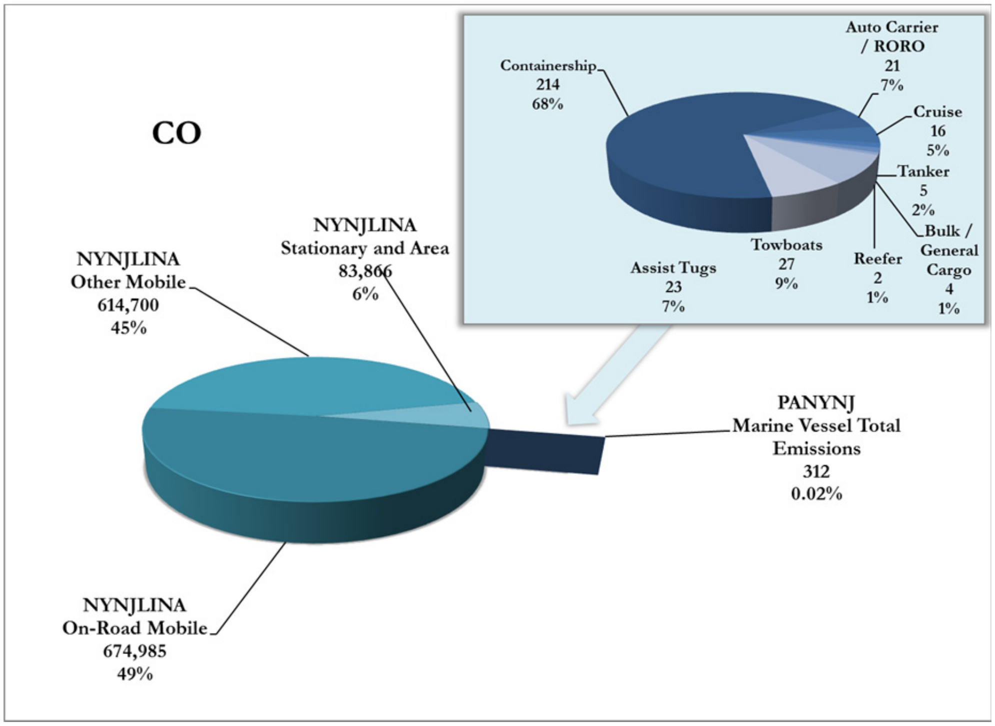


Figure ES5.6: Distribution and Comparison of SO_2 from CMVs, tpy and percent

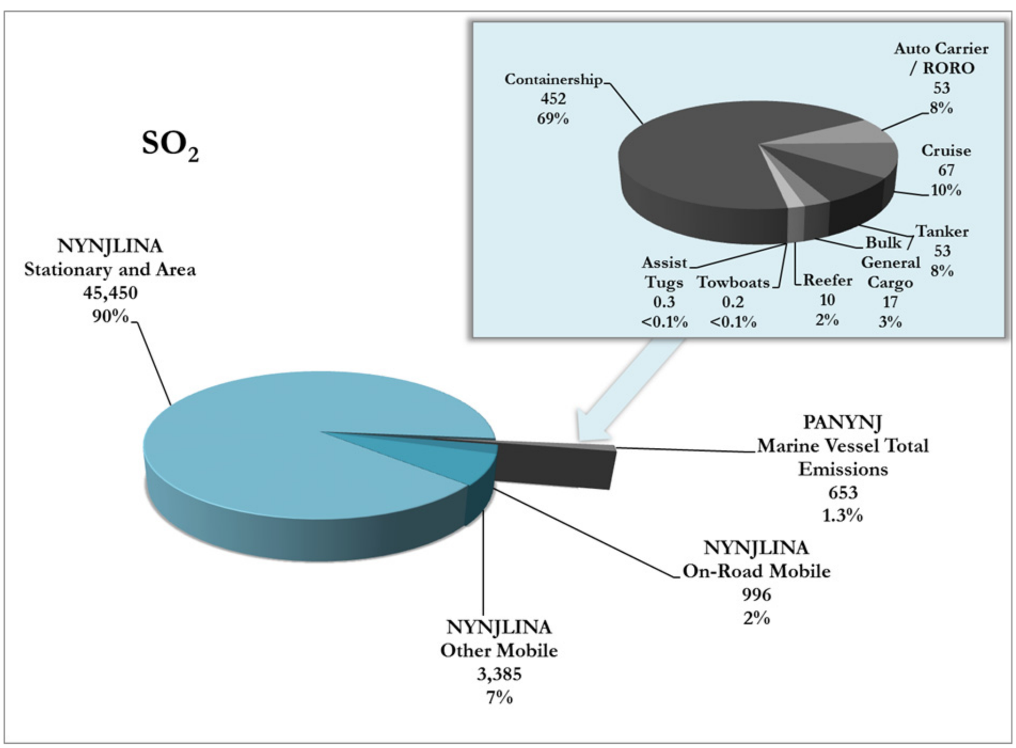
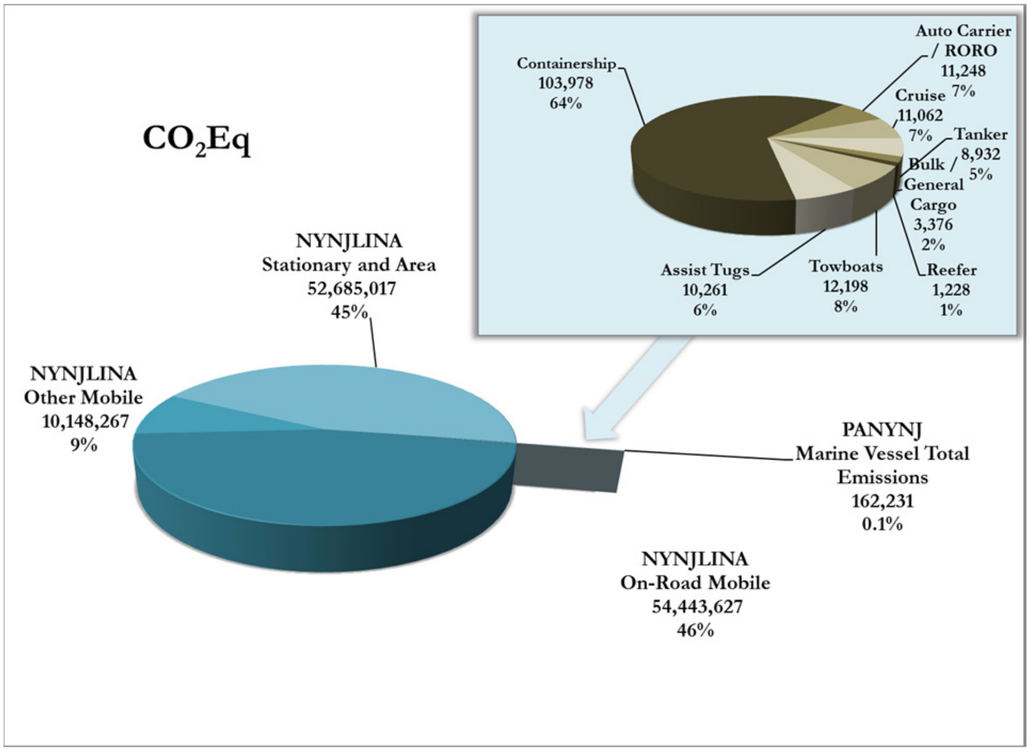


Figure ES5.7: Distribution and Comparison of CO_2 from CMVs, tpy and percent

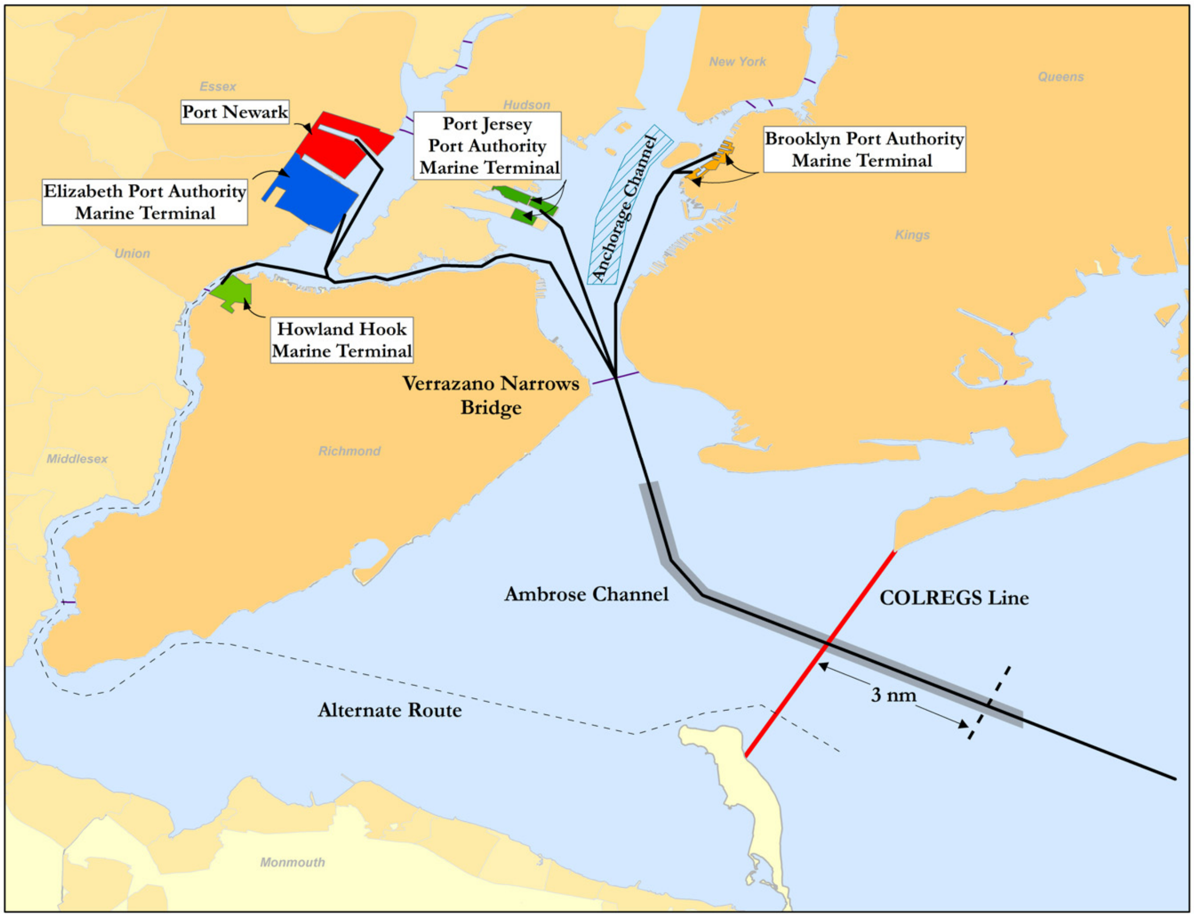


5.1 CMV Emission Estimates

Emission estimates have been developed for commercial marine vessels on the basis of vessel type and engine type. The vessel types include the following ocean-going vessels (OGVs): containerships, cruise ships, automobile and other vehicle carriers, tankers, and bulk carriers. In addition, estimates have been developed for the vessels that assist the ocean-going vessels in maneuvering and docking (assist tugs) and that move cargo barges within the NYNJHS (tugs, tow boats, push boats). The engines on board marine vessels for which emissions have been estimated are main engines, which provide propulsion power; auxiliary engines, which run electrical generators for auxiliary vessel power; and auxiliary boilers, which provide heat for fuel treatment and other on-board uses.

Figure 5.1 illustrates the outer limit of the study area on the ocean side for commercial marine vessels, and the routes taken by OGVs traveling to the terminals covered by this inventory. The outer limit is three nautical miles beyond the line indicated on the figure as the COLREG Line, off the eastern coast of the U.S.

Figure 5.1: Outer Limit of Study Area



The following tables present the estimated marine vessel emissions in several different aspects. Tables 5.1 and 5.2 list the estimated criteria pollutant and greenhouse gas emissions from OGVs by vessel type, Tables 5.3 and 5.4 present the OGV emissions by engine type, Tables 5.5 and 5.6 differentiate emissions according to transiting and dwelling activity, and Tables 5.7 and 5.8 present estimated criteria pollutant and greenhouse gas emissions from the tow boats and assist tugs.

The emission estimates presented in this document are listed in several ways to provide as much information to the reader as possible. The emissions are presented by terminal type, by type of activity, and by county and state. Because of these different modes of display, the numerical values must be rounded, displayed, and summed in different ways. Because of this, it is not always possible to display values in a table that sum exactly to the total shown at the bottom of the table. In developing the tables, priority has been given to maintaining consistent totals for each pollutant across table types.

Table 5.1: OGV Emissions of Criteria Pollutants by Vessel Type, tpy

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Containership	1,951	117	94	127	214	452
Cruise	204	15	12	6	16	67
Auto Carrier	161	10	8	8	16	36
RoRo	57	4	3	3	5	17
Tanker	52	7	5	2	5	53
Bulk	31	3	2	1	3	13
Reefer	27	2	2	1	2	10
General Cargo	14	1	1	1	1	4
Total	**2,495**	**158**	**127**	**149**	**262**	**652**

Table 5.2: OGV Emissions of Greenhouse Gases by Vessel Type, tpy

Vessel Type	CO_2	N_2O	CH_4	CO_2 Eq
Containership	101,961	6.3	2.5	103,978
Cruise	10,906	0.5	0.1	11,062
Auto Carrier	8,365	0.5	0.2	8,516
RoRo	2,685	0.2	0.1	2,732
Tanker	8,728	0.7	0.0	8,932
Bulk	2,220	0.1	0.0	2,264
Reefer	1,652	0.1	0.0	1,679
General Cargo	599	0.0	0.0	610
Total	**137,116**	**8.4**	**3.0**	**139,772**

Table 5.3: OGV Emissions of Criteria Pollutants by Emission Source Type, tpy

Emission Source Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Main Engines	1,049	59	48	104	141	113
Auxiliary Engines	1,359	80	64	41	113	343
Boilers	87	19	15	4	8	196
Total	**2,495**	**158**	**127**	**149**	**262**	**652**

Table 5.4: OGV Emissions of Greenhouse Gases by Emission Source Type, tpy

Emission Source Type	CO_2	N_2O	CH_4	CO_2 Eq
Main Engines	24,270	2.0	2.1	24,920
Auxiliary Engines	72,672	3.1	0.8	73,654
Boilers	40,173	3.3	0.1	41,199
Total	**137,116**	**8.4**	**3.0**	**139,772**

Table 5.5: OGV Emissions of Criteria Pollutants by Operating Mode, tpy

Operating Mode	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Transit	1,429	83	66	115	172	226
Dwelling	1,067	75	60	34	90	426
Total	**2,495**	**158**	**127**	**149**	**262**	**652**

Table 5.6: OGV Emissions of Greenhouse Gases by Operating Mode, tpy

Operating Mode	CO_2	N_2O	CH_4	CO_2 Eq
Transit	48,718	3	2	49,754
Dwelling	88,398	5	1	90,018
Total	**137,116**	**8**	**3**	**139,772**

Table 5.7: Assist Tug/Towboat Emissions of Criteria Pollutants, tpy

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Towboats/Pushboats	209	10	10	8	27	0.2
Assist Tugs	175	8	8	7	23	0.3
Totals	**384**	**19**	**18**	**15**	**50**	**0.5**

Table 5.8: Assist Tug/Towboat Emissions of Greenhouse Gases, tpy

Vessel Type	CO_2	N_2O	CH_4	CO_2 Eq
Towboats/Pushboats	11,696	1	4	12,198
Assist Tugs	9,838	4	9	10,270
Totals	**21,534**	**5**	**13**	**22,468**

Marine vessel emissions by county, and those emissions in relation to overall area emissions by pollutant, are presented and discussed in Section 5.2.

5.2 CMV Emission Comparisons

This subsection presents the marine vessel emission estimates detailed in Section 5.1 in the context of overall county-wide and area-wide emissions, and presents a comparison of 2012 emission estimates with the earlier year inventories developed for 2010, 2008, and 2006. First, Port Authority marine terminal related OGV and tug/tow boat emissions are compared with all emissions in the NYNJLINA on a county-by-county basis. Overall county-level emissions were excerpted from the most recent National Emissions Inventory (NEI) database.[33] These emission comparisons are segregated into ocean-going and assist vessel categories and are presented in sections 5.2.1 and 5.2.2 respectively. Section 5.2.3 presents 2013 OGV and tug/tow boat emission estimates in comparison with 2012, 2010, 2008, and 2006 emission estimates to illustrate the changes in emissions over time.

[33] See: 2008 and 2011 National Emission Inventory versions, as noted above.

5.2.1 Ocean Going Vessel Emission Comparisons

The following series of tables and charts display the contribution that Port Authority marine terminal related OGVs make to overall emissions in the counties and the region. Table 5.9 summarizes estimated criteria pollutant emissions from OGVs at the county level. The subsequent tables, 5.9 through 5.15, present each pollutant individually, comparing Port Authority marine terminal related OGV emissions with total county level emissions. Figures 5.2 through 5.8 summarize the same information visually on an individual county basis. Each column displays the county-wide emissions, and the Port Authority marine terminal related OGV contribution to the total emissions is shown on top of each county-wide column.

Table 5.9: Summary of OGV Criteria Pollutant and GHG Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq
Bergen	NJ	0	0	0	0	0	0	0
Essex	NJ	603	45	36	37	64	199	39,361
Hudson	NJ	469	28	22	23	45	113	24,603
Middlesex	NJ	0	0	0	0	0	0	0
Monmouth	NJ	82	4	3	4	8	16	3,407
Union	NJ	867	53	43	61	97	213	49,535
New Jersey subtotal		**2,021**	**130**	**104**	**125**	**215**	**542**	**116,906**
Bronx	NY	0	0	0	0	0	0	0
Kings	NY	163	10	8	7	15	40	7,896
Nassau	NY	0	0	0	0	0	0	0
New York	NY	43	3	3	1	4	14	2,351
Orange	NY	0	0	0	0	0	0	0
Queens	NY	0	0	0	0	0	0	0
Richmond	NY	269	15	12	15	28	56	12,619
Rockland	NY	0	0	0	0	0	0	0
Suffolk	NY	0	0	0	0	0	0	0
Westchester	NY	0	0	0	0	0	0	0
New York subtotal		**475**	**28**	**22**	**24**	**47**	**111**	**22,866**
TOTAL		**2,495**	**158**	**127**	**149**	**262**	**652**	**139,772**

Table 5.10: Comparison of Ocean Going Vessel NO_x Emissions with Overall NO_x Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen	NJ	14,798	0	0.0%
Essex	NJ	17,195	603	3.5%
Hudson	NJ	9,585	469	4.9%
Middlesex	NJ	14,766	0	0.0%
Monmouth	NJ	10,366	82	0.8%
Union	NJ	12,325	867	7.0%
New Jersey subtotal		**79,035**	**2,021**	**2.6%**
Bronx	NY	13,195	0	0.0%
Kings (Brooklyn)	NY	25,190	163	0.6%
Nassau	NY	21,973	0	0.0%
New York	NY	33,432	43	0.1%
Orange	NY	11,854	0	0.0%
Queens	NY	31,678	0	0.0%
Richmond (Staten Isld)	NY	10,793	269	2.5%
Rockland	NY	5,622	0	0.0%
Suffolk	NY	30,558	0	0.0%
Westchester	NY	16,949	0	0.0%
New York Subtotal		**201,244**	**475**	**0.2%**
TOTAL		**280,279**	**2,495**	**0.9%**

Figure 5.2: Comparison of Ocean Going Vessel NO_x Emissions with Overall NO_x Emissions by County, tpy

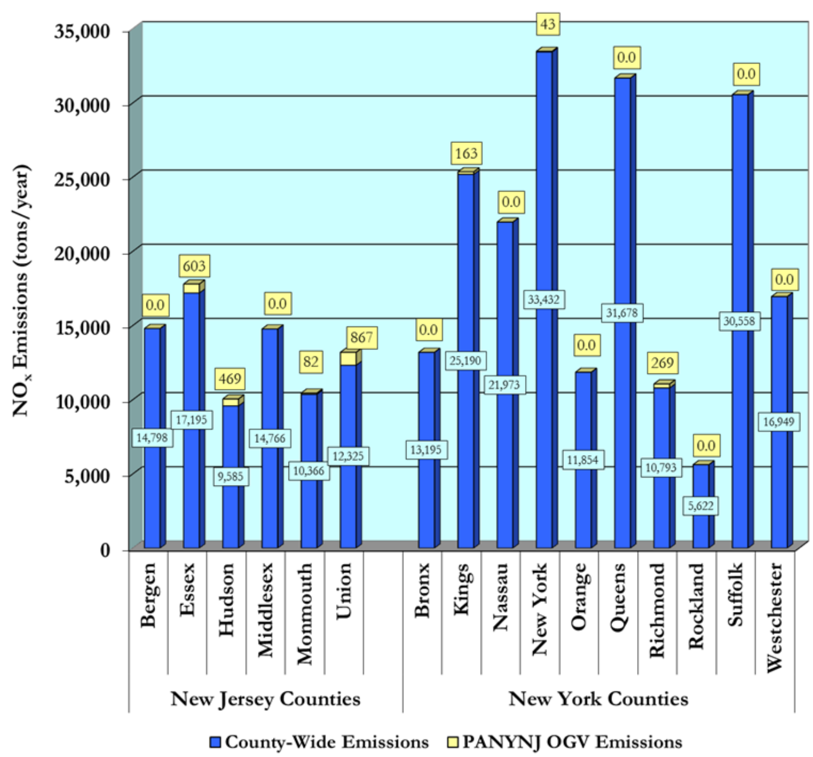


Table 5.11: Comparison of Ocean Going Vessel PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen	NJ	3,565	0	0.0%
Essex	NJ	5,233	45	0.9%
Hudson	NJ	1,732	28	1.6%
Middlesex	NJ	4,288	0	0.0%
Monmouth	NJ	3,334	4	0.1%
Union	NJ	2,787	53	1.9%
New Jersey subtotal		**20,939**	**130**	**0.6%**
Bronx	NY	2,605	0	0.0%
Kings (Brooklyn)	NY	4,779	10	0.2%
Nassau	NY	5,840	0	0.0%
New York	NY	6,363	3	0.1%
Orange	NY	7,595	0	0.0%
Queens	NY	5,244	0	0.0%
Richmond (Staten Isld)	NY	1,885	15	0.8%
Rockland	NY	1,993	0	0.0%
Suffolk	NY	12,931	0	0.0%
Westchester	NY	6,680	0	0.0%
New York Subtotal		**55,915**	**28**	**0.0%**
TOTAL		**76,854**	**158**	**0.2%**

Figure 5.3: Comparison of Ocean Going Vessel PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

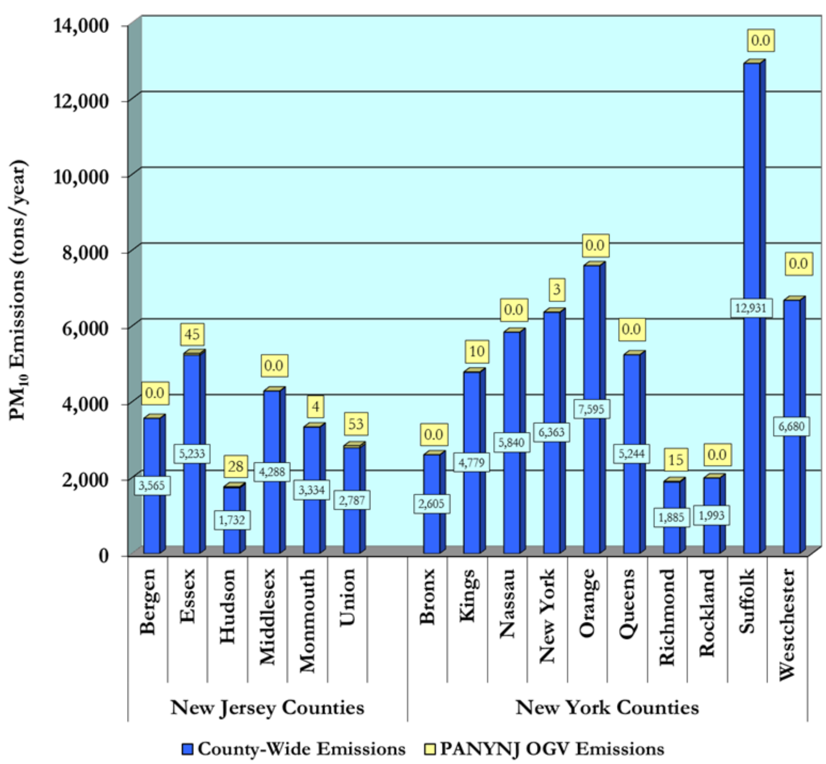


Table 5.12: Comparison of Ocean Going Vessel PM2.5 Emissions with Overall PM2.5 Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen	NJ	2,101	0	0.0%
Essex	NJ	2,574	36	1.4%
Hudson	NJ	1,284	22	1.7%
Middlesex	NJ	2,335	0	0.0%
Monmouth	NJ	1,737	3	0.2%
Union	NJ	1,877	43	2.3%
New Jersey subtotal		**11,908**	**104**	**0.9%**
Bronx	NY	1,474	0	0.0%
Kings (Brooklyn)	NY	2,693	8	0.3%
Nassau	NY	2,740	0	0.0%
New York	NY	3,199	3	0.1%
Orange	NY	2,462	0	0.0%
Queens	NY	3,030	0	0.0%
Richmond (Staten Isld)	NY	1,090	12	1.1%
Rockland	NY	801	0	0.0%
Suffolk	NY	5,117	0	0.0%
Westchester	NY	2,656	0	0.0%
New York Subtotal		**25,262**	**22**	**0.1%**
TOTAL		**37,170**	**127**	**0.3%**

Figure 5.4: Comparison of Ocean Going Vessel $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

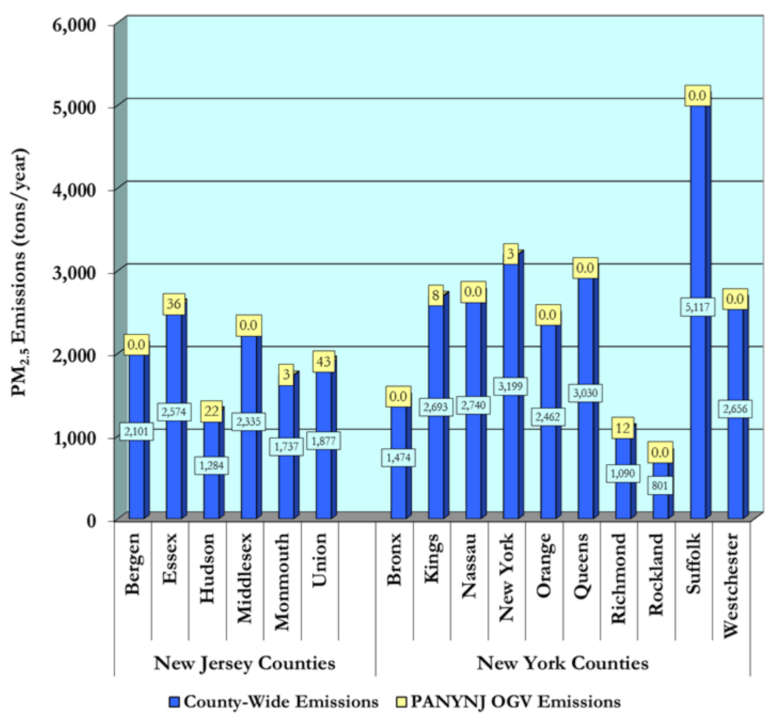


Table 5.13: Comparison of Ocean Going Vessel VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen	NJ	17,028	0	0.00%
Essex	NJ	16,814	37	0.22%
Hudson	NJ	9,244	23	0.25%
Middlesex	NJ	16,653	0	0.00%
Monmouth	NJ	12,551	4	0.03%
Union	NJ	11,037	61	0.56%
New Jersey subtotal		**83,327**	**125**	**0.15%**
Bronx	NY	14,156	0	0.00%
Kings (Brooklyn)	NY	26,367	7	0.03%
Nassau	NY	21,541	0	0.00%
New York	NY	21,185	1	0.01%
Orange	NY	9,654	0	0.00%
Queens	NY	27,358	0	0.00%
Richmond (Staten Isld)	NY	6,576	15	0.23%
Rockland	NY	5,701	0	0.00%
Suffolk	NY	33,256	0	0.00%
Westchester	NY	17,665	0	0.00%
New York Subtotal		**183,459**	**24**	**0.01%**
TOTAL		**266,786**	**149**	**0.06%**

Figure 5.5: Comparison of Ocean Going Vessel VOC Emissions with Overall VOC Emissions by County, tpy

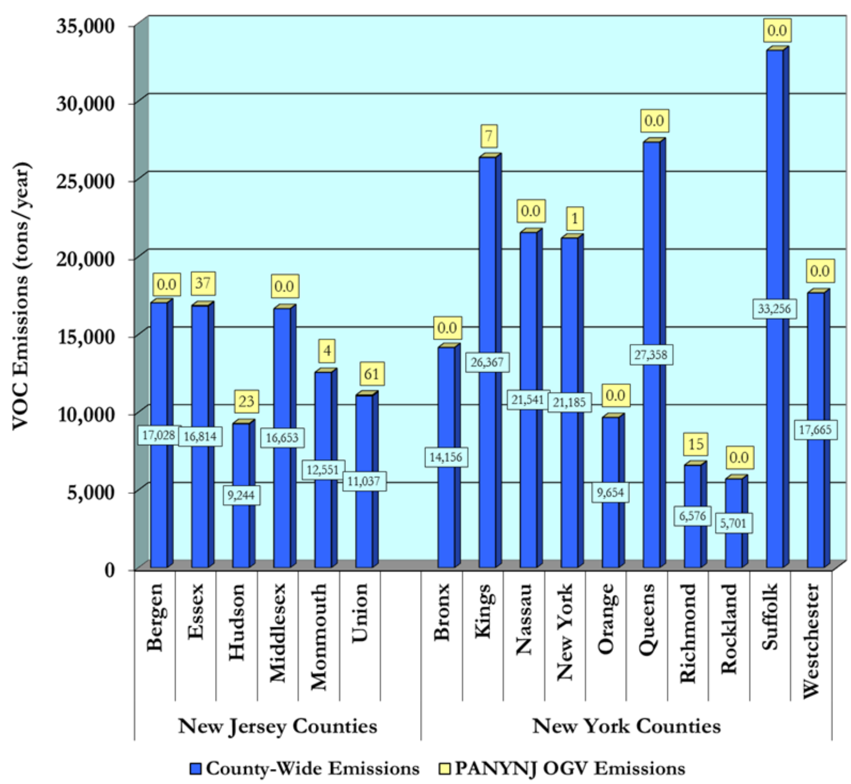


Table 5.14: Comparison of Ocean Going Vessel CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen	NJ	110,855	0	0.00%
Essex	NJ	79,450	64	0.08%
Hudson	NJ	37,073	45	0.12%
Middlesex	NJ	87,617	0	0.00%
Monmouth	NJ	74,655	8	0.01%
Union	NJ	55,299	97	0.18%
New Jersey subtotal		**444,949**	**215**	**0.05%**
Bronx	NY	52,643	0	0.00%
Kings (Brooklyn)	NY	101,980	15	0.02%
Nassau	NY	124,041	0	0.00%
New York	NY	124,401	4	0.00%
Orange	NY	48,412	0	0.00%
Queens	NY	123,921	0	0.00%
Richmond (Staten Isld)	NY	33,262	28	0.08%
Rockland	NY	32,711	0	0.00%
Suffolk	NY	182,114	0	0.00%
Westchester	NY	105,117	0	0.00%
New York Subtotal		**928,602**	**47**	**0.01%**
TOTAL		**1,373,551**	**262**	**0.02%**

Figure 5.6: Comparison of Ocean Going Vessel CO Emissions with Overall CO Emissions by County, tpy

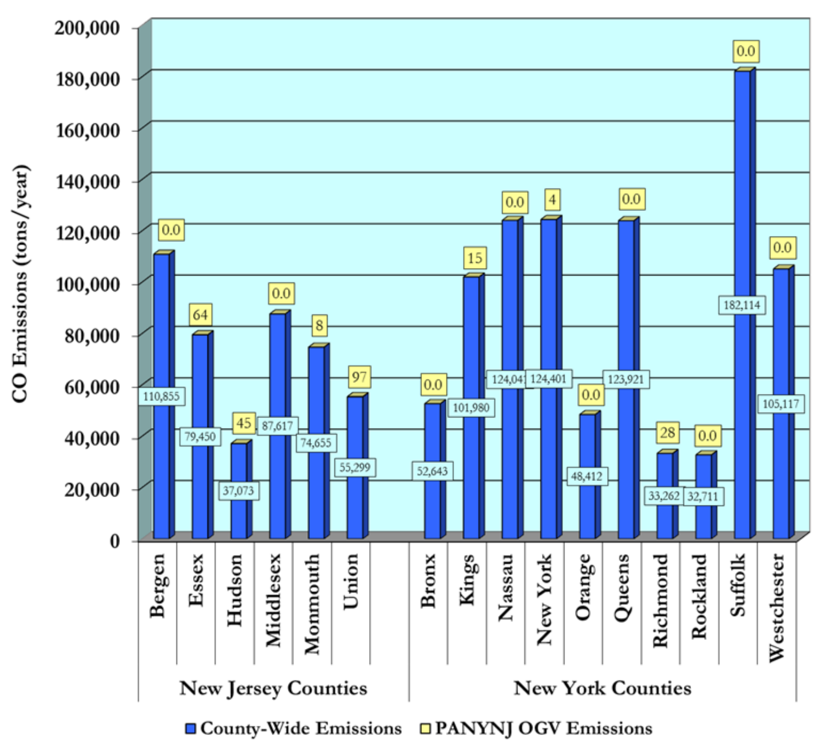


Table 5.15: Comparison of Ocean Going Vessel SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen	NJ	679	0	0.0%
Essex	NJ	2,630	199	7.6%
Hudson	NJ	1,817	113	6.2%
Middlesex	NJ	771	0	0.0%
Monmouth	NJ	671	16	2.4%
Union	NJ	1,053	213	20.2%
New Jersey subtotal		**7,621**	**542**	**7.1%**
Bronx	NY	1,769	0	0.0%
Kings (Brooklyn)	NY	2,021	40	2.0%
Nassau	NY	3,045	0	0.0%
New York	NY	6,776	14	0.2%
Orange	NY	10,728	0	0.0%
Queens	NY	2,932	0	0.0%
Richmond (Staten Isld)	NY	383	56	14.7%
Rockland	NY	461	0	0.0%
Suffolk	NY	11,488	0	0.0%
Westchester	NY	2,612	0	0.0%
New York Subtotal		**42,215**	**111**	**0.3%**
TOTAL		**49,836**	**652**	**1.3%**

Figure 5.7: Comparison of Ocean Going Vessel SO_2 Emissions with Overall SO_2 Emissions by County, tpy

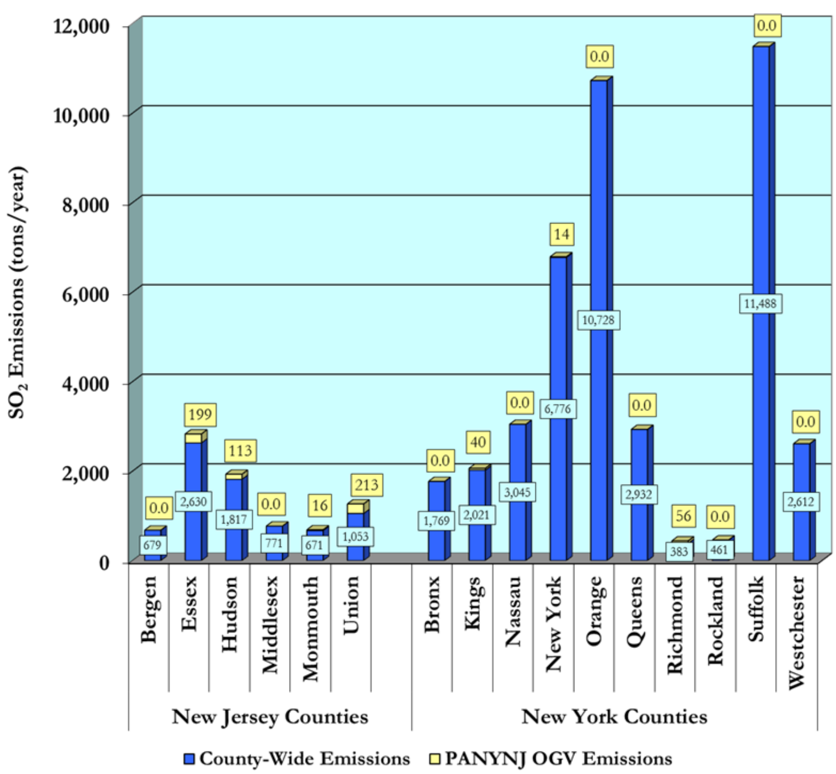
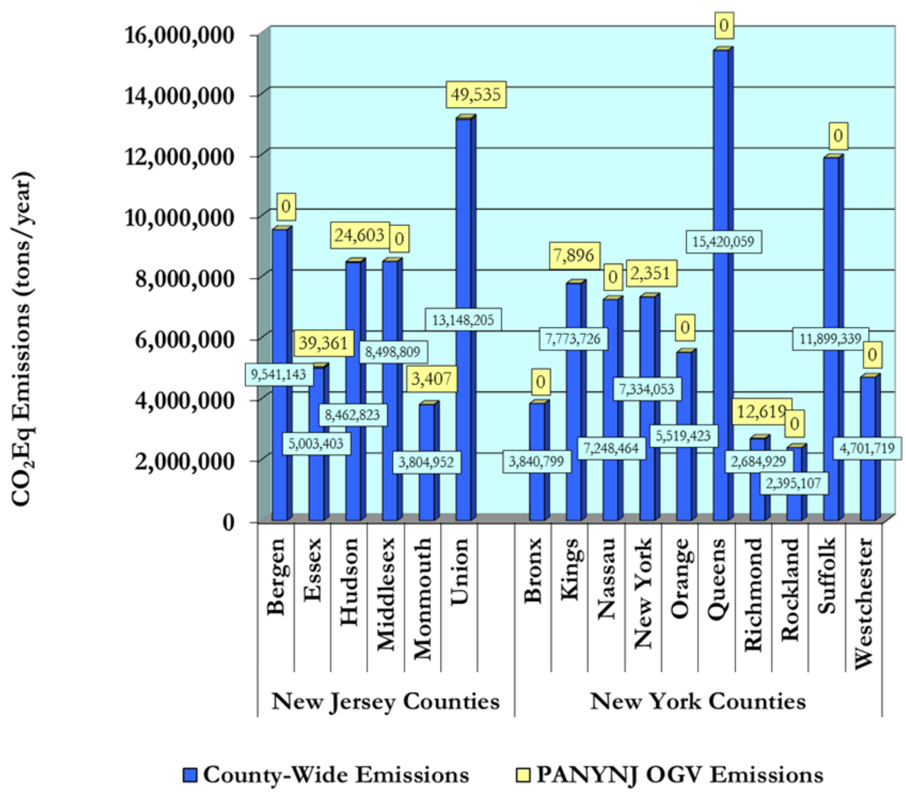


Table 5.16: Comparison of Ocean Going Vessel CO_2 Emissions with Overall CO_2 Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen	NJ	9,541,143	0	0.0%
Essex	NJ	5,003,403	39,361	0.8%
Hudson	NJ	8,462,823	24,603	0.3%
Middlesex	NJ	8,498,809	0	0.0%
Monmouth	NJ	3,804,952	3,407	0.1%
Union	NJ	13,148,205	49,535	0.4%
New Jersey subtotal		**48,459,335**	**116,906**	**0.2%**
Bronx	NY	3,840,799	0	0.0%
Kings (Brooklyn)	NY	7,773,726	7,896	0.1%
Nassau	NY	7,248,464	0	0.0%
New York	NY	7,334,053	2,351	0.0%
Orange	NY	5,519,423	0	0.0%
Queens	NY	15,420,059	0	0.0%
Richmond (Staten Isld)	NY	2,684,929	12,619	0.5%
Rockland	NY	2,395,107	0	0.0%
Suffolk	NY	11,899,339	0	0.0%
Westchester	NY	4,701,719	0	0.0%
New York Subtotal		**68,817,618**	**22,866**	**0.0%**
TOTAL		**117,276,953**	**139,772**	**0.1%**

Figure 5.8: Comparison of Ocean Going Vessel CO_2 Emissions with Overall CO_2 Emissions by County, tpy



5.2.2 Tug and Tow Boat Emission Comparisons

The following series of tables and charts display the contribution of Port Authority marine terminal related tug and tow boat emissions on regional emissions. Table 5.17 summarizes estimated criteria pollutant emissions from these vessels at the county level. The subsequent tables, 5.18 through 5.24, present each pollutant individually, comparing Port Authority marine terminal related tug and towboat activity with total county level emissions. Figures 5.9 through 5.15 summarize the same information visually on an individual county basis. Each column displays the county wide emissions, and the contribution of Port Authority marine terminal related tug and tow boats to total area emissions is shown at the top of the column.

Table 5.17: Summary of Harbor Craft Criteria Pollutant and GHG Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq
Bergen	NJ	2	0.1	0.1	0.1	0.3	0.0	121
Essex	NJ	65	3.1	3.0	2.6	8.5	0.1	3,775
Hudson	NJ	70	3.4	3.3	2.8	9.2	0.1	4,095
Middlesex	NJ	14	0.7	0.7	0.6	1.9	0.0	830
Monmouth	NJ	10	0.5	0.5	0.4	1.4	0.0	611
Union	NJ	95	4.6	4.4	3.8	12.5	0.2	5,566
New Jersey subtotal		**257**	**12.3**	**11.9**	**10.2**	**33.6**	**0.4**	**14,998**
Bronx	NY	0	0.0	0.0	0.0	0.0	0.0	25
Kings (Brooklyn)	NY	18	0.8	0.8	0.7	2.3	0.0	1,024
Nassau	NY	3	0.1	0.1	0.1	0.4	0.0	160
New York	NY	4	0.2	0.2	0.1	0.5	0.0	207
Orange	NY	2	0.1	0.1	0.1	0.3	0.0	135
Queens	NY	4	0.2	0.2	0.2	0.5	0.0	240
Richmond (Staten Isld)	NY	82	3.9	3.8	3.3	10.7	0.1	4,770
Rockland	NY	3	0.1	0.1	0.1	0.4	0.0	166
Suffolk	NY	9	0.4	0.4	0.4	1.2	0.0	537
Westchester	NY	4	0.2	0.2	0.1	0.5	0.0	205
New York subtotal		**128**	**6.2**	**6.0**	**5.1**	**16.7**	**0.1**	**7,470**
TOTAL		**384**	**19**	**18**	**15**	**50**	**0.5**	**22,468**

Table 5.18: Comparison of Harbor Craft NO_x Emissions with Overall NO_x Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	14,798	2	0.01%
Essex	NJ	17,195	65	0.38%
Hudson	NJ	9,585	70	0.73%
Middlesex	NJ	14,766	14	0.10%
Monmouth	NJ	10,366	10	0.10%
Union	NJ	12,325	95	0.77%
New Jersey Subtotal		**79,035**	**257**	**0.32%**
Bronx	NY	13,195	0	0.00%
Kings (Brooklyn)	NY	25,190	18	0.07%
Nassau	NY	21,973	3	0.01%
New York	NY	33,432	4	0.01%
Orange	NY	11,854	2	0.02%
Queens	NY	31,678	4	0.01%
Richmond (Staten Isld)	NY	10,793	82	0.76%
Rockland	NY	5,622	3	0.05%
Suffolk	NY	30,558	9	0.03%
Westchester	NY	16,949	4	0.02%
New York Subtotal		**201,244**	**128**	**0.06%**
TOTAL		**280,279**	**384**	**0.14%**

Figure 5.9: Comparison of Harbor Craft NO_x Emissions with Overall NO_x Emissions by County, tpy

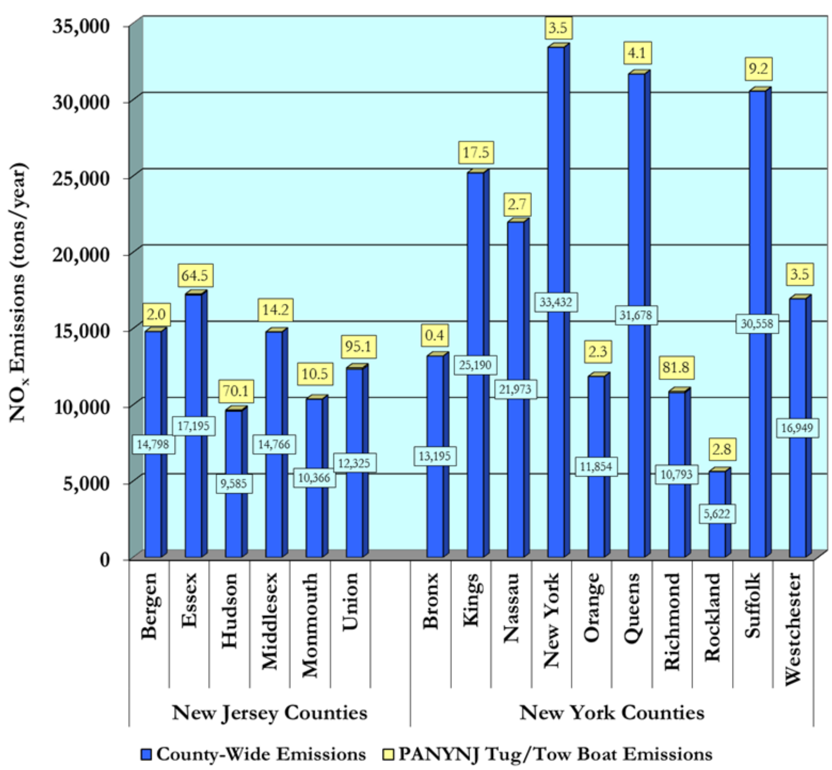


Table 5.19: Comparison of Harbor Craft PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	3,565	0	0.00%
Essex	NJ	5,233	3	0.06%
Hudson	NJ	1,732	3	0.20%
Middlesex	NJ	4,288	1	0.02%
Monmouth	NJ	3,334	1	0.02%
Union	NJ	2,787	5	0.16%
New Jersey Subtotal		**20,939**	**12**	**0.06%**
Bronx	NY	2,605	0	0.00%
Kings (Brooklyn)	NY	4,779	1	0.02%
Nassau	NY	5,840	0	0.00%
New York	NY	6,363	0	0.00%
Orange	NY	7,595	0	0.00%
Queens	NY	5,244	0	0.00%
Richmond (Staten Isld)	NY	1,885	4	0.21%
Rockland	NY	1,993	0	0.01%
Suffolk	NY	12,931	0	0.00%
Westchester	NY	6,680	0	0.00%
New York Subtotal		**55,915**	**6**	**0.01%**
TOTAL		**76,854**	**19**	**0.02%**

Figure 5.10: Comparison of Harbor Craft PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

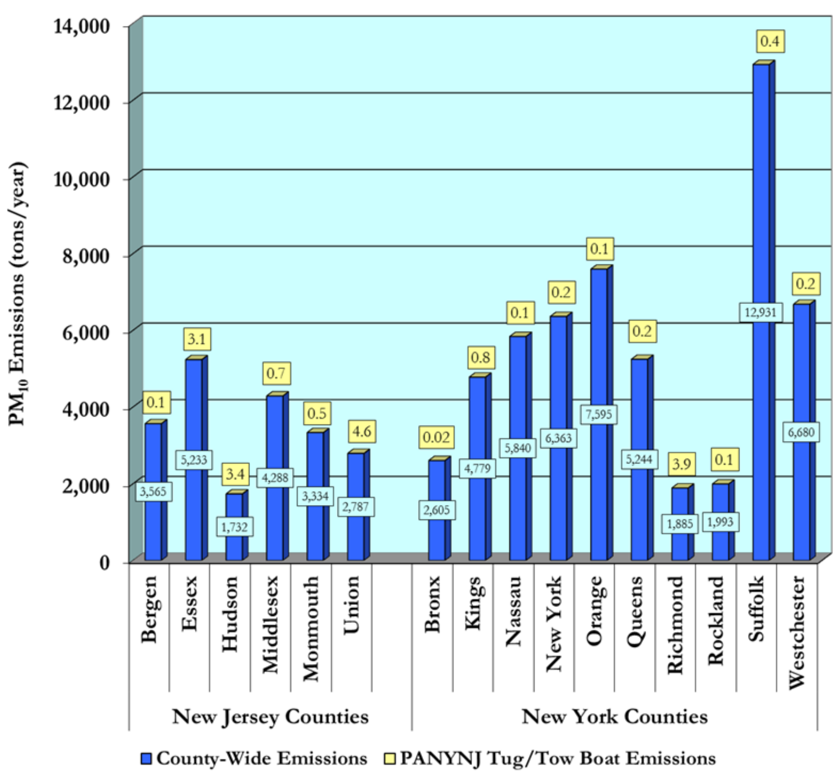


Table 5.20: Comparison of Harbor Craft $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	2,101	0	0.00%
Essex	NJ	2,574	3	0.12%
Hudson	NJ	1,284	3	0.25%
Middlesex	NJ	2,335	1	0.03%
Monmouth	NJ	1,737	0	0.03%
Union	NJ	1,877	4	0.24%
New Jersey Subtotal		**11,908**	**12**	**0.10%**
Bronx	NY	1,474	0	0.00%
Kings (Brooklyn)	NY	2,693	1	0.03%
Nassau	NY	2,740	0	0.00%
New York	NY	3,199	0	0.01%
Orange	NY	2,462	0	0.00%
Queens	NY	3,030	0	0.01%
Richmond (Staten Isld)	NY	1,090	4	0.35%
Rockland	NY	801	0	0.02%
Suffolk	NY	5,117	0	0.01%
Westchester	NY	2,656	0	0.01%
New York Subtotal		**25,262**	**6**	**0.02%**
TOTAL		**37,170**	**18**	**0.05%**

Figure 5.11: Comparison of Harbor Craft $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

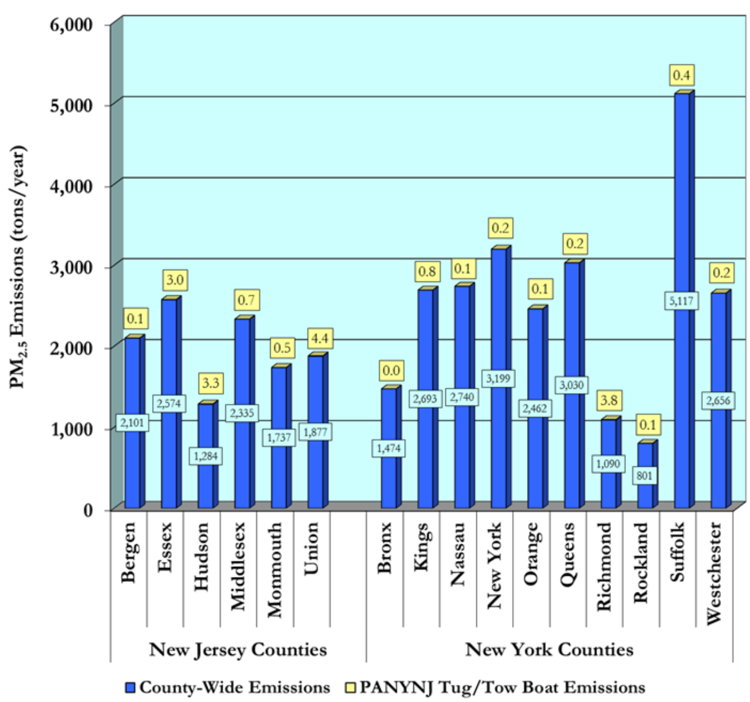


Table 5.21: Comparison of Harbor Craft VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	17,028	0	0.000%
Essex	NJ	16,814	3	0.015%
Hudson	NJ	9,244	3	0.030%
Middlesex	NJ	16,653	1	0.003%
Monmouth	NJ	12,551	0	0.003%
Union	NJ	11,037	4	0.034%
New Jersey Subtotal		**83,327**	**10**	**0.012%**
Bronx	NY	14,156	0	0.000%
Kings (Brooklyn)	NY	26,367	1	0.003%
Nassau	NY	21,541	0	0.001%
New York	NY	21,185	0	0.001%
Orange	NY	9,654	0	0.001%
Queens	NY	27,358	0	0.001%
Richmond (Staten Isld)	NY	6,576	3	0.050%
Rockland	NY	5,701	0	0.002%
Suffolk	NY	33,256	0	0.001%
Westchester	NY	17,665	0	0.001%
New York Subtotal		**183,459**	**5**	**0.003%**
TOTAL		**266,786**	**15**	**0.006%**

Figure 5.12: Comparison of Harbor Craft VOC Emissions with Overall VOC Emissions by County, tpy

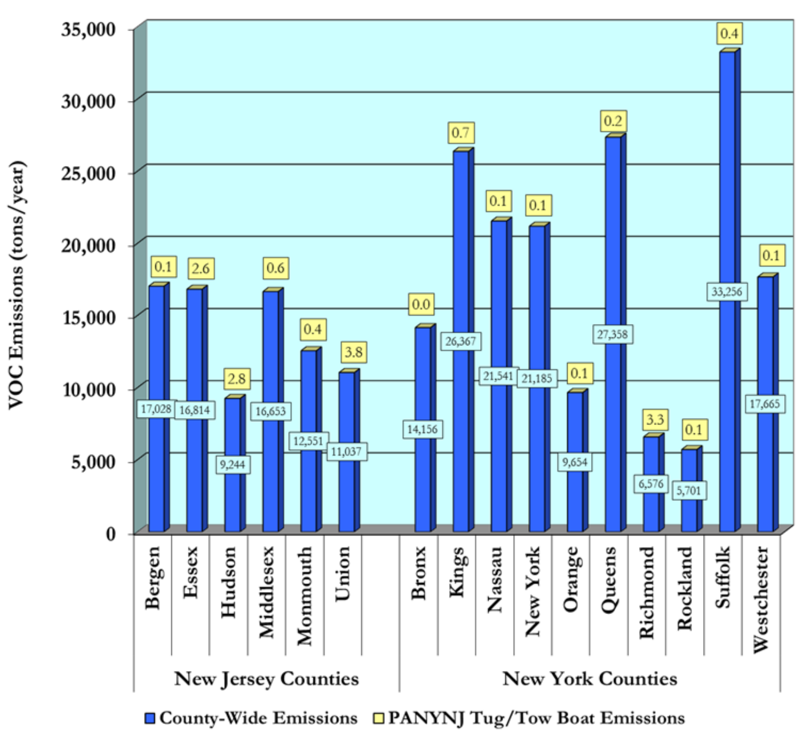


Table 5.22: Comparison of Harbor Craft CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	110,855	0	0.000%
Essex	NJ	79,450	8	0.011%
Hudson	NJ	37,073	9	0.025%
Middlesex	NJ	87,617	2	0.002%
Monmouth	NJ	74,655	1	0.002%
Union	NJ	55,299	12	0.023%
New Jersey Subtotal		**444,949**	**34**	**0.008%**
Bronx	NY	52,643	0	0.000%
Kings (Brooklyn)	NY	101,980	2	0.002%
Nassau	NY	124,041	0	0.000%
New York	NY	124,401	0	0.000%
Orange	NY	48,412	0	0.001%
Queens	NY	123,921	1	0.000%
Richmond (Staten Isld)	NY	33,262	11	0.032%
Rockland	NY	32,711	0	0.001%
Suffolk	NY	182,114	1	0.001%
Westchester	NY	105,117	0	0.000%
New York Subtotal		**928,602**	**17**	**0.002%**
TOTAL		**1,373,551**	**50**	**0.004%**

Figure 5.13: Comparison of Harbor Craft CO Emissions with Overall CO Emissions by County, tpy

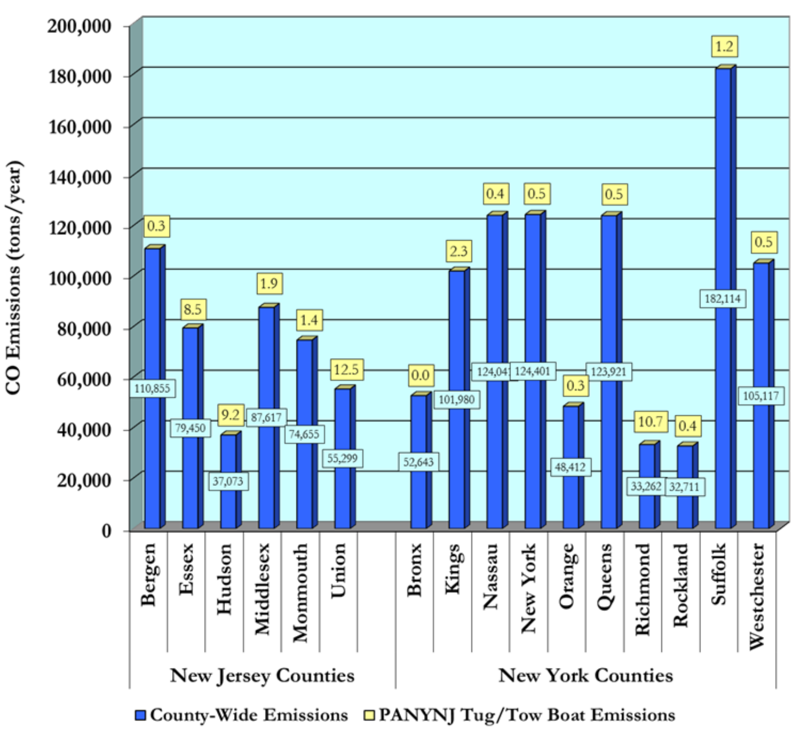


Table 5.23: Comparison of Harbor Craft SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	679	0.0	0.00%
Essex	NJ	2,630	0.1	0.00%
Hudson	NJ	1,817	0.1	0.00%
Middlesex	NJ	771	0.0	0.00%
Monmouth	NJ	671	0.0	0.00%
Union	NJ	1,053	0.2	0.01%
New Jersey Subtotal		**7,621**	**0.4**	**0.00%**
Bronx	NY	1,769	0.0	0.000%
Kings (Brooklyn)	NY	2,021	0.0	0.001%
Nassau	NY	3,045	0.0	0.000%
New York	NY	6,776	0.0	0.000%
Orange	NY	10,728	0.0	0.000%
Queens	NY	2,932	0.0	0.000%
Richmond (Staten Isld)	NY	383	0.1	0.020%
Rockland	NY	461	0.0	0.001%
Suffolk	NY	11,488	0.0	0.000%
Westchester	NY	2,612	0.0	0.000%
New York Subtotal		**42,215**	**0.1**	**0.000%**
TOTAL		**49,836**	**0.5**	**0.001%**

Figure 5.14: Comparison of Harbor Craft SO_2 Emissions with Overall SO_2 Emissions by County, tpy

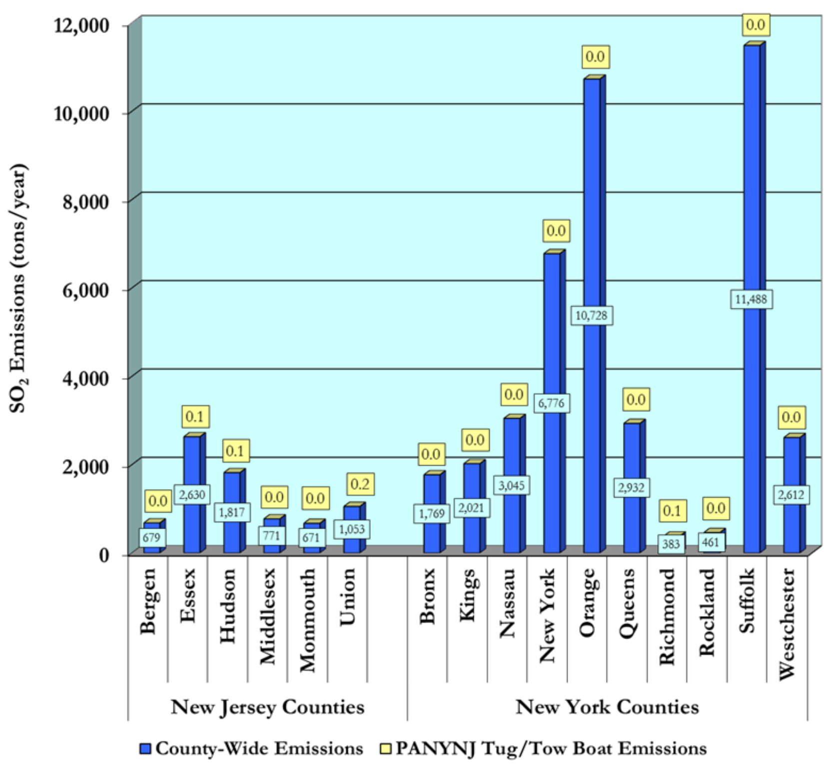
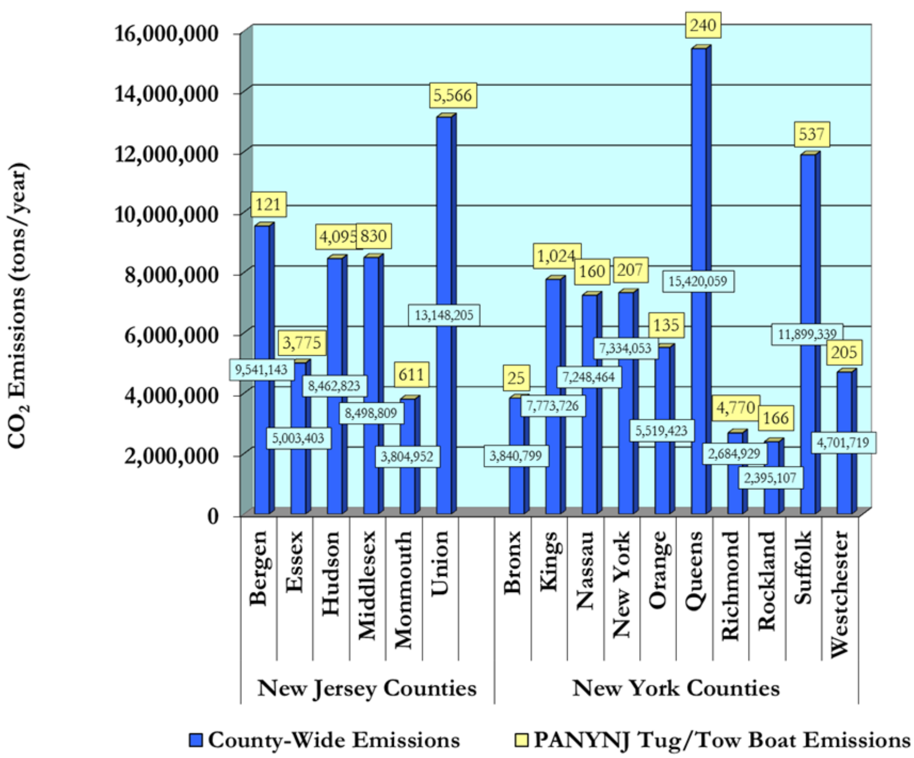


Table 5.24: Comparison of Harbor Craft CO_2 Emissions with Overall CO_2 Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	9,541,143	121	0.00%
Essex	NJ	5,003,403	3,775	0.08%
Hudson	NJ	8,462,823	4,095	0.05%
Middlesex	NJ	8,498,809	830	0.01%
Monmouth	NJ	3,804,952	611	0.02%
Union	NJ	13,148,205	5,566	0.04%
New Jersey Subtotal		**48,459,335**	**14,998**	**0.03%**
Bronx	NY	3,840,799	25	0.00%
Kings (Brooklyn)	NY	7,773,726	1,024	0.01%
Nassau	NY	7,248,464	160	0.00%
New York	NY	7,334,053	207	0.00%
Orange	NY	5,519,423	135	0.00%
Queens	NY	15,420,059	240	0.00%
Richmond (Staten Isld)	NY	2,684,929	4,770	0.18%
Rockland	NY	2,395,107	166	0.01%
Suffolk	NY	11,899,339	537	0.00%
Westchester	NY	4,701,719	205	0.00%
New York Subtotal		**68,817,618**	**7,470**	**0.01%**
TOTAL		**117,276,953**	**22,468**	**0.02%**

Figure 5.15: Comparison of Harbor Craft CO_2 Emissions with Overall CO_2 Emissions by County, tpy



5.2.3 Comparison of CMV Emissions with Prior Year Emission Estimates

Emission changes from OGVs as compared to prior years' emissions are due to many factors such as changing levels of cargo of different types, higher number of calls by newer ships, programs implemented by the Port Authority to lower emissions, including the Clean Vessel Incentive Program, and implementation of the North American Emission Control Area (ECA) which mandates lower sulfur fuels within a specified distance of the North American coast. Each of these factors affects each pollutant to a different degree, so the net change in emissions of each pollutant over time is the sum of positive and negative effects of different magnitude. Some pollutants may increase somewhat whereas others, especially pollutants that are the target of emission reduction measures, may decrease.

There were no methodology changes in the quantification of OGV emissions. Differences between the 2013 inventory and the previous 2012 inventory that had an impact on emissions include:

- The North American Emission Control Area (ECA) was in effect for the full year in 2013 as opposed to only the latter part of 2012. The ECA came into effect August 1, 2012, bringing stricter limits on fuel sulfur content, reducing emissions of SO_2 and PM. The sulfur content limit for fuel oil for OGVs operating in ECAs is 1% S.
- The Port Authority of New York and New Jersey Clean Vessel Incentive (CVI) Program was in effect the full year in 2013. This program aims to provide incentives to vessel operators that perform better in reducing air emissions than required by the current international emissions standards. In 2013, 229 vessels that visited the Port Authority marine terminals participated in the CVI program, making a total of 552 calls that earned incentive payments for reducing emissions by traveling slower and using cleaner fuel than required. Participating vessels switched to lower sulfur fuel than the 1% S ECA requirement while at port.

Table 5.25 presents a comparison of 2013 OGV emissions with emissions in earlier inventory years, and Table 5.26 present the comparison for harbor craft. Each table lists the annual OGV or harbor craft emissions as estimated in the respective emissions inventories, the emissions for each year as adjusted with the addition of the new terminals, the percentage difference between each prior inventory's adjusted emissions and the 2013 estimates, emissions in tons per million TEUs, and the percentage differences in tons per million TEUs between the prior years and 2013. The OGV emissions presented in Table 5.25 estimates emissions to the three mile boundary.

Emissions of all pollutants, except as noted below, were lower in 2013 than in earlier years, especially SO_2, particulate matter, and NO_x, as shown in Table 5.25. With the only exception being VOC, these are all emissions that are reduced by lower sulfur fuels.

Table 5.25: Comparison of 2013 OGV Emissions with Prior Year Emissions, tons per year and percent

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq	Million TEUs
Tons per year, as published								
2013	2,495	158	127	149	262	652	139,772	5.467
2012	2,513	250	197	144	256	1,728	143,780	5.530
2010	3,059	295	236	138	293	2,699	158,562	5.007
2008	2,934	288	230	113	255	2,935	175,517	4.711
2006	3,691	348	279	165	319	3,270	197,664	4.657
Tons per year, with adjustments								
2013	2,495	158	127	149	262	652	139,772	5.467
2012	2,513	250	197	144	256	1,728	143,780	5.530
2010	2,797	294	235	170	289	2,445	142,923	5.292
2008	3,334	328	262	128	290	3,336	199,479	5.265
2006	4,121	387	310	183	356	3,626	219,220	5.093
Percent change relative to 2013 - tons per year (adjusted)								
2012 - 2013	-1%	-37%	-36%	3%	2%	-62%	-3%	-1%
2010 - 2013	-11%	-46%	-46%	-12%	-9%	-73%	-2%	3%
2008 - 2013	-25%	-52%	-52%	16%	-10%	-80%	-30%	4%
2006 - 2013	-39%	-59%	-59%	-19%	-26%	-82%	-36%	7%
Tons per million TEU								
2013	456	29	23	27	48	119	25,566	
2012	454	45	36	26	46	313	26,000	
2010	529	56	44	32	55	462	27,007	
2008	633	62	50	24	55	634	37,888	
2006	809	76	61	36	70	712	43,043	
Percent change relative to 2013 - tons per million TEU								
2012 - 2013	0%	-36%	-36%	4%	4%	-62%	-2%	
2010 - 2013	-14%	-48%	-48%	-16%	-13%	-74%	-5%	
2008 - 2013	-28%	-53%	-54%	13%	-13%	-81%	-33%	
2006 - 2013	-44%	-62%	-62%	-25%	-31%	-83%	-41%	

Table 5.26 presents, for harbor craft, similar information as presented above for OGVs.

Table 5.26: Comparison of 2013 Harbor Craft Emissions with Prior Year Emissions, tons per year and percent

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2 Eq	Million TEUs
Tons per year, as published								
2013	384	19	18	15	50	0	22,468	5.467
2012	403	22	21	16	45	1.7	22,796	5.530
2010	360	20	19	14	40	8	20,385	5.007
2008	425	23	22	16	48	9	24,077	4.711
2006	486	26	24	18	41	50	26,691	4.657
Tons per year, with adjustments								
2013	384	19	18	15	50	0	22,468	5.467
2012	403	22	21	16	45	2	22,796	5.530
2010	369	20	19	14	41	8	20,871	5.292
2008	443	24	23	17	50	9	25,100	5.265
2006	505	27	25	19	43	52	27,712	5.093
Percent change relative to 2013 - tons per year (adjusted)								
2012 - 2013	-4%	-15%	-16%	-1%	13%	-72%	-1%	-1%
2010 - 2013	4%	-7%	-8%	8%	23%	-94%	8%	3%
2008 - 2013	-13%	-23%	-23%	-10%	1%	-95%	-10%	4%
2006 - 2013	-24%	-32%	-29%	-19%	17%	-99%	-19%	7%
Tons per million TEU								
2013	70	3.4	3.3	2.8	9.2	0.1	4,110	
2012	73	4.0	3.8	2.8	8.1	0.3	4,122	
2010	70	3.8	3.7	2.7	7.7	1.5	3,944	
2008	84	4.6	4.4	3.3	9.4	1.8	4,767	
2006	99	5.4	4.9	3.7	8.5	10.2	5,441	
Percent change relative to 2013 - tons per million TEU								
2012 - 2013	-4%	-15%	-13%	0%	14%	-67%	0%	
2010 - 2013	0%	-11%	-11%	4%	19%	-93%	4%	
2008 - 2013	-17%	-26%	-25%	-15%	-2%	-94%	-14%	
2006 - 2013	-29%	-37%	-33%	-24%	8%	-99%	-24%	

5.3 CMV Emission Calculation Methodology

This section discusses the information sources used to develop physical and operational profiles of marine vessel activity, and the methods used to estimate emissions. The emission estimates are based on locally specific data on vessel movements to and from the Port Authority marine terminals listed above based on Automatic Identification System (AIS) information provided by the U.S. Coast Guard. Information from IHS–Fairplay (commonly known as "Lloyd's data" due to previous company ownership) has been used to develop profiles of the physical and operational parameters of OGVs.

5.3.1 Data Sources

This subsection discusses the sources of information used in developing the emission estimates for commercial marine vessels associated with the Port Authority marine terminals. The vessel categories of OGVs, assist tugs, and towboats are discussed in turn.

5.3.1.1 Ocean-Going Vessels

The AIS data for vessels that called the Port Authority marine terminals forms the basis of the emission estimates presented in this report. Some of the terminals provided the number of calls for their terminals in 2013, which were used to check the AIS activity data results. The AIS vessel data for the Port Authority marine terminals was used to develop vessel type characteristic averages to be used for vessels that did not have specific data, and to determine speeds, routes, and dwelling times.

OGV emissions have been estimated for the two general modes of ship operations: transit and dwelling. Transit refers to the activity that occurs between the study area boundary and the terminal berth, while dwelling (also known as hotelling) refers to the vessel's operation while at berth. Activity levels have been evaluated based on the number of calls the vessels made to Port Authority marine terminals and speed profiles within the channel based on information developed from the AIS data using geographical information system (GIS) data analysis. The vessel specific data was used to profile each vessel type's characteristics such as engine type, propulsion horsepower, onboard auxiliary horsepower, nation of registry, and other parameters.

Vessel call activity and main engine horsepower, along with estimated speed and time-in-mode data, have been used to estimate OGV emissions. Transit emissions have been differentiated by ship type and terminal of call. In addition, emissions have been estimated for the three primary ship-related emission sources: propulsion engines, auxiliary engines and auxiliary boilers. Different emission factors and calculation methods have been used for each emission source type, as appropriate.

The emission estimates developed for this report are based exclusively on the number of OGV calls to Port Authority-owned marine terminals, a subset of all NYNJHS calls. Based on AIS data, the numbers of calls of each vessel type to Port Authority owned marine terminals are listed in Table 5.27.

Table 5.27: Vessel Movements for the Port Authority Marine Terminals

Vessel Type	**Arrivals/ Calls**
Auto Carrier	292
Bulk Carrier	69
Containership	2,131
Cruise Ship	83
General Cargo	22
Reefer	39
RoRo	78
Tanker	57
Total	**2,771**

Average main engine power for each vessel was obtained from the Lloyd's data based on the specific vessels that called. Auxiliary engine and auxiliary boiler engine loads are not included in the Lloyd's data so values for these engines were obtained from recently released marine vessel emissions inventories.[34] The averages in the table are shown as a summary of the data and were used as defaults in the circumstance that Lloyd's did not have information on a specific vessel.

Table 5.28: Average OGV Engine and Boiler Power (kW)

Vessel Type	Main Power (kW)	Auxiliary Load (kW)	Boiler Load (kW)
Auto Carrier	14,628	3,764	253
Bulk	8,481	1,776	132
Bulk - Heavy Load	7,200	1,499	132
Containership 1000	12,684	3,789	241
Containership 2000	22,848	5,436	325
Containership 3000	30,893	6,253	474
Containership 4000	40,328	7,493	492
Containership 5000	49,051	10,133	630
Containership 6000	56,573	9,388	565
Containership 7000	68,639	11,840	565
Containership 8000	65,467	12,843	525
Containership 9000	67,254	11,552	547
Cruise	84,003	2,247	NA
General Cargo	6,193	1,971	137
Reefer	16,320	6,848	255
Ro-Ro	17,845	9,042	248
Tanker - Chemical	8,503	2,984	3,000
Tanker - Handysize	9,180	1,839	3,000
Tanker - Panamax	11,055	2,018	3,000

[34] Port of Los Angeles Inventory of Air Emissions, 2012

5.3.1.2 Assist Tugs

Assist tug emissions have been estimated on the basis of typical assist tug activity associated with each OGV entering or exiting from the channel (e.g., how many tugs per call, the duration of assistance, etc.). The emission factors (see section 5.3.2) were updated to take into account the Tier level of the assist tugs in the harbor. Table 5.29 lists the number of vessel assists and the average number of assist tugs per arrival or departure for the various vessel types.

Table 5.29: Assist Tug Operating Data and Assumptions

Vessel Type	Inbound trips	Outbound trips	Shifts	Total trips	Average Assists per Movement	Total Assists
Auto Carrier	292	292	50	634	2	1,268
Bulk Carrier	69	69	24	162	2	324
Containership	2,131	2,128	55	4,314	2	8,628
Cruise Ship	83	83	0	166	1	166
General Cargo	22	22	5	49	2	98
Reefer	39	39	0	78	2	156
RoRo	78	78	44	200	2	400
Tanker	57	57	21	135	2	270
Total	**2,771**	**2,768**	**199**	**5,738**		**11,310**

5.3.1.3 Towboats/Pushboats

The various marine terminals provided a record of the towboat/pushboat arrivals and departures related to Port Authority marine terminals. The types of materials moved to or from the terminals included containers, fuel, dry bulk such as scrap metal, and dredged material from wharf maintenance dredging. The vessel operating characteristics such as onboard engine horsepower and average load factors are consistent with the previous emissions inventories. The same emission factors were used for these vessels as for assist tugs, because the vessels share many of the same characteristics.

5.3.2 Emission Estimating Methodology

Emission estimates have been developed for the three combustion emission source types associated with marine vessels: main (or propulsion) engines, auxiliary engines, and, for OGVs, auxiliary boilers. OGV emissions have been further segregated into transit (arrival/departure) and dwelling (at-berth) components. Operating data and the methods of estimating emissions are discussed below for the three source types – differences between transit and dwelling methodologies are discussed where appropriate. Fuel sulfur content plays an important role in marine vessel emissions. The estimates were made assuming that all OGVs calling the port terminals used HFO with an average sulfur content of 1% per IMO's requirement for the North American Emissions Control Area (ECA). Exceptions were made for vessels that participated in the Clean Vessel Incentive program using MDO/MGO with lower sulfur content during dwelling.

5.3.2.1 OGV Main Engines

Main engine emissions are only estimated for transiting because in almost all cases a vessel's main engines are turned off while the vessel is tied up at berth. The emission calculation can be described using the following equation:

Equation 5.1

Emissions (grams) = MCR power (kW) x LF x activity (hours) x EF (g/kW-hr) x FCF (unitless)

Where:

Emissions in grams are converted to tons by dividing by 453.59 grams per pound and 2,000 pounds per ton
MCR power = maximum continuous rated power
LF = load factor, calculated as $(\text{actual speed}/\text{sea speed})^3$
activity = hours at the given (actual) speed, calculated as distance/speed
EF = factor that expresses mass emissions (grams) in terms of kW-hrs (g/kW-hr)
FCF = fuel correction factor that adjusts the emission factor for a different fuel form the fuel on which the original emission factor was based, such as HFO, MDO, or MGO with different sulfur content.

The load factor is calculated using a relationship between vessel speed and power requirement known as the Propeller Law, which holds that the power required to move a vessel through the water varies with the cube of the ratio of the vessel's actual speed to its maximum speed. Therefore, the maximum power multiplied by the cube of actual speed divided by maximum speed provides an estimate of the actual power demand at that speed.

Most of the emission factors used to estimate emissions were reported in a 2002 Entec study,[35] updated based on newer information.[36] The PM_{10} and SO_2 emission factors have been based on the following equations[37] for HFO fuel with 2.7% sulfur content:

Equation 5.2

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

Where:

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

[35] Entec, UK Limited, *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community, Final Report*, July 2002. Prepared for the European Commission.
[36] IVL, Methodology for Calculating Emissions from Ships: Update on Emission Factors," February 2004. Prepared by IVL Swedish Environmental Research Institute for the Swedish Environmental Protection Agency. (IVL 2004)
[37] Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report, April 2009

Equation 5.3

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

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

The emission factors used for main and auxiliary engines and for auxiliary boilers based on HFO with a sulfur content of 2.7% are listed in Tables 5.30 (criteria pollutants) and 5.31 (greenhouse gases).

Table 5.30: OGV Criteria Pollutant Emission Factors (g/kW-hr)

Engine Category	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Slow Speed Main (Tier 0)	1999 and older	18.1	1.4	1.1	0.6	1.4	10.3
Slow Speed Main (Tier 1)	2000 to 2011	17	1.4	1.1	0.6	1.4	10.3
Slow Speed Main (Tier 2)	2011 to 2016	15.3	1.4	1.1	0.6	1.4	10.3
Medium Speed Main (Tier 0)	1999 and older	14	1.4	1.1	0.5	1.1	11.3
Medium Speed Main (Tier 1)	2000 to 2011	13	1.4	1.1	0.5	1.1	11.3
Medium Speed Main (Tier2)	2011 to 2016	11.2	1.4	1.1	0.5	1.1	11.3
Steam Main and Boiler	All	2.1	0.8	0.64	0.1	0.2	16.5
Medium Auxiliary (Tier 0)	1999 and older	14.7	1.4	1.1	0.4	1.1	12.0
Medium Auxiliary (Tier 1)	2000 to 2011	13	1.4	1.1	0.4	1.1	12.0
Medium Auxiliary (Tier 2)	2011 to 2016	11.2	1.4	1.1	0.4	1.1	12.0

Table 5.31: OGV Greenhouse Gas Emission Factors (g/kW-hr)

Engine Category	Model Year Range	CO_2	N_2O	CH_4
Slow Speed Main (Tiers 0 to 2)	All	620	0.031	0.012
Medium Speed Main (Tiers 0 to 2)	All	683	0.031	0.012
Steam Main and Boiler	All	970	0.08	0.002
Medium Auxiliary (Tiers 0 to 2)	All	722	0.031	0.008

Emission factors are adjusted upward for speeds at which loads are less than 20% because vessel emissions are believed to increase at very low loads due to lower engine operating efficiency. Table 5.32 lists the low load adjustment factors used in estimating slow speed emissions. These unitless adjustment factors are included in Equation 5.1 above as an additional multiplier. Currently, greenhouse gas emission factors are not adjusted for low load operation.

Table 5.32: OGV Low Load Adjustment Factors

Load	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
2%	4.63	7.29	7.29	21.18	9.68	1.00
3%	2.92	4.33	4.33	11.68	6.46	1.00
4%	2.21	3.09	3.09	7.71	4.86	1.00
5%	1.83	2.44	2.44	5.61	3.89	1.00
6%	1.6	2.04	2.04	4.35	3.25	1.00
7%	1.45	1.79	1.79	3.52	2.79	1.00
8%	1.35	1.61	1.61	2.95	2.45	1.00
9%	1.27	1.48	1.48	2.52	2.18	1.00
10%	1.22	1.38	1.38	2.18	1.96	1.00
11%	1.17	1.3	1.3	1.96	1.79	1.00
12%	1.14	1.24	1.24	1.76	1.64	1.00
13%	1.11	1.19	1.19	1.6	1.52	1.00
14%	1.08	1.15	1.15	1.47	1.41	1.00
15%	1.06	1.11	1.11	1.36	1.32	1.00
16%	1.05	1.08	1.08	1.26	1.24	1.00
17%	1.03	1.06	1.06	1.18	1.17	1.00
18%	1.02	1.04	1.04	1.11	1.11	1.00
19%	1.01	1.02	1.02	1.05	1.05	1.00
20%	1.00	1.00	1.00	1.00	1.00	1.00

5.3.2.2 OGV Auxiliary Engines

Auxiliary engine emissions are estimated using an equation similar to the main engine equation:

Equation 5.4

Emissions (grams) = total rated power (kW) x LF x activity (hours) x EF (g/kW-hr) x FCF (unitless)

Where:

Emissions in grams are converted to tons by dividing by 453.59 grams per pound and 2,000 pounds per ton

total rated power = the sum of the rated power of all installed auxiliary engines

LF = load factor, the average load over all installed auxiliary engines

activity = hours at the given load, calculated as distance/speed for transit and average dwelling duration for time at berth

EF = factor that expresses mass emissions (grams) in terms of kW-hrs (g/kW-hr)

FCF = fuel correction factor that adjusts the emission factor for fuel (such as HFO, MDO, and MGO with different sulfur content) other than the base fuel on which the original emission factors were estimated.

OGVs are equipped with two or more auxiliary engines, and they are operated to run at the most efficient level for a given load situation. For example, an OGV equipped with four auxiliary engines may run three at 75% load when power needs are high during maneuvering, to power bow thrusters as well as to meet general operating needs. While at berth the vessel's power needs are less – instead of running the three engines at greatly reduced load, typically only one or two will be operated, which saves wear and tear on the others, and allows the operating engine to run at its optimal and (higher) operating levels. In general, actual auxiliary engine and auxiliary boiler loads are not readily available for specific vessels. The information used for these estimates has been collected during vessel boarding programs where the operators of the ship are interviewed to collect actual engine load information, and summaries have been published by the port(s) sponsoring these programs.[38] Table 5.33 lists the OGV auxiliary load factor assumptions used in this inventory.

[38] Port of Los Angeles Inventory of Emissions, 2012.

Table 5.33: OGV Auxiliary Engine Load by Mode

Vessel Type	Transit (kW)	Manuevering (kW)	Berth Dwelling (kW)
Auto Carrier	503	1,508	838
Bulk	255	675	150
Bulk - Heavy Load	255	675	150
Container1000	396	942	297
Container2000	981	2,180	1,035
Container3000	602	2,063	516
Container4000	1,434	2,526	1,161
Container5000	1,176	4,200	1,008
Container6000	1,425	2,178	986
Container8000	1,416	3,158	980
Container9000	1,502	3,350	1,040
Cruise	5,104	8,166	5,104
General Cargo	516	1,439	722
Reefer	513	1,540	890
RoRo	434	1,301	751
Tanker - Chemical	677	931	734
Tanker - Handysize	441	607	478
Tanker - Panamax	574	789	622

For diesel electric cruise ships, house load defaults are listed in Table 5.34. Most cruise ships that called the cruise terminal were diesel electric, with the exception of two small cruise ships.

Table 5.34: Diesel Electric Cruise Ship Auxiliary Engine Load, kW

Vessel Type	Passenger Count	Transit	Maneuvering	Dwelling
Cruise, Diesel Electric	0-1,499	3,500	3,500	3,000
Cruise, Diesel Electric	1,500-1,999	7,000	7,000	6,500
Cruise, Diesel Electric	2,000-2,499	10,500	10,500	9,500
Cruise, Diesel Electric	2,500-2,999	11,000	11,000	10,000
Cruise, Diesel Electric	3,000-3,499	11,500	11,500	10,500
Cruise, Diesel Electric	3,500-3,999	12,000	12,000	11,000
Cruise, Diesel Electric	4,000-999,999	13,000	13,000	12,000

Operating hours (activity) are based on the same distance/speed calculation as for main engines for periods the vessels are in motion and on the specific dwell times provided by vessel call. Dwell times for this inventory were calculated from the AIS data for each call and these times were used in the emissions calculations. Table 5.35 lists the minimum, maximum, and average dwell times for the different vessel types and sizes that called at Port Authority terminals.

Table 5.35: Summary of Dwell Time, hours

Vessel Type	Min	Max	Average
Auto Carrier	0	47	17
Bulk	0	340	67
Bulk - Heavy Load	93	93	93
Containership 1000	6	101	20
Containership 2000	0	36	14
Containership 3000	0	88	23
Containership 4000	0	90	21
Containership 5000	10	86	26
Containership 6000	12	51	22
Containership 7000	14	42	27
Containership 8000	24	126	46
Containership 9000	24	50	41
Cruise	3	15	10
General Cargo	0	1,071	74
Reefer	4	10	7
Ro-Ro	0	435	14
Tanker - Chemical	0	136	29
Tanker - Handysize	0	37	24
Tanker - Panamax	0	30	13

For this 2013 EI, it should be noted that there were 2 general cargo vessels included with very high dwell times (as high as 1,071 hours) which increased the average dwelling time for this vessel category from 13.6 to 74 hours. These vessels were tracked on AIS data, but the terminals did not show these vessels in their call list when asked for further information on the nature of the long stay at berth. For sake of completeness and to be conservative with the emission estimates, the vessels were included in the inventory and estimated as tracked on the AIS data, with the high dwelling time.

5.3.2.3 OGV Auxiliary Boilers

The same basic equation is used to estimate auxiliary boiler emissions as main and auxiliary engines. Boilers typically are not needed when vessels are under way since most vessels are equipped with economizers (waste heat boilers) that recover main engine exhaust heat. The auxiliary boilers start up as exhaust temperatures decrease when vessel speed decreases upon arrival in the harbor system, and they are assumed to be fully operating during maneuvering conditions.

The boiler kW values shown in Table 5.28 have been converted from fuel consumption data to standardize the calculation methodology. The values presented are in-use estimates for normal operation, so the load factor for operating boilers is 100% except for tankers while maneuvering, in which case the load factor is 7%. This special treatment of tankers is made because many tankers operate very large boilers to run discharge pumps when they are off-loading cargo, so the kW value used for tanker boilers represents this high operating level for much of the tankers' dwelling time. During maneuvering the boilers are not operating at this high rate, so the load factor is reduced to account for the lower level of operation. Boiler load factor assumptions are presented below in Table 5.36.

Table 5.36: OGV Boiler Load Factors

Vessel Type	Boilers Harbor	Boilers Dwelling
Auto Carrier / RORO	100%	100%
Bulk Carrier	100%	100%
Containership	100%	100%
Cruise Ship (diesel electric)	0%	0%
Cruise Ship (direct drive)	100%	100%
General Cargo	100%	100%
Reefer	100%	100%
Tanker	7%	100%

5.3.2.4 OGV Fuel Correction Factors

As shown in equations 5.1 and 5.2, fuel correction factors are applied to reflect the effect of fuel on emissions when the actual fuel used is different than the fuel used to develop the emission factors. As discussed earlier, main, auxiliary and auxiliary boiler emission factors are based on HFO with an average 1% sulfur content to meet IMO sulfur limit requirements in the ECA established in the October 2008 MARPOL Annex VI agreement. In addition, several vessels under the CVI program used MDO/MGO lower sulfur fuel at berth. Table 5.37 shows the FCF[39] used to adjust the emission factors which are based on HFO with 2.7% sulfur. The vessels used lower sulfur fuel with several different sulfur contents and the FCF was estimated accordingly. The sulfur contents shown in the table are representative of the fuel used, but it is not a complete list of all the various sulfur contents.

Table 5.37: Fuel Correction Factors (unitless)

Actual Fuel Used Content	Sulfur Content by weight %	Fuel Correction Factors							
		NOx	PM	VOC	CO	SO_2	CO_2	N_2O	CH_4
HFO	1.00%	1.000	0.730	1.000	1.000	0.370	1.000	1.000	1.000
MDO/MGO	0.50%	0.940	0.250	1.000	1.000	0.185	0.950	0.940	1.000
MDO/MGO	0.40%	0.940	0.230	1.000	1.000	0.148	0.950	0.940	1.000
MDO/MGO	0.30%	0.940	0.210	1.000	1.000	0.111	0.950	0.940	1.000
MDO/MGO	0.20%	0.940	0.190	1.000	1.000	0.074	0.950	0.940	1.000
MDO/MGO	0.10%	0.940	0.170	1.000	1.000	0.037	0.950	0.940	1.000
MDO/MGO	0.05%	0.940	0.160	1.000	1.000	0.019	0.950	0.940	1.000
MDO/MGO	0.02%	0.940	0.150	1.000	1.000	0.007	0.950	0.940	1.000
MDO/MGO	0.01%	0.940	0.150	1.000	1.000	0.004	0.950	0.940	1.000

[39] 2012 Port of Los Angeles Inventory of Air Emissions, 2012

5.3.2.5 Assist Tugs, Towboats, Pushboats

The emission estimating methodology for assist tugs and towboats/pushboats is similar, based on an estimate of operating time of the vessels in service related to the Port Authority owned marine terminals. The basic equation for estimating main and auxiliary engine emissions is similar, and is illustrated below.

Equation 5.5

Emissions (grams) = engine power (kW) x LF x activity (hours) x EF (g/kW-hr)

Where:

Emissions in grams are converted to tons by dividing by 453.59 grams per pound and 2,000 pounds per ton

engine power = the sum of the rated power of all installed main or auxiliary engines (many vessels are equipped with two main engines that work in tandem, most have only one auxiliary engine)

LF = load factor for each engine

activity = hours of engine operation at the given load

EF = factor that expresses mass emissions (grams) in terms of kW-hrs (g/kW-hr)

The load factors used for assist tugs are 31% for main engines and 43% for auxiliary engines. The 31% for assist tugs is based on empirical data first published in the Port of Los Angeles' 2001 vessel emission inventory,[40] and which has been used widely since that time. The 43% factor for auxiliary engines is based on the EPA NONROAD model guidance[41] and has also been used in this inventory for the towboat/pushboat emission estimates. The main engine load factor for towboats and pushboats is 68% and is based on a California survey findings report[42] and has been used in previous inventories.

As discussed above, the operating time of assist tugs has been estimated on the basis of the amount of time spent assisting per OGV call, the average number of assist tugs per OGV call, and the total number of OGV calls to the Port Authority owned marine terminals in 2013. The operating time of towboats and pushboats has been estimated from the number of visits to the terminals and a profiled time from the 2006 towboat detailed activity data in which time was estimated by dividing trip length by speed in mode. Since detailed origination-destination data was not available for this inventory as it was for 2006, the earlier trip times were averaged and the resulting average trip time of 2.7 hours was used.

[40] 2001 POLA Baseline Emissions Inventory

[41] EPA, *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling*, December 2002, EPA 420-P-02-014.

[42] California Air Resources Board, *Statewide Commercial Harbor Craft Survey*, Final Report, March 2004.

The emission factors used for assist tug, towboat, and pushboat main and auxiliary engines are listed in Table 5.38.

Table 5.38: Assist Tug and Towboat/Pushboat Emission Factors, g/kW-hr

Engine	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2	N_2O	CH_4
Main Engines	12.4	0.60	0.58	0.50	1.61	0.01	690	0.08	0.23
Auxiliary Engines	10.0	0.40	0.39	0.27	1.70	0.05	690	0.08	0.23

The base emission factors[43] are based on marine engine standards (i.e., Tier 1, Tier 2) and the EPA engine category. Main engines for the tugboat fleet in NYNJ harbor mainly fall into Category 2 and the auxiliary engines are typically Category 1. EPA identifies the engine category in terms of cylinder displacement. Category 1 engines have 1 to 5 liters per cylinder displacement, while category 2 engines have a cylinder displacement between 5 to 30 liters.

For 2013 calendar year, the weighted emission factors were re-evaluated based on current assist tug fleet data and were updated accordingly based on the newer fleet data. A list of 38 specific tugboats was updated by the predominant vessel assist tugboat companies in the harbor. The majority of these vessels have marine engines that are pre-regulation or Tier 0 engines (engines older than 1999). There were 9 vessels that had main engines with newer engines due vessel repower, new vessels in the fleet, or had engine remanufacture kits installed. Four of the vessels had engines that fell into Tier 1 (IMO regulation for NO_x starting in the year 2000) and five of the vessels had engines that were Tier 2 (EPA regulation that affects engines with model year 2005 and newer). In order to take into account the newer vessels and vessels with new engines, a weighted emission factor was calculated for the main engines using the number of vessels subject to each emission standard. The same emission factors are used for assist tugs, towboats, and pushboats. Information on specifically which boats work within the harbor is not available at this time, but is believed the assist tugs and towboats/pushboats have similar characteristics and the use of the same emission factors may be a conservative assumption since there have been numerous vessel repowers in the region.

The SO_2 emission factor was calculated using a mass-balance method with an assumed diesel fuel sulfur content of 19 ppm in 2013. The average 19 ppm is based on EPA's Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder.[44]

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

[44] *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder,* EPA420-R-08-001, March 2008.

5.4 Description of Marine Vessels and Vessel Activity

The types of marine vessel evaluated in this emissions inventory include ocean-going vessels (OGVs), their assist tugs, and associated towboats and pushboats, such as those that provide bunkering (refueling) services or transport materials from wharf maintenance dredging activities.

5.4.1 Ocean-Going Vessels

OGVs are seafaring vessels that are primarily involved in international trade. Generally, these vessels are over 300 feet in length and can make seaward passages greater than 25 miles. The following are types of OGVs that have been evaluated in this study:

Bulk and Break Bulk (General Cargo) Carriers carry granulated products in bulk (e.g., cement, sugar, coking coal) as well as goods known as break bulk such as machinery, steel, palletized goods, and livestock. In general, bulk carriers are slower and older than most other types of OGVs.

Figure 5.16: Bulk Carrier

Photograph courtesy of Petter Folkedahl Knutsen, Tuvika, Norway
http://home.nktv.no/petknu/skip.htm

Containerships carry standard-sized, steel-reinforced containers. Their capacity is measured in "twenty-foot equivalent units" (TEUs). Containers are an economical mode of marine transportation for a wide variety of dry and liquid cargos. Specialized containers can be equipped for refrigeration, and many ships have a number of electrical connections to store and power refrigerated units.

Figure 5.17: Containership at Berth

Passenger Cruise Ships have high diesel-powered generation capacities from auxiliary engines which are used to provide electricity, air conditioning, hot water, refrigeration, and other power-related demands associated with the ship.

Figure 5.18: Cruise Ship

Roll-on/Roll-off (RORO) Vessels and Car Carriers carry vehicles and other wheeled equipment. Some carry heavy-duty equipment such as military tanks, excavators, bulldozers and other similar equipment. Their unique feature is a moveable ramp that allows the vessel to load and unload wheeled vehicles and equipment. *Car Carriers* are a specialized type of RORO outfitted with lower deck heights specifically for the transport of cars, trucks, and other vehicles.

Figure 5.19: Car Carrier

Tankers carry crude oil, finished liquid petroleum products, and other liquids. Parcel tankers are specialized tankers that carry several different products at the same time in separate on-board tanks. Other liquids that may be carried include sewage, water, liquefied petroleum gas (LPG) and fruit juices.

Figure 5.20: Tanker

5.4.2 Assist Tugs, Towboats, Pushboats

Assist tugs help maneuver OGVs within the NYNJHS and during docking and departing from berths. Towboats are vessels that tow barges within the NYNJHS, moving cargo such as bunker fuel for refueling visiting OGVs. Boats used as assist tugs can also do duty as towboats. Pushboats are similar to towboats, except, as their name implies, they push barges rather than tow them. They can be used to move bulk liquids, scrap metal, bulk materials, rock, sand, dredged materials, and other materials.

Figure 5.21: Tugboat