THE PORT AUTHORITY OF NEW YORK AND NEW JERSEY

PORT COMMERCE DEPARTMENT

2014 MULTI-FACILITY EMISSIONS INVENTORY OF CARGO HANDLING EQUIPMENT, HEAVY-DUTY DIESEL VEHICLES, RAILROAD LOCOMOTIVES, AND COMMERCIAL MARINE VESSELS

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Prepared for:
The Port Authority of New York and New Jersey

Prepared by:

Starcrest Consulting Group, LLC
P.O. Box 434
Poulsbo, WA 98370

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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_2e	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
GTC	Global Container Terminal
GTM	gross ton-miles
GVWR	gross vehicle weight rating
GWP	global warming potential
HDDV	heavy-duty diesel vehicle
hp	horsepower
hp-hr	horsepower hour
kW	kilowatt
LPG	liquefied petroleum gas
MOBILE6.2	EPA's prior on-road vehicle emission estimating model
MOVES2014	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 emissions inventory (EI) is to estimate air emissions generated in 2014 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 2014 EI report is an update of the 2013 Multi-Facility Emissions Inventory and one of a series of such reports evaluating and documenting changes in emissions associated with these facilities over time.

ES.1 Trends in Emissions

Although the primary purpose of the 2014 calendar year emissions inventory and report is to provide an update to the emission estimates presented in the previous 2013 inventory report, additional findings should also be discussed. The 2013 emissions inventory report included emissions estimated for the previous years' inventories back to 2006, adjusted to account for emissions modeling changes from year to year. That report included tables showing the originally published emissions as well as the estimates that had been adjusted to account for methodology changes. The following table and figures that show the year-to-year emission changes are based on the adjusted emission estimates, which are comparable to the 2014 estimates.

In Table ES.1, which summarizes the emissions in each year for which an inventory was developed and the percent change relative to 2014, a negative percent change is a reduction in emissions while a positive percent change is an increase in emissions. The table also shows the change in Port throughput in terms of million TEUs (twenty-foot equivalent units of containerized cargo). These numbers remove the effect of throughput changes from the increases and decreases over time, leaving primarily the effects of lower-emission technologies and fuels, and efficiency improvements.

Table ES.1: Trends in Emissions over Inventory Years, tons per year

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e	Million TEUs
Tons per year, with adjustments								
2014	6,410	350	310	436	1,391	546	600,104	5.772
2013	6,585	396	355	447	1,489	657	612,866	5.467
2012	6,581	488	424	439	1,468	1,735	601,298	5.530
2010	7,147	576	495	439	1,421	2,460	596,146	5.292
2008	8,202	683	589	419	1,614	3,371	647,311	5.265
2006	8,845	778	665	481	1,706	3,972	684,015	5.093
Percent change relative to 2014 - tons per year								
2013 - 2014	-3%	-12%	-13%	-2%	-7%	-17%	-2%	6%
2012 - 2014	-3%	-28%	-27%	-1%	-5%	-69%	0%	4%
2010 - 2014	-10%	-39%	-37%	-1%	-2%	-78%	1%	9%
2008 - 2014	-22%	-49%	-47%	4%	-14%	-84%	-7%	10%
2006 - 2014	-28%	-55%	-53%	-9%	-18%	-86%	-12%	13%
Tons per million TEU								
2014	1,111	61	54	75	241	95	103,968	
2013	1,204	73	65	82	272	120	112,103	
2012	1,190	88	77	79	266	314	108,734	
2010	1,350	109	94	83	269	465	112,650	
2008	1,558	130	112	80	307	640	122,946	
2006	1,737	153	131	94	335	780	134,305	
Percent change relative to 2014 - tons per million TEU								
2013 - 2014	-8%	-16%	-17%	-9%	-11%	-21%	-7%	
2012 - 2014	-7%	-31%	-30%	-5%	-9%	-70%	-4%	
2010 - 2014	-18%	-44%	-43%	-10%	-10%	-80%	-8%	
2008 - 2014	-29%	-53%	-52%	-6%	-21%	-85%	-15%	
2006 - 2014	-36%	-60%	-59%	-20%	-28%	-88%	-23%	

Figures ES.1 through ES.7 graphically illustrate the changes in emissions, in tons per year, between the 2006 baseline emissions inventory and the 2014 update. The 2006 emissions are shown in each figure as a dashed line horizontal with the x axis, and the overall percent change between 2006 and 2014 is shown to the right of each chart, with an arrow indicating the direction of change in emissions. The units on the y-axis are tons per year. Inventories were developed for even numbered years between 2006 and 2012, so for the intervening odd-numbered years the charts have been prepared by interpolating between even numbered years. The inventories became annual starting with the 2012 update.

Figure ES.1: NO_x Emissions Trend

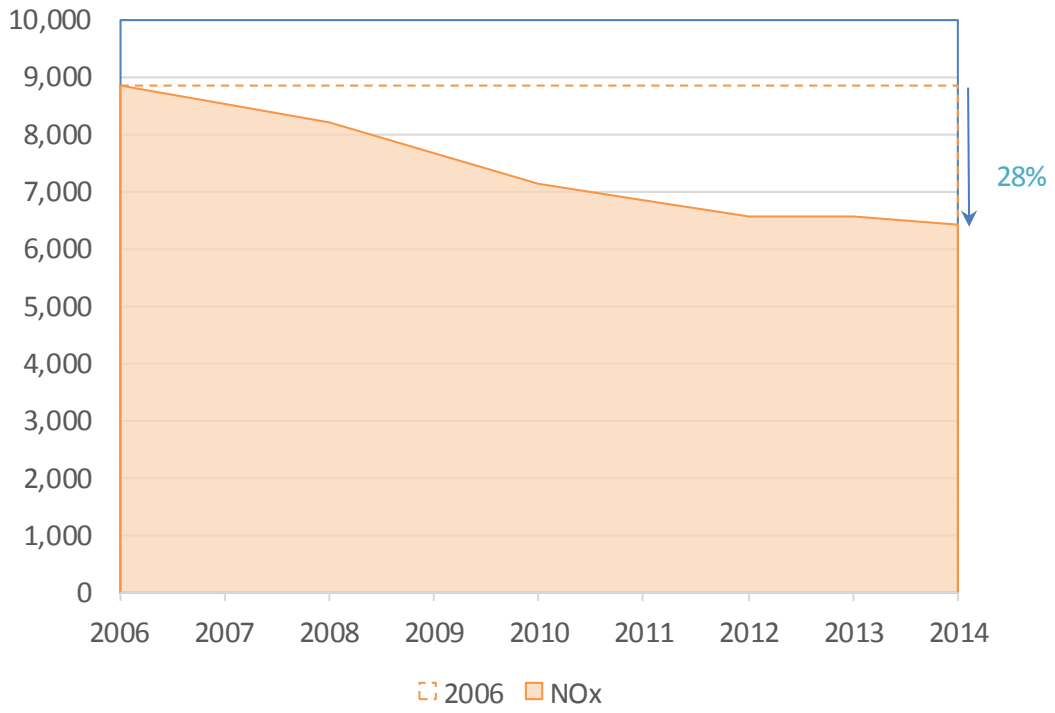


Figure ES.2: PM_{10} Emissions Trend

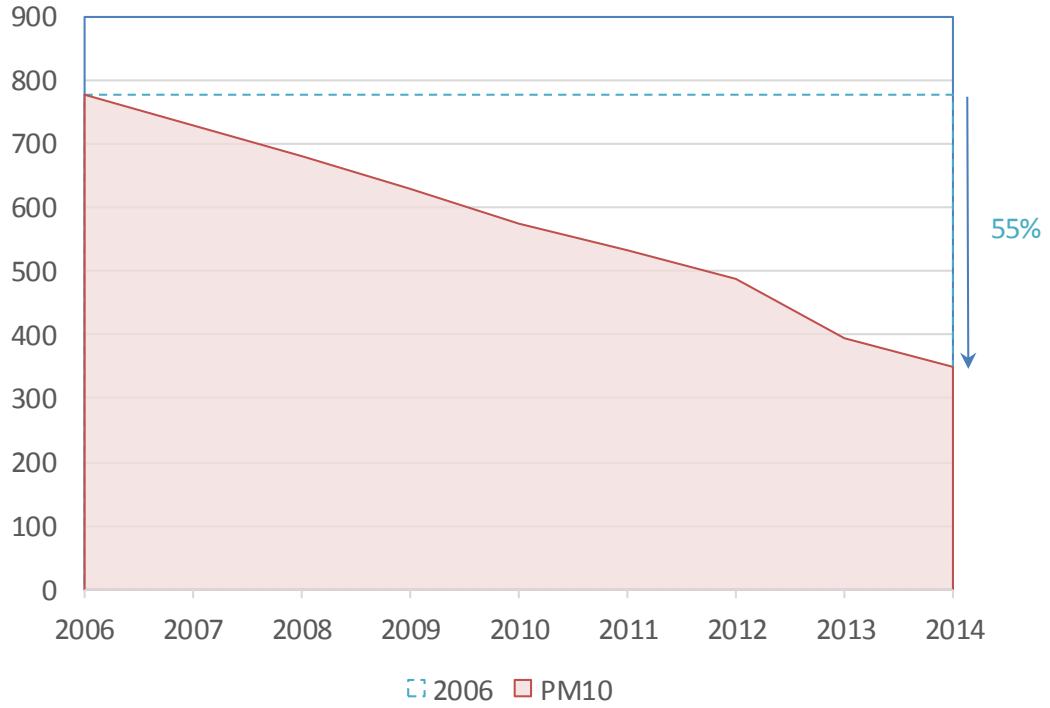


Figure ES.3: $PM_{2.5}$ Emissions Trend

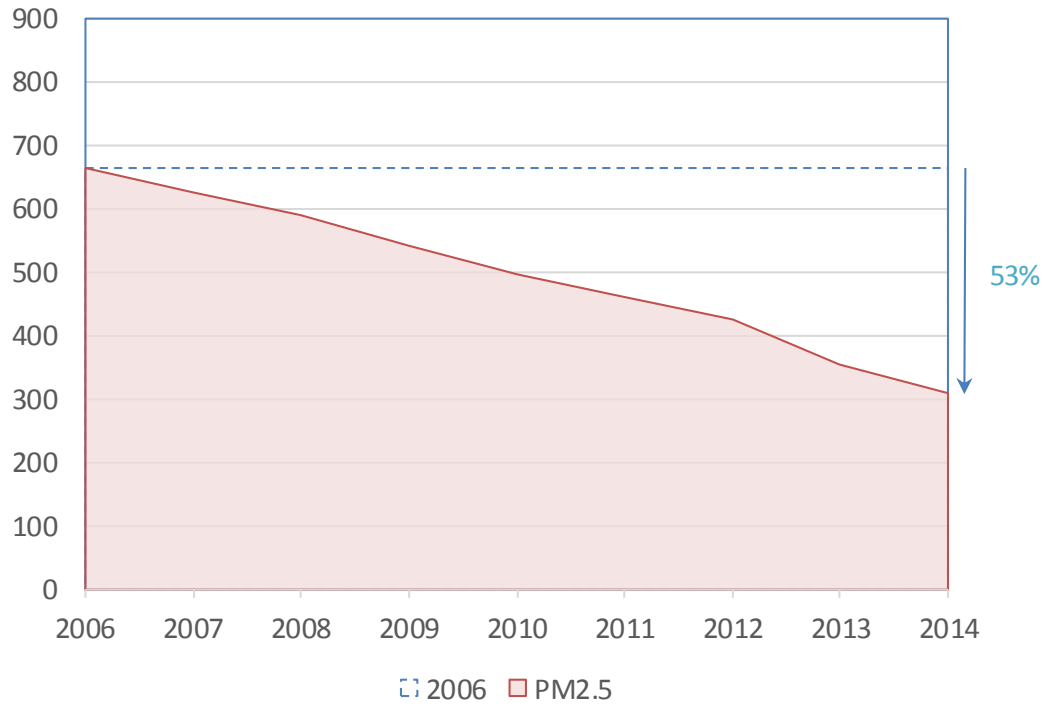


Figure ES.4: VOC Emissions Trend

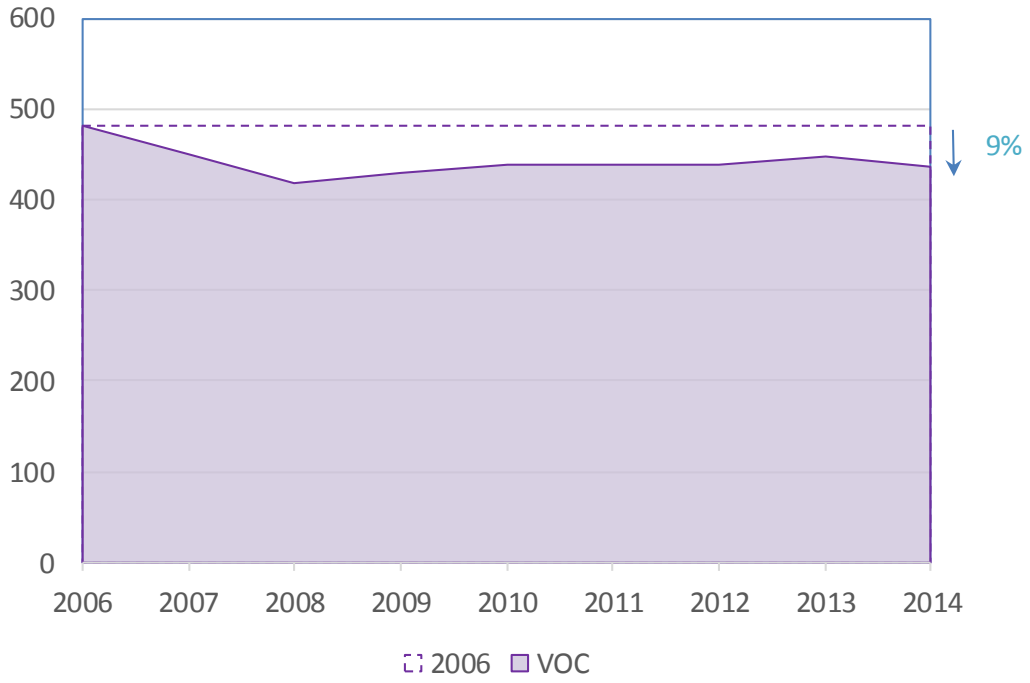


Figure ES.5: CO Emissions Trend

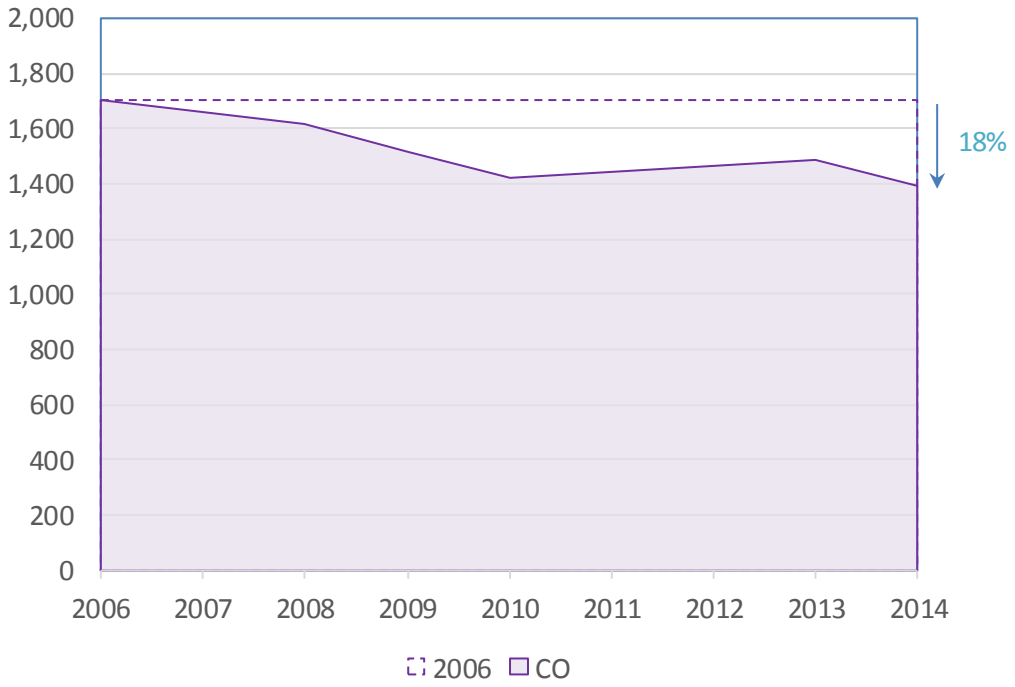


Figure ES.6: SO_2 Emissions Trend

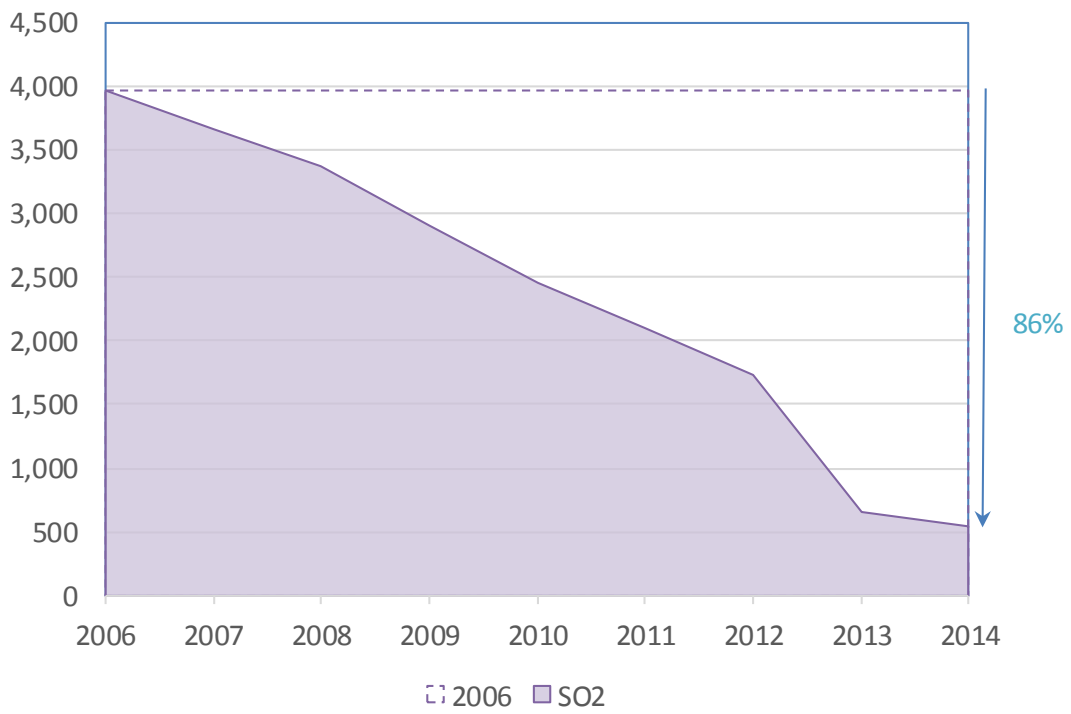
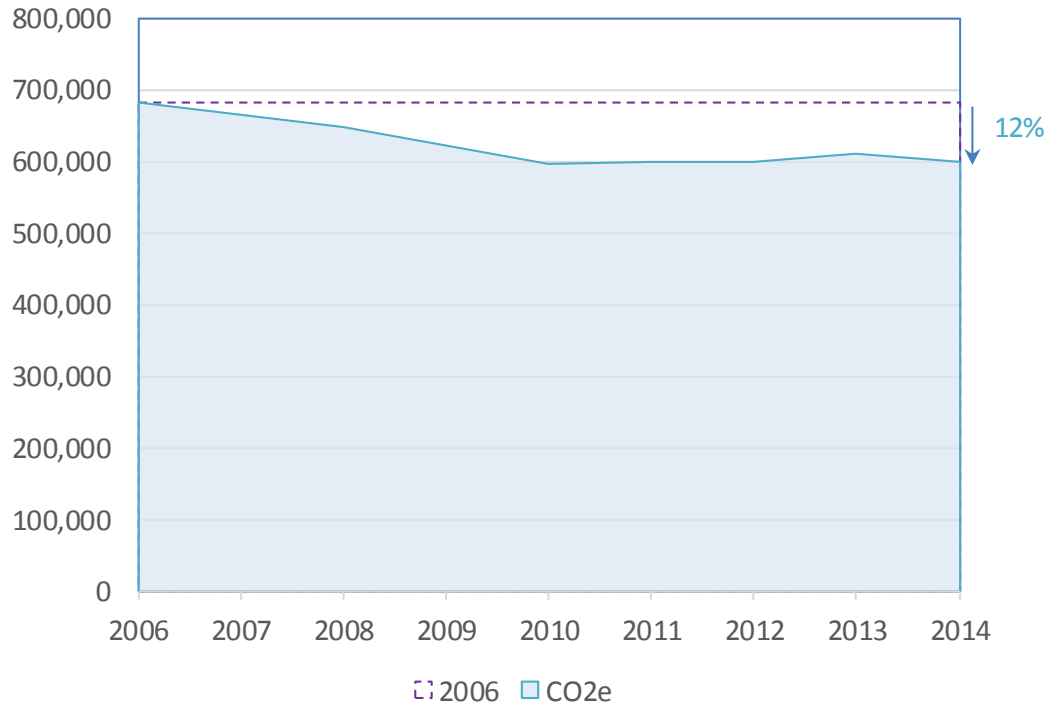


Figure ES.7: CO_2e Emissions Trend



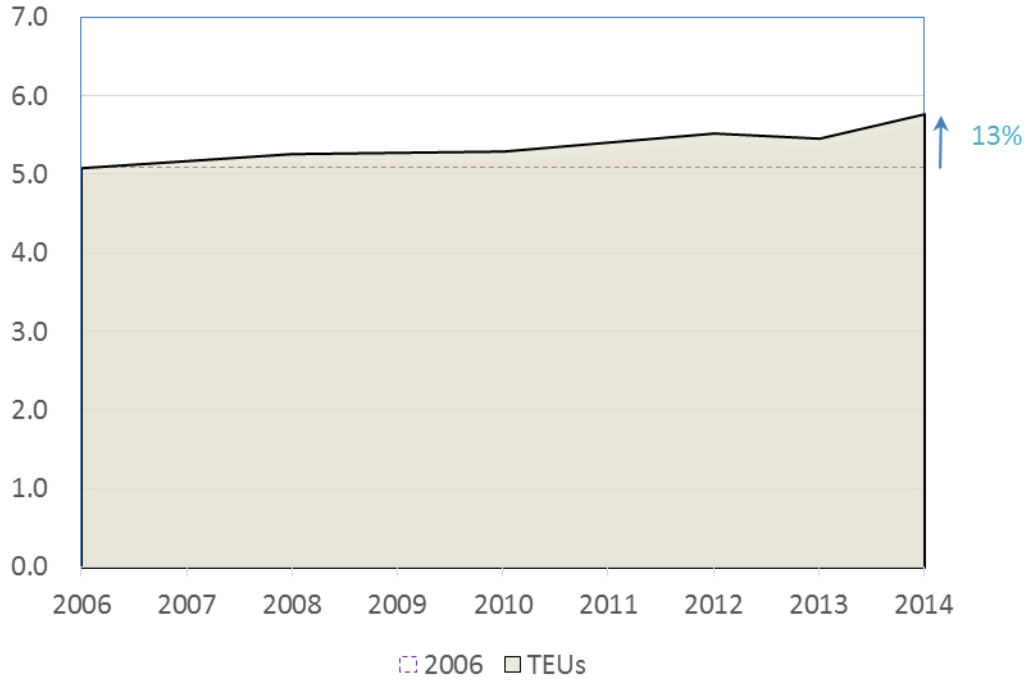
The following overall conclusions can be drawn from Table ES.1.

- Port Authority maritime emissions of oxides of nitrogen (NO_x) related to the Port Authority marine terminals were 3% lower in tons between 2014 and 2013, and 28% lower than in 2006. On an emissions-per-TEU basis, emissions in 2014 were 8% lower than the 2013 estimates and 36% lower than the 2006 estimates.
- Port Authority maritime emissions of particulate matter less than 10 microns (PM_{10}) related to the Port Authority marine terminals were 12% lower in tons in 2014 than in 2013 and 55% lower than in 2006. On an emissions-per-TEU basis, emissions in 2014 were 16% lower than the 2013 estimates and 60% lower than the 2006 estimates.
- Port Authority maritime emissions of particulate matter less than 2.5 microns ($PM_{2.5}$) related to the Port Authority marine terminals were 13% lower in tons in 2014 than in 2013 and 53% lower than in 2006. On an emissions-per-TEU basis, emissions in 2014 were 17% lower than the 2013 estimates and 59% lower than the 2006 estimates.
- Port Authority maritime emissions of volatile organic compounds (VOCs) related to the Port Authority marine terminals were 2% lower in tons in 2014 than in 2013 and 9% lower than in 2006. On an emissions-per-TEU basis, emissions in 2014 were 9% lower than the 2013 estimates and 20% lower than the 2006 estimates.
- Port Authority maritime emissions of carbon monoxide (CO) related to the Port Authority marine terminals were 7% lower in tons in 2014 than in 2013 and 18% lower than in 2006. On an emissions-per-TEU basis, emissions in 2014 were 11% lower than the 2012 estimates and 28% lower than the 2006 estimates.
- Port Authority maritime emissions of sulfur dioxide (SO_2) related to the Port Authority marine terminals were 17% lower in tons in 2014 than in 2013 and 86% lower than in 2006. On an emissions-per-TEU basis, emissions in 2014 were 21% lower than the 2013 estimates and 88% lower than the 2006 estimates.
- Emissions of greenhouse gases[1] (GHG), presented as carbon dioxide equivalent (CO_2e), related to the Port Authority marine terminals were 2% lower in tons in 2013 than in 2013 and 12% lower than in 2006. On an emissions-per-TEU basis, emissions in 2014 were 7% lower than the 2013 estimates and 23% lower than the 2006 estimates.

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

Figure ES.8 illustrates the generally upward trend in Port throughput, as measured by TEUs, between 2006 and 2014. The odd-numbered years between 2006 and 2012 have been interpolated for consistency with the pollutant figures presented above. The units on the y-axis are million TEUs.

Figure ES.8: TEU Throughput Trend



Despite the 13% increase in TEU throughput since 2006, the overall emissions were lower in 2014 as compared to 2006. Reasons for the emission reductions are listed below and include both regulatory items and measures from the PANYNJ Clean Air Strategy that have been implemented to date.

- The PANYNJ Low-Sulfur Fuel Incentive Program and Clean Vessel Incentive (CVI) Program which provide financial incentives to ocean-going vessel (OGV) operators to voluntarily reduce emissions. It impacts mainly SO_2, NO_x and PM emissions.
- North American Emissions Control Area (ECA) in place since mid-2012. The regulation lowers sulfur fuel (1% HFO) used by OGV transiting within 200 nm of the North American coast. It impacts SO_2, NO_x and PM emissions.
- Use of ultra-low sulfur diesel fuel (ULSD) by all land-based emission sources. It impacts SO_2, NO_x and PM emissions.
- The PANYNJ CHE modernization program and fleet turnover, plus using electric-powered equipment when possible.
- PANYNJ Truck Replacement Program provided incentives and financing to replace pre-1994 trucks with 2004 or newer trucks.
- Some container terminals have undergone gate modernization projects.
- Newer and cleaner rail switchers resulting from the PANYNJ and DJDEP locomotive genset retrofit program.

- Assist tug fleet turnover and repowers accomplished under the NYCDOT and New Jersey Clean Cities Coalition (NJCCC) repower programs.

ES.2 Emission Estimates

The emission estimates developed as described in this report are summarized below. Table ES.2 presents the criteria pollutant and CO_2e emissions by source category, the total PANYNJ emissions, the total emissions in the NYNJLINA[2] in tons per year, and the percentage that the PANYNJ emissions made up of the total NYNJLINA emissions in 2014.

Table ES.2: Emission Summary by Source Category, tpy

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Cargo Handling Equipment	754	52	51	84	319	1.0	115,219
Heavy-Duty Diesel Vehicles	2,383	126	116	158	673	2.7	294,165
Railroad Locomotives	274	10	9	20	53	0.2	19,866
Ocean-Going Vessels	2,624	150	123	160	284	541.7	148,928
Harbor Craft	376	12	12	14	63	0.3	22,236
Total PANYNJ Emissions	**6,410**	**350**	**310**	**436**	**1,391**	**545.9**	**600,414**
NYNJLINA Emissions	**272,796**	**79,551**	**36,399**	**316,874**	**1,335,320**	**37,497**	**127,000,943**
PANYNJ Percentage	**2.3%**	**0.4%**	**0.9%**	**0.1%**	**0.1%**	**1.5%**	**0.5%**

- Emissions of NO_x in 2014 constituted approximately 2.3% of the overall NYNJLINA NO_x emissions.
- Emissions of PM_{10} in 2014 constituted approximately 0.4% of the overall NYNJLINA PM_{10} emissions.
- Emissions of $PM_{2.5}$ in 2014 constituted approximately 0.9% of the overall NYNJLINA $PM_{2.5}$ emissions.
- Emissions of VOCs in 2014 constituted approximately 0.1% of the overall NYNJLINA VOC emissions.
- Emissions of CO in 2014 constituted approximately 0.1% of the overall NYNJLINA CO emissions.
- Emissions of SO_2 in 2014 constituted approximately 1.5% of the overall NYNJLINA SO_2 emissions.
- Emissions of CO_2e in 2014 constituted approximately 0.5% of the overall NYNJLINA CO_2e emissions.

[2] 2011 National Emission Inventory Database, US EPA.

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, and the PANYNJ emissions are shown as a percentage of the overall emissions. The PANYNJ emissions are further broken down by emission source category showing the tons and percentages of each category. 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.9: Distribution of NO_x Emissions by Source Category

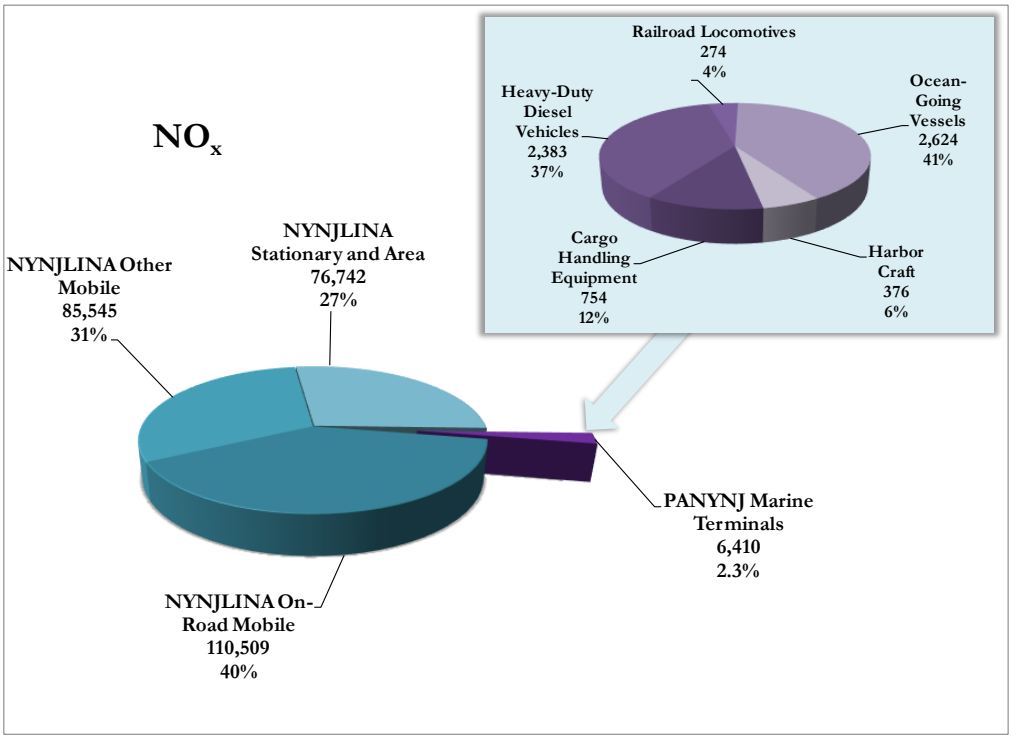


Figure ES.10: Distribution of PM_{10} Emissions by Source Category

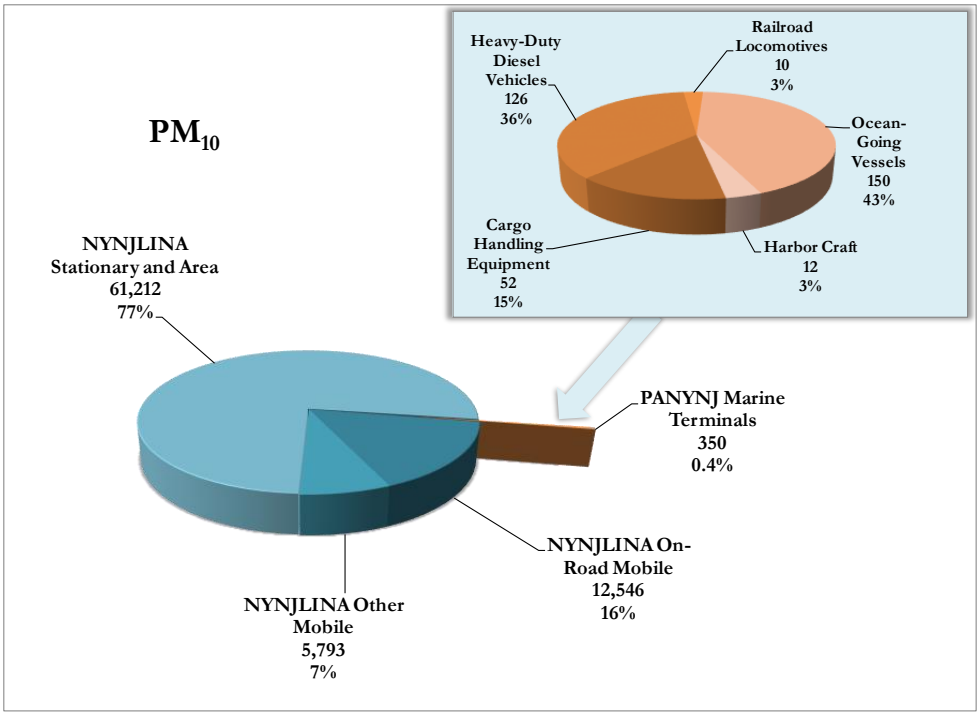


Figure ES.11: Distribution of $PM_{2.5}$ Emissions by Source Category

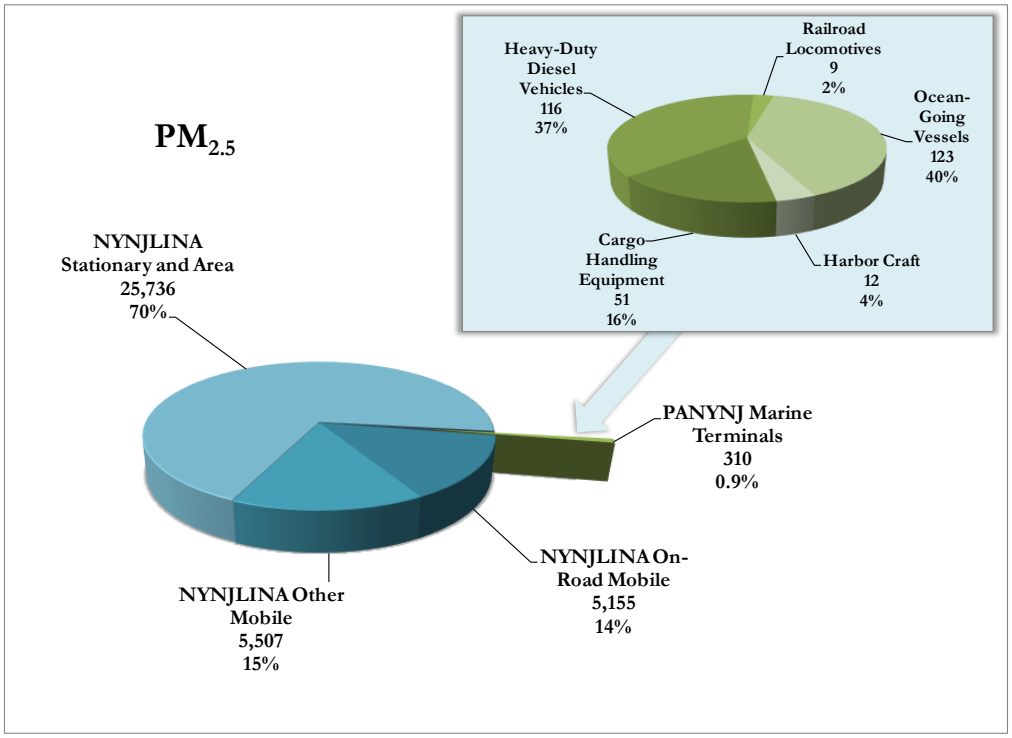


Figure ES.12: Distribution of VOC Emissions by Source Category

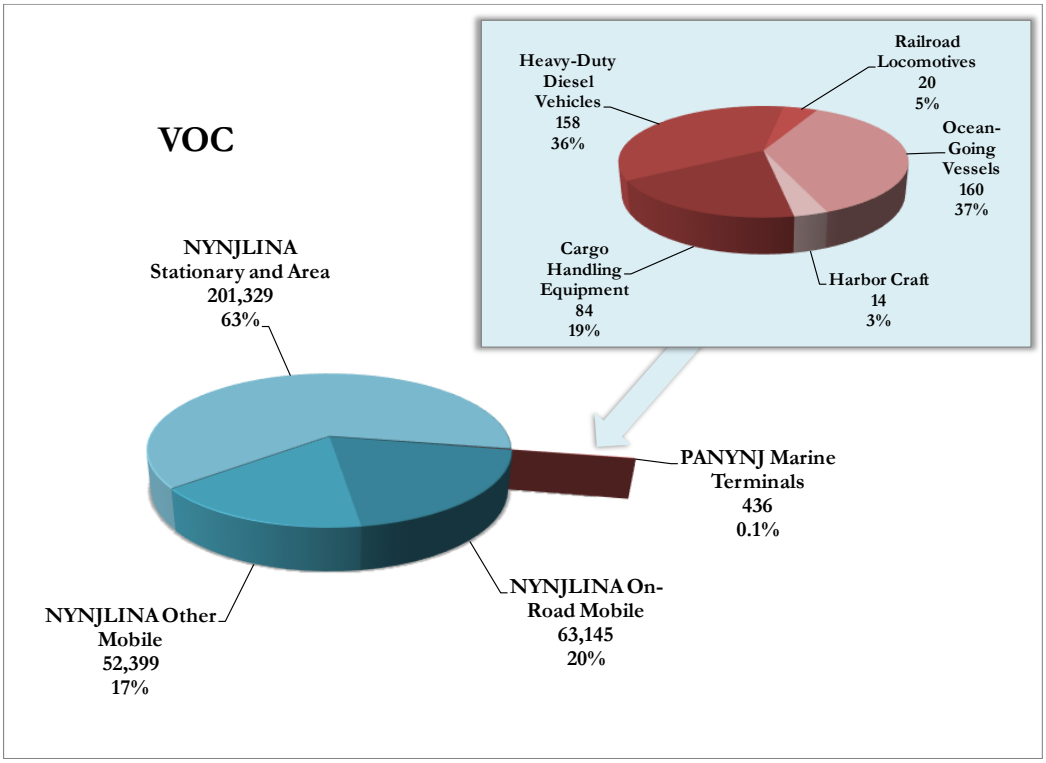


Figure ES.13: Distribution of CO Emissions by Source Category

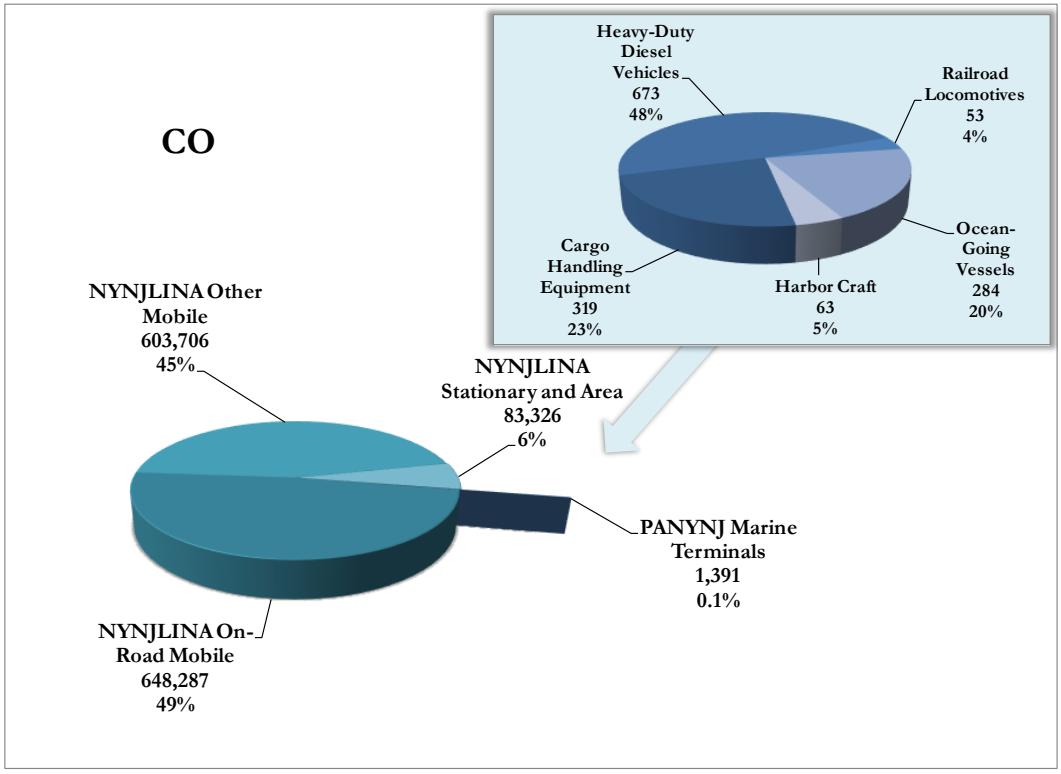


Figure ES.14: Distribution of SO_2 Emissions by Source Category

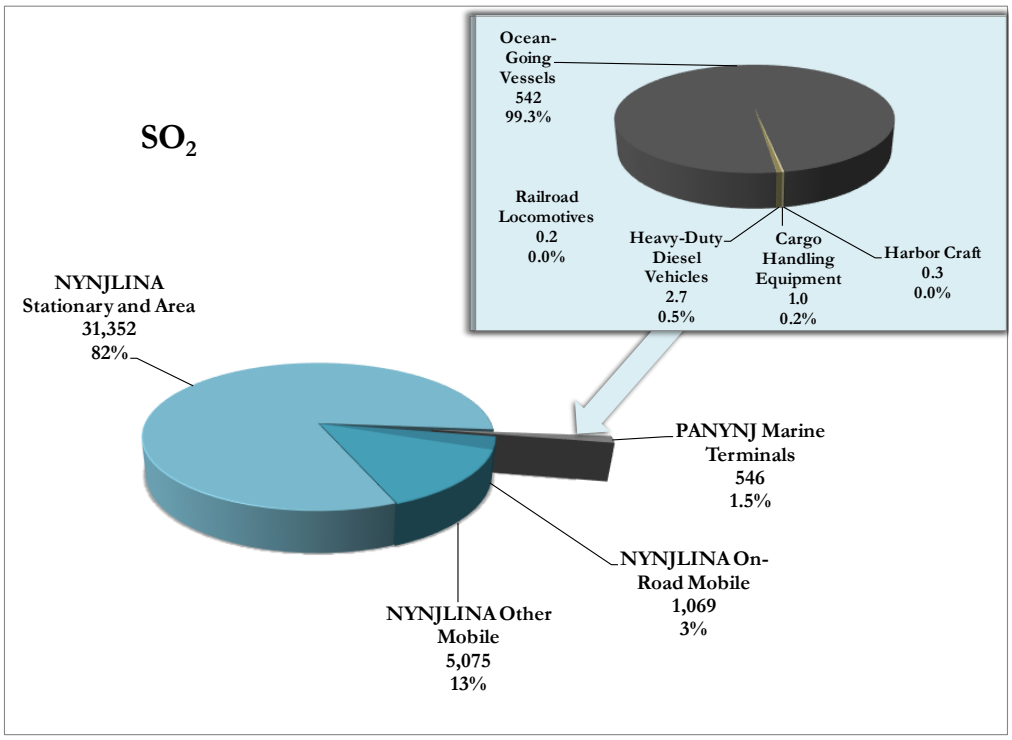
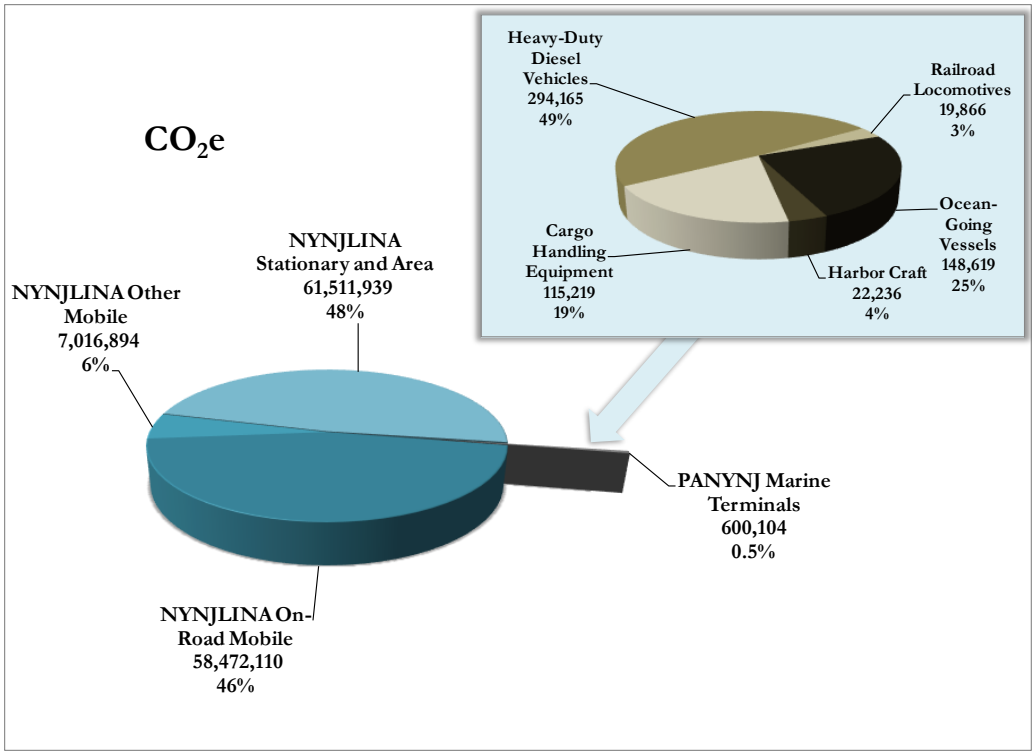


Figure ES.15: Distribution of CO_2e Emissions by Source Category



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). 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).

This inventory does not include emissions from activities linked to the various marine terminals that are entirely privately owned and operated 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, also known as drayage trucks), locomotives, and commercial marine vessels (CMV), which include ocean going vessels (OGV) and harbor craft. The Port Authority's marine terminals are within an area known as the New York/Northern New Jersey/Long Island Ozone Non-Attainment Area (NYNJLINA). The NYNJLINA includes 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 ($PM_{2.5}$).[3]

The purpose of this 2014 emissions inventory is to update the emission estimates presented in the 2013 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 2014, which allows for a comparison with the earlier emission estimates for those source categories as presented in the 2013 report. The goals of this emissions inventory include:

- Estimate the contribution to overall emissions in the NYNJLINA attributable to CHE, HDDV, locomotives, and CMV associated with the five Port Authority marine terminals;
- Illustrate trends over time in emissions 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.

[3] 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*

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 collected activity and operational data 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 2014 Emissions of the following criteria pollutants are included:

- 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 following fuel combustion-related greenhouse gas emissions are also included:

- Carbon dioxide (CO_2)
- Nitrous oxide (N_2O)
- Methane (CH_4)

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

- CO_2 - 1
- N_2O - 298
- CH_4 – 25

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

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.

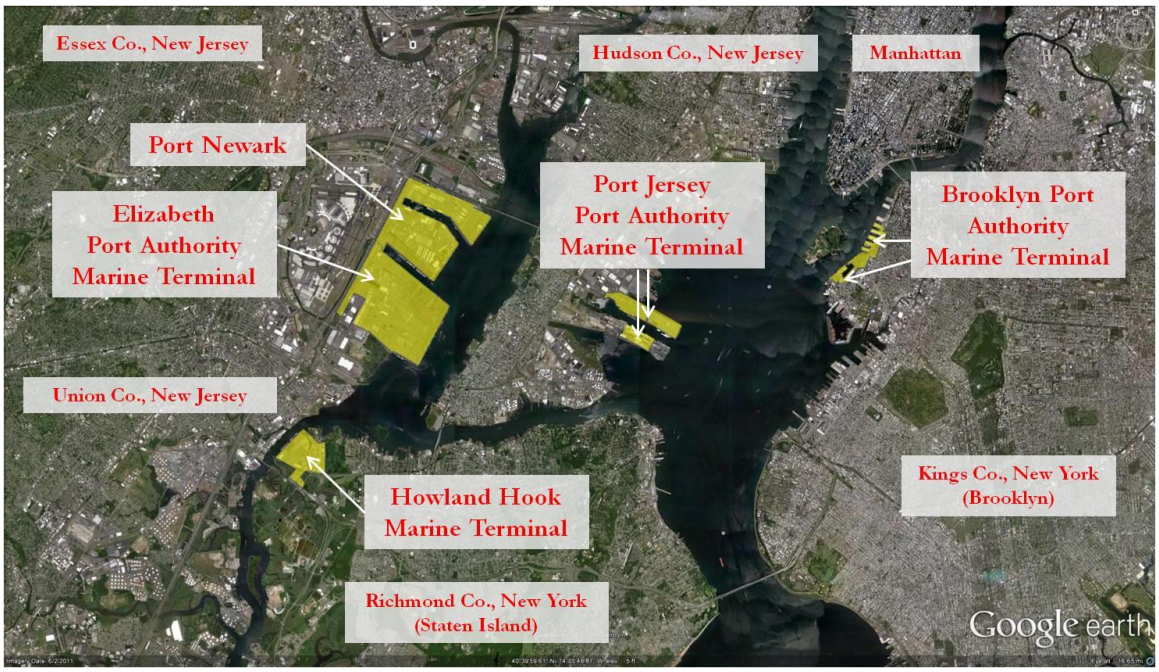
The Port Authority's New Jersey marine terminals are:

- 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 2014

There were no major changes in methodology or activity in 2014 as compared to the previous year. Some minor changes are:

- The emission estimates were developed assuming sulfur content of 15 ppm in the fuel used by locomotive and marine engines in 2014 as compared to 19 ppm[5] in 2013.
- The GWP values were updated in 2014 to be consistent with recent EPA guidance.[6] This change results in a very minor effect on the CO_2e estimates.
- Harbor craft emission factors were updated, resulting in minor changes to previous years' emission estimates for comparison purposes.

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_2e emissions by source category, the total PANYNJ emissions (the emissions included in this report), the total emissions in the NYNJLINA[7] in tons per year, and the percentage that the PANYNJ emissions makeup of the total NYNJLINA emissions. The NYNJLINA GHG emissions are of CO_2 alone, not including N_2O and CH_4, but the contributions of these two GHGs adds very little to the overall CO_2e values.

Table 1.1: Emission Summary by Source Category, tpy

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Cargo Handling Equipment	754	52	51	84	319	1.0	115,219
Heavy-Duty Diesel Vehicles	2,383	126	116	158	673	2.7	294,165
Railroad Locomotives	274	10	9	20	53	0.2	19,866
Ocean-Going Vessels	2,624	150	123	160	284	541.7	148,928
Harbor Craft	376	12	12	14	63	0.3	22,236
Total PANYNJ Emissions	**6,410**	**350**	**310**	**436**	**1,391**	**545.9**	**600,414**
NYNJLINA Emissions	**272,796**	**79,551**	**36,399**	**316,874**	**1,335,320**	**37,497**	**127,000,943**
PANYNJ Percentage	**2.3%**	**0.4%**	**0.9%**	**0.1%**	**0.1%**	**1.5%**	**0.5%**

[5] Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines, EPA420-R-04-007 (May 2004)
[6] U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, April 2015.
[7] 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.

Table 1.2: Emission Summary by Source Category, percent

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Cargo Handling Equipment	12%	15%	16%	19%	23%	0.2%	19%
Heavy-Duty Diesel Vehicles	37%	36%	37%	36%	48%	0.5%	49%
Railroad Locomotives	4%	3%	3%	5%	4%	0.0%	3%
Ocean-Going Vessels	41%	43%	40%	37%	20%	99.2%	25%
Harbor Craft	6%	4%	4%	3%	5%	0.1%	4%
Total PANYNJ Emissions	100%	100%	100%	100%	100%	100%	100%

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.

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, and the PANYNJ emissions are shown as a percentage of the overall emissions. The PANYNJ emissions are further broken down by emission source category showing the tons and percentages of each category. 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 1.2: Distribution of NO_x Emissions by Source Category

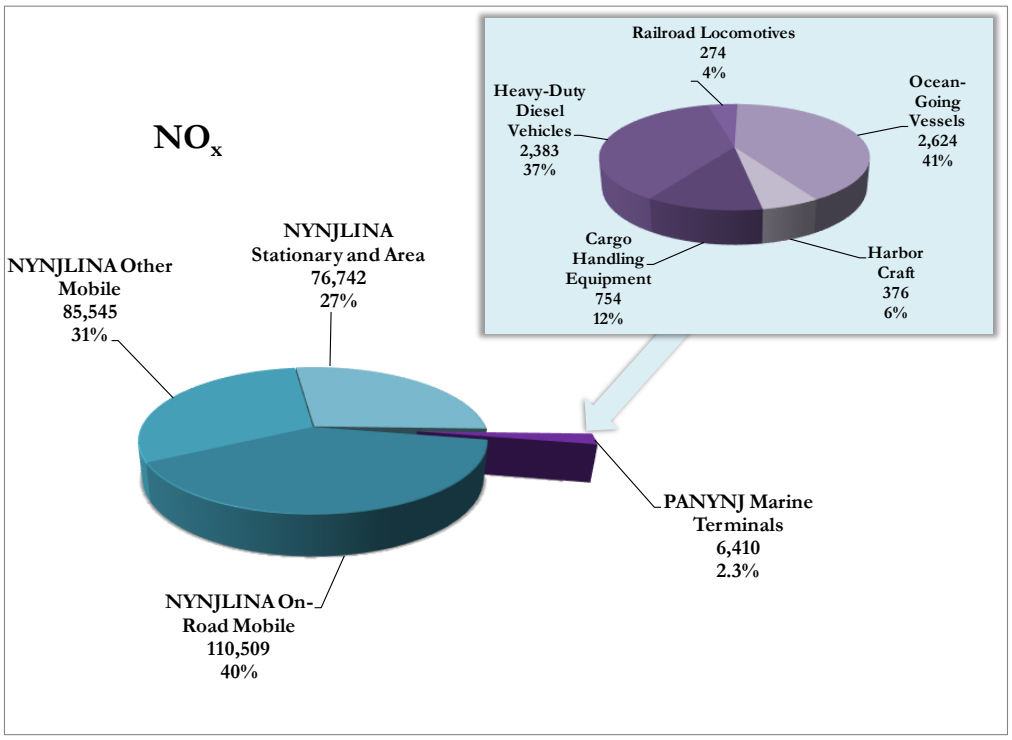


Figure 1.3: Distribution of PM_{10} Emissions by Source Category

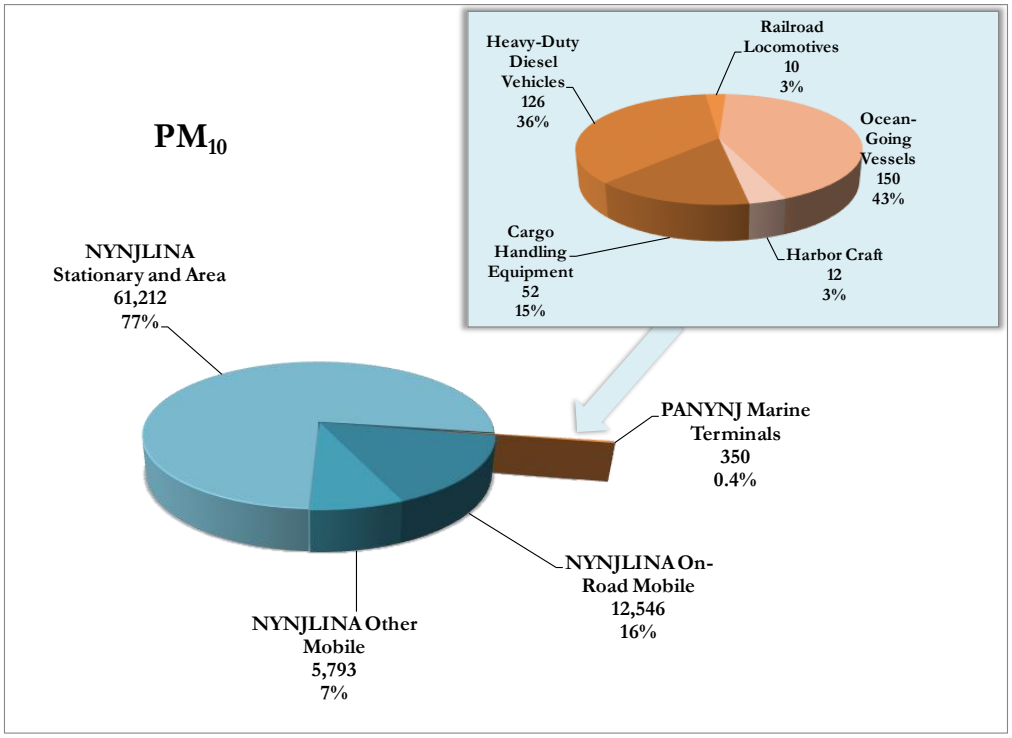


Figure 1.4: Distribution of $PM_{2.5}$ Emissions by Source Category

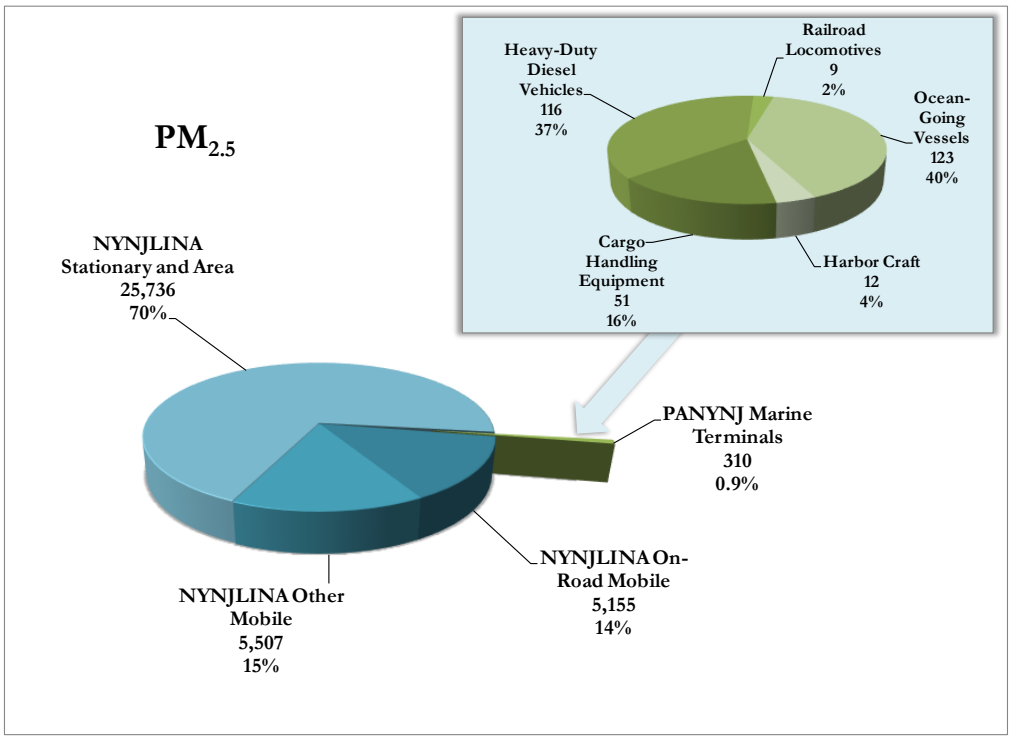


Figure 1.5: Distribution of VOC Emissions by Source Category

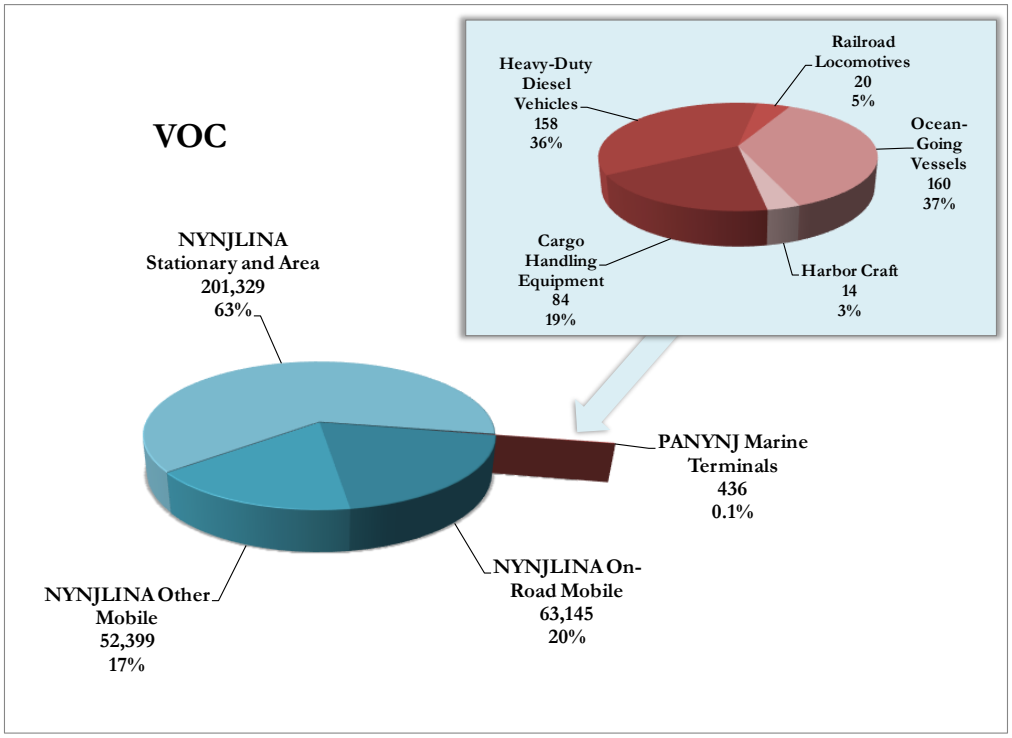


Figure 1.6: Distribution of CO Emissions by Source Category

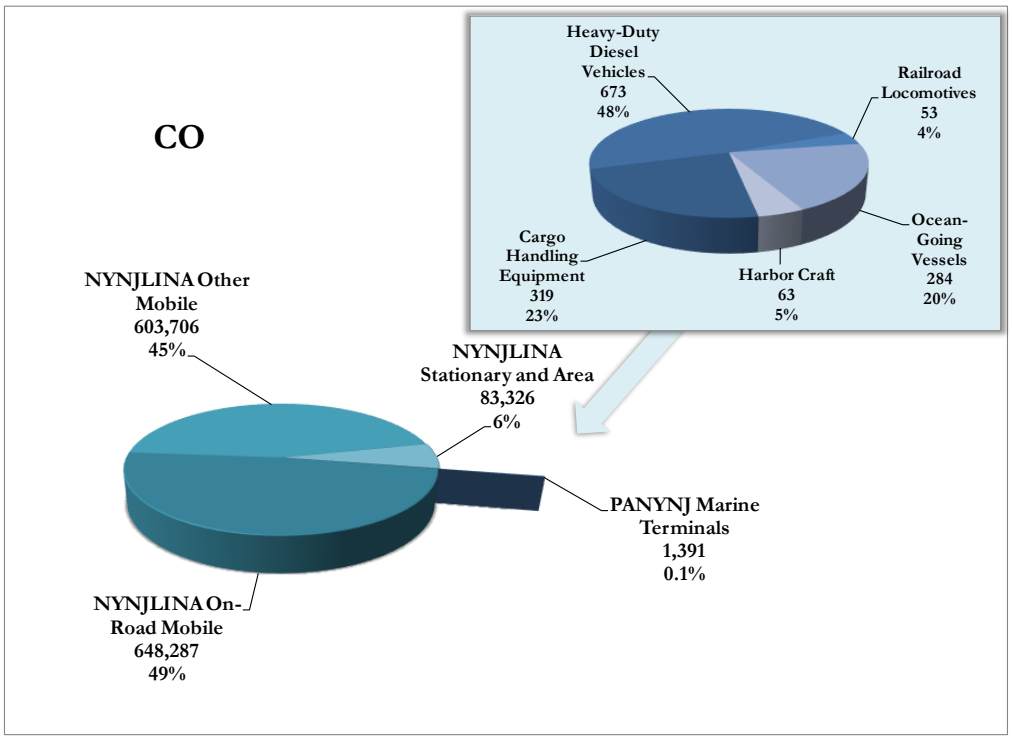


Figure 1.7: Distribution of SO_2 Emissions by Source Category

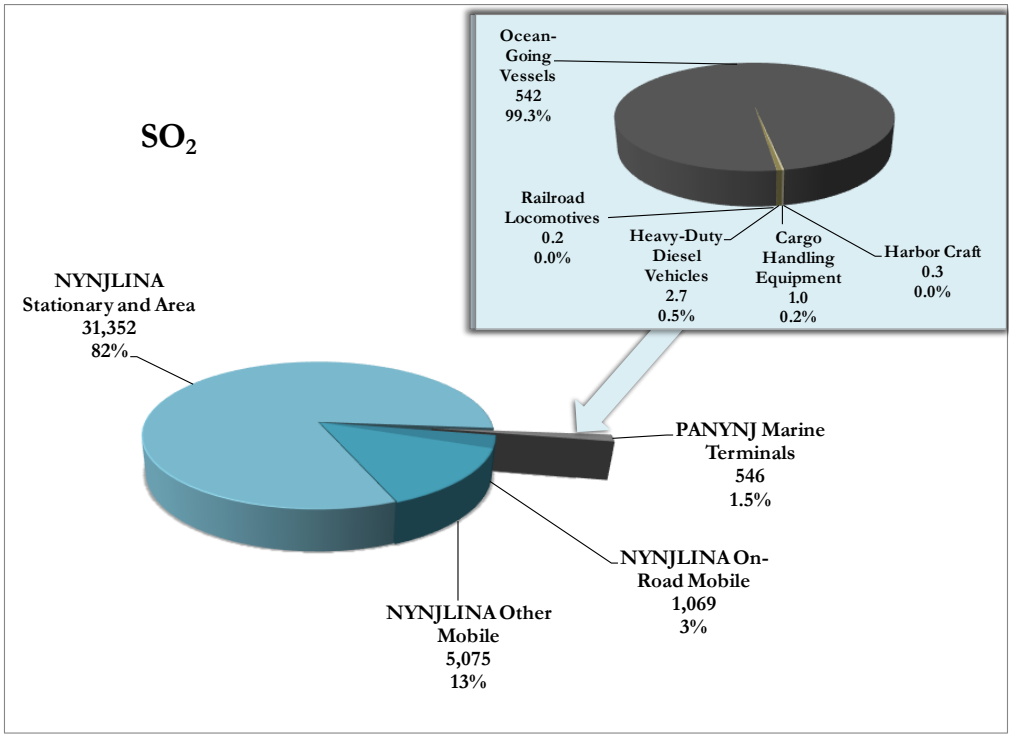
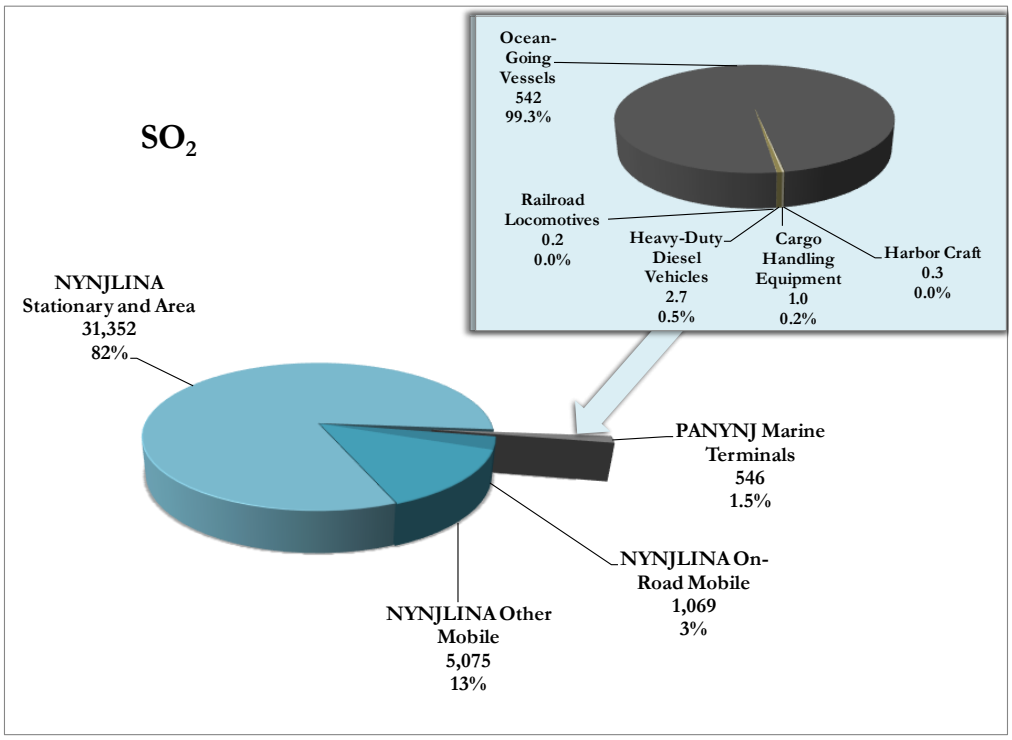


Figure 1.8: Distribution of CO_2e Emissions by Source Category



1.4 Overall Comparison of Emissions Related to 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 from the five source categories 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. [8]

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

Table 1.3 summarizes by county the estimated emissions from the Port Authority marine terminal related activities covered by this report, and Table 1.4 lists total emissions of each criteria pollutant by county and state, as reported in the most recent National Emissions Inventory database.

Table 1.3: Port Authority Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	167	7	7	9	43	0	19,449
Essex	NJ	1,567	87	77	106	327	162	149,498
Hudson	NJ	992	54	47	57	193	110	90,869
Middlesex	NJ	464	22	20	26	125	1	57,144
Monmouth	NJ	126	6	5	6	18	15	7,967
Union	NJ	1,980	119	106	171	461	170	182,703
New Jersey subtotal		**5,296**	**296**	**262**	**374**	**1,167**	**457**	**507,630**
Bronx	NY	40	2	2	2	11	0	4,958
Kings (Brooklyn)	NY	293	15	13	15	56	33	23,427
Nassau	NY	71	3	3	4	19	0	8,726
New York	NY	63	3	3	3	9	9	4,871
Orange	NY	43	2	2	2	12	0	5,318
Queens	NY	36	2	2	2	9	0	4,307
Richmond (Staten Island)	NY	440	22	19	27	77	47	28,427
Rockland	NY	54	2	1	2	11	0	4,339
Suffolk	NY	32	1	1	2	8	0	3,454
Westchester	NY	41	2	2	2	11	0	4,958
New York subtotal		**1,114**	**54**	**48**	**62**	**223**	**89**	**92,784**
PANYNJ Total		**6,410**	**350**	**310**	**436**	**1,391**	**546**	**600,414**

Table 1.4: Summary of NYNJLINA Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	15,763	3,896	2,097	18,980	111,914	685	12,083,110
Essex	NJ	14,172	2,631	1,627	14,151	64,014	1,226	5,054,723
Hudson	NJ	10,059	1,641	1,105	9,429	36,789	1,840	7,261,187
Middlesex	NJ	15,574	4,486	2,309	19,479	87,469	785	11,596,949
Monmouth	NJ	10,795	3,406	1,635	19,080	71,524	687	5,242,102
Union	NJ	13,636	2,761	1,704	12,608	53,352	1,583	12,936,127
New Jersey subtotal		**79,999**	**18,821**	**10,477**	**93,727**	**425,060**	**6,806**	**54,174,197**
Bronx	NY	9,912	2,713	1,407	13,272	36,134	1,547	2,898,414
Kings (Brooklyn)	NY	19,011	4,984	2,600	24,871	78,793	1,525	5,729,063
Nassau	NY	23,967	6,975	2,984	27,629	143,985	2,563	10,045,818
New York	NY	33,400	7,049	3,295	20,469	109,627	5,574	7,090,866
Orange	NY	8,857	7,645	2,395	19,383	45,498	6,251	5,609,965
Queens	NY	29,220	5,881	3,167	27,772	111,129	2,513	15,051,786
Richmond (Staten Island)	NY	7,531	1,972	1,000	7,600	32,985	409	2,572,653
Rockland	NY	5,494	2,149	827	8,861	33,695	297	2,791,076
Suffolk	NY	39,142	14,340	5,705	49,647	212,558	7,875	15,290,461
Westchester	NY	16,263	7,023	2,540	23,643	105,856	2,137	5,746,644
New York subtotal		**192,797**	**60,730**	**25,922**	**223,147**	**910,259**	**30,691**	**72,826,745**
NYNJLINA Total		**272,796**	**79,551**	**36,399**	**316,874**	**1,335,320**	**37,497**	**127,000,943**

The subsequent tables 1.5 through 1.11 provide additional pollutant specific detail to this county level data for criteria pollutants and CO_2e, placing emissions tied to Port Authority owned marine terminals into a local and regional perspective. Each table 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. 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 1.5: Comparison of NO_x Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	15,763	167	1.1%
Essex	NJ	14,172	1,567	11.1%
Hudson	NJ	10,059	992	9.9%
Middlesex	NJ	15,574	464	3.0%
Monmouth	NJ	10,795	126	1.2%
Union	NJ	13,636	1,980	14.5%
New Jersey subtotal		**79,999**	**5,296**	**6.6%**
Bronx	NY	9,912	40	0.4%
Kings (Brooklyn)	NY	19,011	293	1.5%
Nassau	NY	23,967	71	0.3%
New York	NY	33,400	63	0.2%
Orange	NY	8,857	43	0.5%
Queens	NY	29,220	36	0.1%
Richmond (Staten Island)	NY	7,531	440	5.8%
Rockland	NY	5,494	54	1.0%
Suffolk	NY	39,142	32	0.1%
Westchester	NY	16,263	41	0.3%
New York subtotal		**192,797**	**1,114**	**0.6%**
NYNJLINA and PANYNJ Total		**272,796**	**6,410**	**2.3%**

Figure 1.9: Comparison of NO_x Emissions by County, tpy

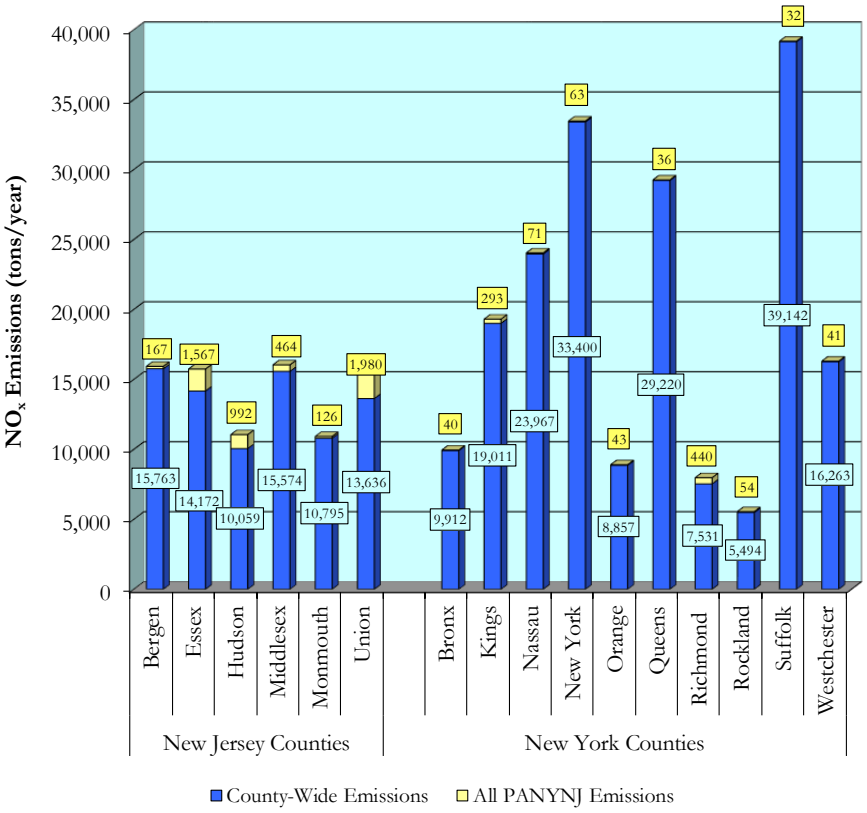


Table 1.6: Comparison of PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	3,896	7	0.2%
Essex	NJ	2,631	87	3.3%
Hudson	NJ	1,641	54	3.3%
Middlesex	NJ	4,486	22	0.5%
Monmouth	NJ	3,406	6	0.2%
Union	NJ	2,761	119	4.3%
New Jersey subtotal		**18,821**	**296**	**1.6%**
Bronx	NY	2,713	2	0.1%
Kings (Brooklyn)	NY	4,984	15	0.3%
Nassau	NY	6,975	3	0.0%
New York	NY	7,049	3	0.0%
Orange	NY	7,645	2	0.0%
Queens	NY	5,881	2	0.0%
Richmond (Staten Island)	NY	1,972	22	1.1%
Rockland	NY	2,149	2	0.1%
Suffolk	NY	14,340	1	0.0%
Westchester	NY	7,023	2	0.0%
New York subtotal		**60,730**	**54**	**0.1%**
NYNJLINA and PANYNJ Total		**79,551**	**350**	**0.4%**

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

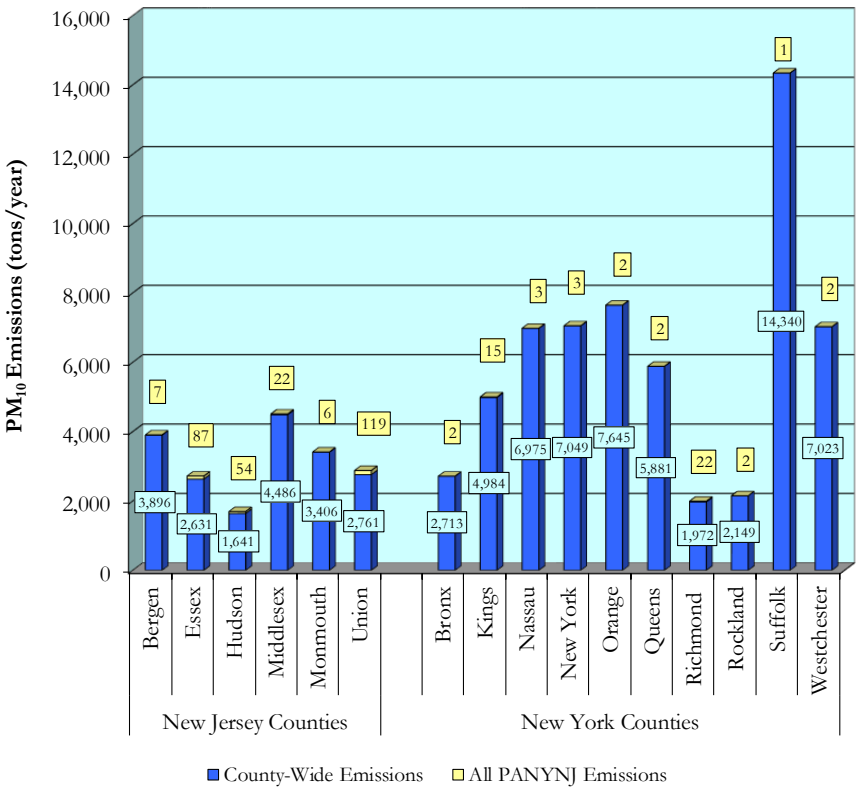


Table 1.7: Comparison of $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	2,097	7	0.3%
Essex	NJ	1,627	77	4.7%
Hudson	NJ	1,105	47	4.3%
Middlesex	NJ	2,309	20	0.9%
Monmouth	NJ	1,635	5	0.3%
Union	NJ	1,704	106	6.2%
New Jersey subtotal		**10,477**	**262**	**2.5%**
Bronx	NY	1,407	2	0.1%
Kings (Brooklyn)	NY	2,600	13	0.5%
Nassau	NY	2,984	3	0.1%
New York	NY	3,295	3	0.1%
Orange	NY	2,395	2	0.1%
Queens	NY	3,167	2	0.0%
Richmond (Staten Island)	NY	1,000	19	1.9%
Rockland	NY	827	1	0.2%
Suffolk	NY	5,705	1	0.0%
Westchester	NY	2,540	2	0.1%
New York subtotal		**25,922**	**48**	**0.2%**
NYNJLINA and PANYNJ Total		**36,399**	**310**	**0.9%**

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

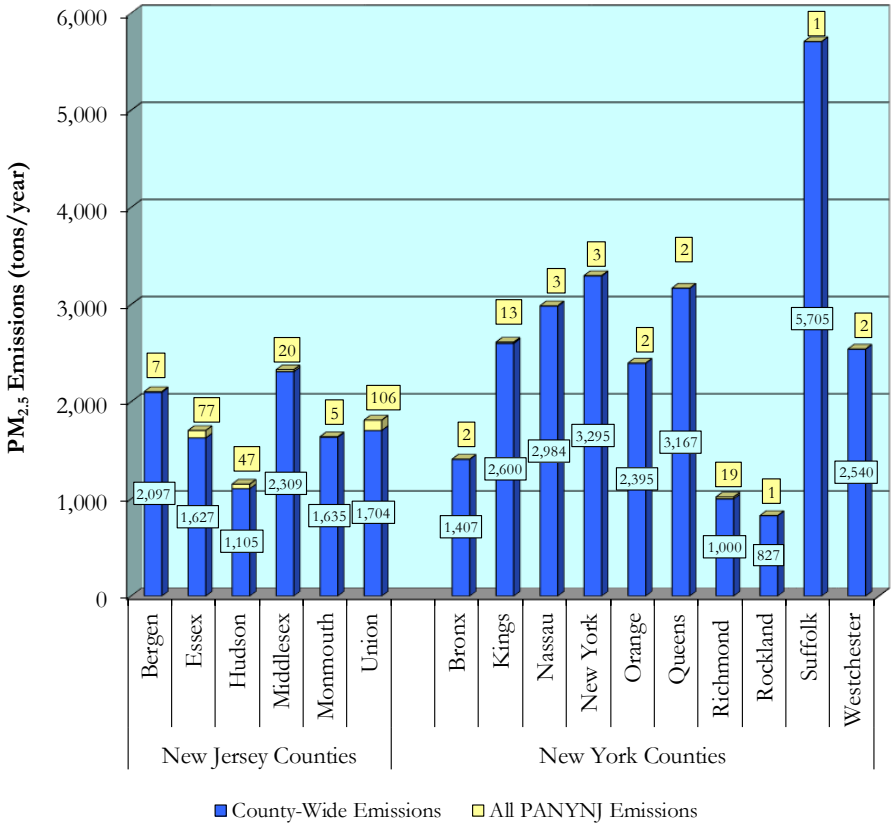


Table 1.8: Comparison of VOC Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	18,980	9	0.0%
Essex	NJ	14,151	106	0.7%
Hudson	NJ	9,429	57	0.6%
Middlesex	NJ	19,479	26	0.1%
Monmouth	NJ	19,080	6	0.0%
Union	NJ	12,608	171	1.4%
New Jersey subtotal		**93,727**	**374**	**0.4%**
Bronx	NY	13,272	2	0.0%
Kings (Brooklyn)	NY	24,871	15	0.1%
Nassau	NY	27,629	4	0.0%
New York	NY	20,469	3	0.0%
Orange	NY	19,383	2	0.0%
Queens	NY	27,772	2	0.0%
Richmond (Staten Island)	NY	7,600	27	0.4%
Rockland	NY	8,861	2	0.0%
Suffolk	NY	49,647	2	0.0%
Westchester	NY	23,643	2	0.0%
New York subtotal		**223,147**	**62**	**0.0%**
NYNJLINA and PANYNJ Total		**316,874**	**436**	**0.1%**

Figure 1.12: Comparison of VOC Emissions by County, tpy

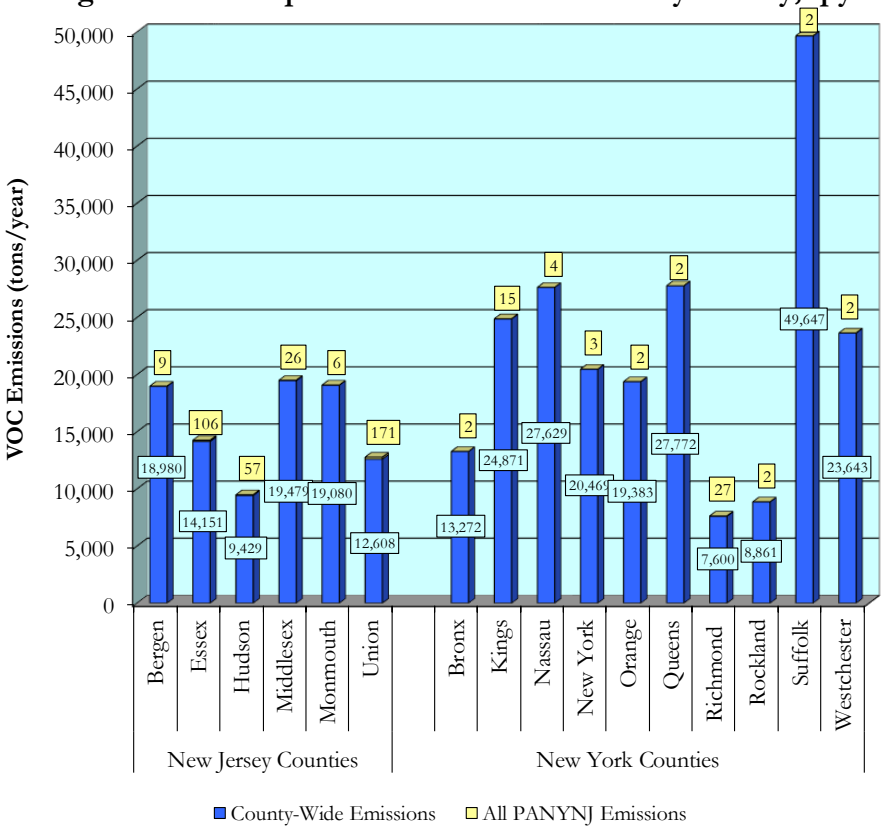


Table 1.9: Comparison of CO Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	111,914	43	0.0%
Essex	NJ	64,014	327	0.5%
Hudson	NJ	36,789	193	0.5%
Middlesex	NJ	87,469	125	0.1%
Monmouth	NJ	71,524	18	0.0%
Union	NJ	53,352	461	0.9%
New Jersey subtotal		**425,060**	**1,167**	**0.3%**
Bronx	NY	36,134	11	0.0%
Kings (Brooklyn)	NY	78,793	56	0.1%
Nassau	NY	143,985	19	0.0%
New York	NY	109,627	9	0.0%
Orange	NY	45,498	12	0.0%
Queens	NY	111,129	9	0.0%
Richmond (Staten Island)	NY	32,985	77	0.2%
Rockland	NY	33,695	11	0.0%
Suffolk	NY	212,558	8	0.0%
Westchester	NY	105,856	11	0.0%
New York subtotal		**910,259**	**223**	**0.0%**
NYNJLINA and PANYNJ Total		**1,335,320**	**1,391**	**0.1%**

Figure 1.13: Comparison of CO Emissions by County, tpy

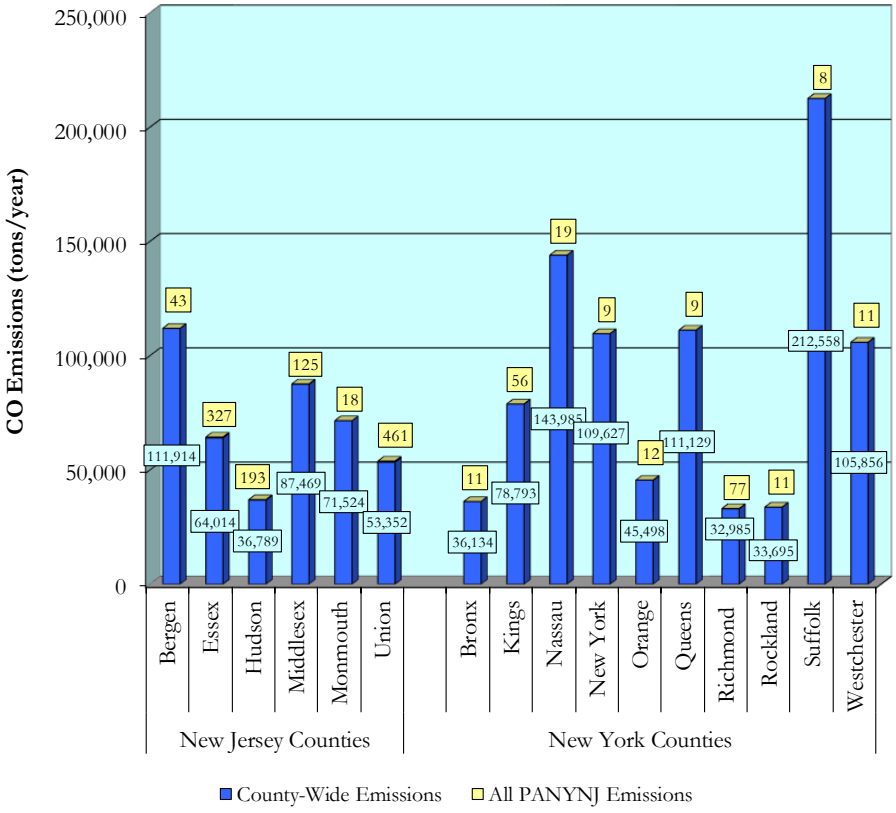


Table 1.10: Comparison of SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	685	0	0.0%
Essex	NJ	1,226	162	13.2%
Hudson	NJ	1,840	110	6.0%
Middlesex	NJ	785	1	0.1%
Monmouth	NJ	687	15	2.2%
Union	NJ	1,583	170	10.7%
New Jersey subtotal		**6,806**	**457**	**6.7%**
Bronx	NY	1,547	0	0.0%
Kings (Brooklyn)	NY	1,525	33	2.1%
Nassau	NY	2,563	0	0.0%
New York	NY	5,574	9	0.2%
Orange	NY	6,251	0	0.0%
Queens	NY	2,513	0	0.0%
Richmond (Staten Island)	NY	409	47	11.4%
Rockland	NY	297	0	0.0%
Suffolk	NY	7,875	0	0.0%
Westchester	NY	2,137	0	0.0%
New York subtotal		**30,691**	**89**	**0.3%**
NYNJLINA and PANYNJ Total		**37,497**	**545**	**1.5%**

Figure 1.14: Comparison of SO_2 Emissions by County, tpy

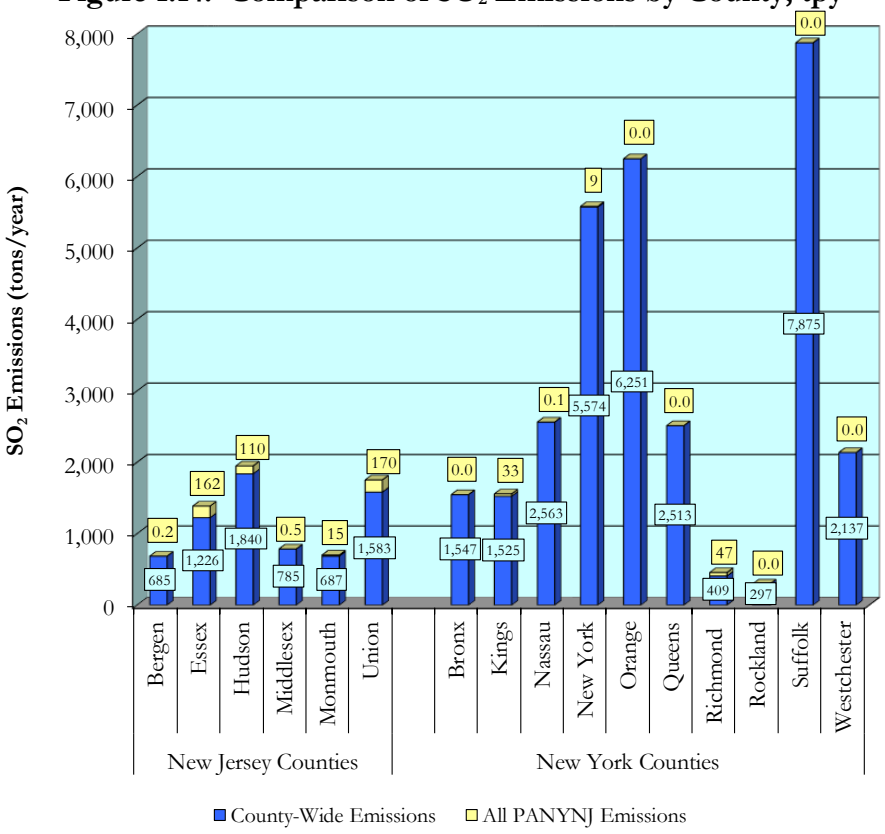
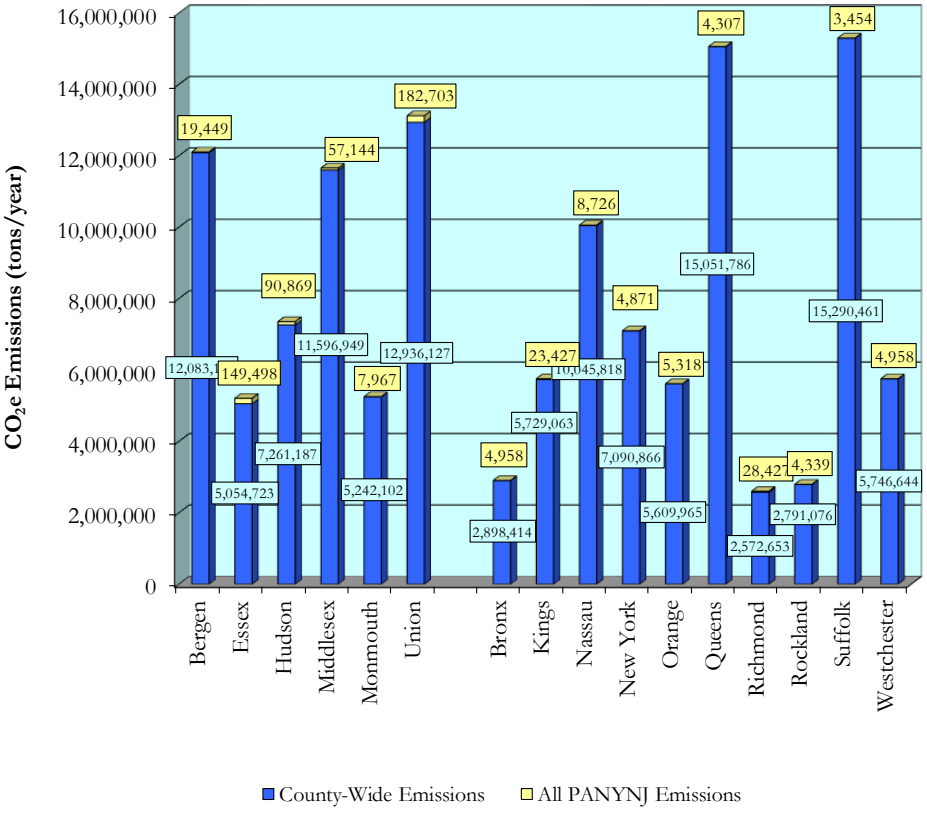


Table 1.11: Comparison of CO_2e Emissions by County, tpy

County	State	County-Wide Emissions	All PANYNJ Emissions in Inventory	Percent of Total
Bergen	NJ	12,083,110	19,449	0.2%
Essex	NJ	5,054,723	149,498	3.0%
Hudson	NJ	7,261,187	90,869	1.3%
Middlesex	NJ	11,596,949	57,144	0.5%
Monmouth	NJ	5,242,102	7,967	0.2%
Union	NJ	12,936,127	182,703	1.4%
New Jersey subtotal		**54,174,197**	**507,630**	**0.9%**
Bronx	NY	2,898,414	4,958	0.2%
Kings (Brooklyn)	NY	5,729,063	23,427	0.4%
Nassau	NY	10,045,818	8,726	0.1%
New York	NY	7,090,866	4,871	0.1%
Orange	NY	5,609,965	5,318	0.1%
Queens	NY	15,051,786	4,307	0.0%
Richmond (Staten Island)	NY	2,572,653	28,427	1.1%
Rockland	NY	2,791,076	4,339	0.2%
Suffolk	NY	15,290,461	3,454	0.0%
Westchester	NY	5,746,644	4,958	0.1%
New York subtotal		**72,826,745**	**92,784**	**0.1%**
NYNJLINA and PANYNJ Total		**127,000,943**	**600,414**	**0.5%**

Figure 1.15: Comparison of CO_2e Emissions by County, tpy



1.5 Comparison of 2014 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 largely 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 2014 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 and 2013 emissions inventory reports, adjustments have been made to earlier emission estimates to make them compatible with the latest estimates to account for changes in emission estimating methodology.

Table 1.12 presents the annual emissions from 2006, 2008, 2010, 2012, and 2013 as adjusted to be compatible with the latest estimates for 2014. Because no significant methodology changes were made between the 2013 and 2014 inventories, no adjustments have been made to the prior year estimates presented in the 2013 report, with the exception of minor updates made to the harbor craft emission factors. The emissions are expressed as tons per year and as tons per million TEUs, and as the percentage increases or decreases between each prior inventory year and 2014 for both tons per year and tons per million TEUs. This table shows that there has been a general downward trend in emissions in tons per year and tons per million TEUs between 2006 and 2014. The greatest reductions have 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. The table also lists the TEU throughput from each of the inventory years to illustrate the increases that have taken place. The TEU figures include the Global Container Terminal Bayonne TEUs for all inventory years.

Table 1.12: 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_2e	Million TEUs
Tons per year, with adjustments								
2014	6,410	350	310	436	1,391	546	600,104	5.772
2013	6,585	396	355	447	1,489	657	612,866	5.467
2012	6,581	488	424	439	1,468	1,735	601,298	5.530
2010	7,147	576	495	439	1,421	2,460	596,146	5.292
2008	8,202	683	589	419	1,614	3,371	647,311	5.265
2006	8,845	778	665	481	1,706	3,972	684,015	5.093
Percent change relative to 2014 - tons per year								
2013 - 2014	-3%	-12%	-13%	-2%	-7%	-17%	-2%	6%
2012 - 2014	-3%	-28%	-27%	-1%	-5%	-69%	0%	4%
2010 - 2014	-10%	-39%	-37%	-1%	-2%	-78%	1%	9%
2008 - 2014	-22%	-49%	-47%	4%	-14%	-84%	-7%	10%
2006 - 2014	-28%	-55%	-53%	-9%	-18%	-86%	-12%	13%
Tons per million TEU								
2014	1,111	61	54	75	241	95	103,968	
2013	1,204	73	65	82	272	120	112,103	
2012	1,190	88	77	79	266	314	108,734	
2010	1,350	109	94	83	269	465	112,650	
2008	1,558	130	112	80	307	640	122,946	
2006	1,737	153	131	94	335	780	134,305	
Percent change relative to 2014 - tons per million TEU								
2013 - 2014	-8%	-16%	-17%	-9%	-11%	-21%	-7%	
2012 - 2014	-7%	-31%	-30%	-5%	-9%	-70%	-4%	
2010 - 2014	-18%	-44%	-43%	-10%	-10%	-80%	-8%	
2008 - 2014	-29%	-53%	-52%	-6%	-21%	-85%	-15%	
2006 - 2014	-36%	-60%	-59%	-20%	-28%	-88%	-23%	

Figures 1.9 through 1.15 graphically illustrate the changes in emissions between the 2006 baseline emissions inventory and the 2014 update. The 2006 emissions are shown in each figure as a dashed line horizontal with the x axis, and the overall percent change between 2006 and 2014 is shown to the right of each chart, with an arrow indicating the direction of change in emissions. Inventories were developed for even numbered years between 2006 and 2012, so for the intervening odd-numbered years the charts have been prepared by interpolating between even numbered years. The inventories became annual starting with the 2012 update. Figure 1.16 illustrates the generally upward trend in Port throughput between 2006 and 2014. The odd-numbered years between 2006 and 2012 have been interpolated for consistency with the pollutant figures presented above.

Figure 1.16: NO_x Emissions Trend

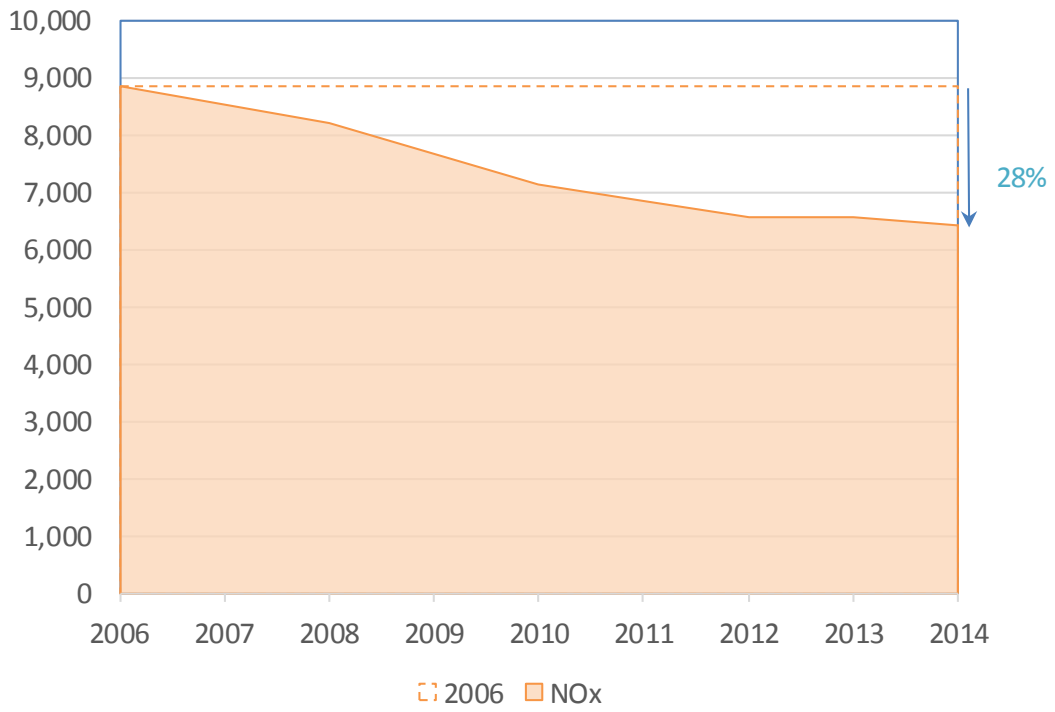


Figure 1.17: PM_{10} Emissions Trend

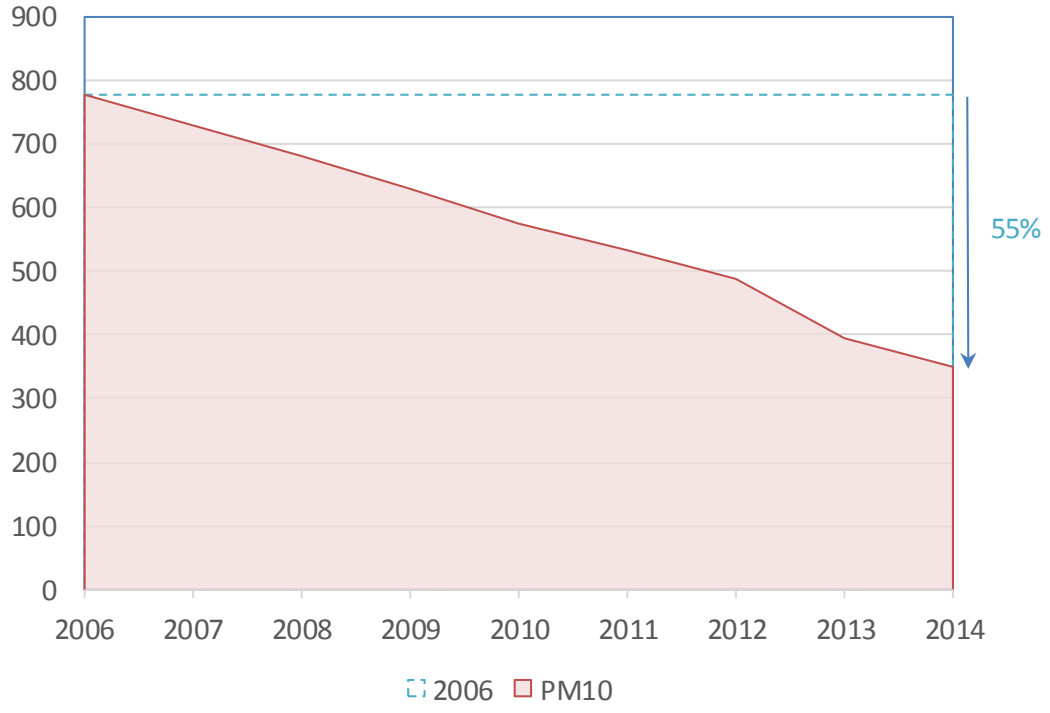


Figure 1.18: $PM_{2.5}$ Emissions Trend

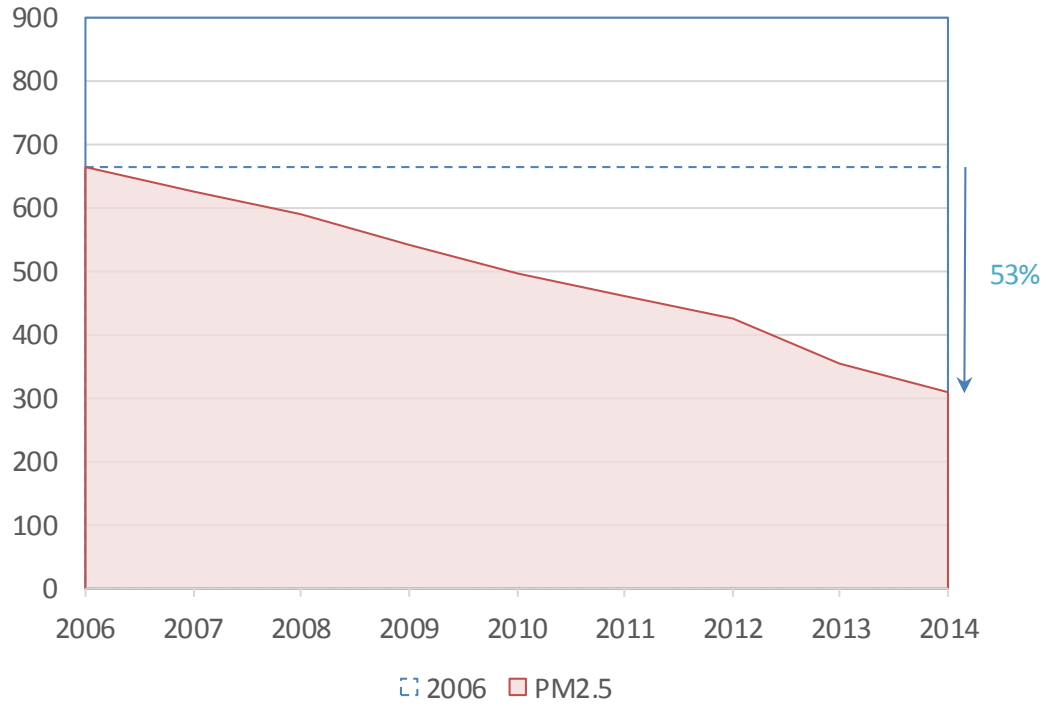


Figure 1.19: VOC Emissions Trend

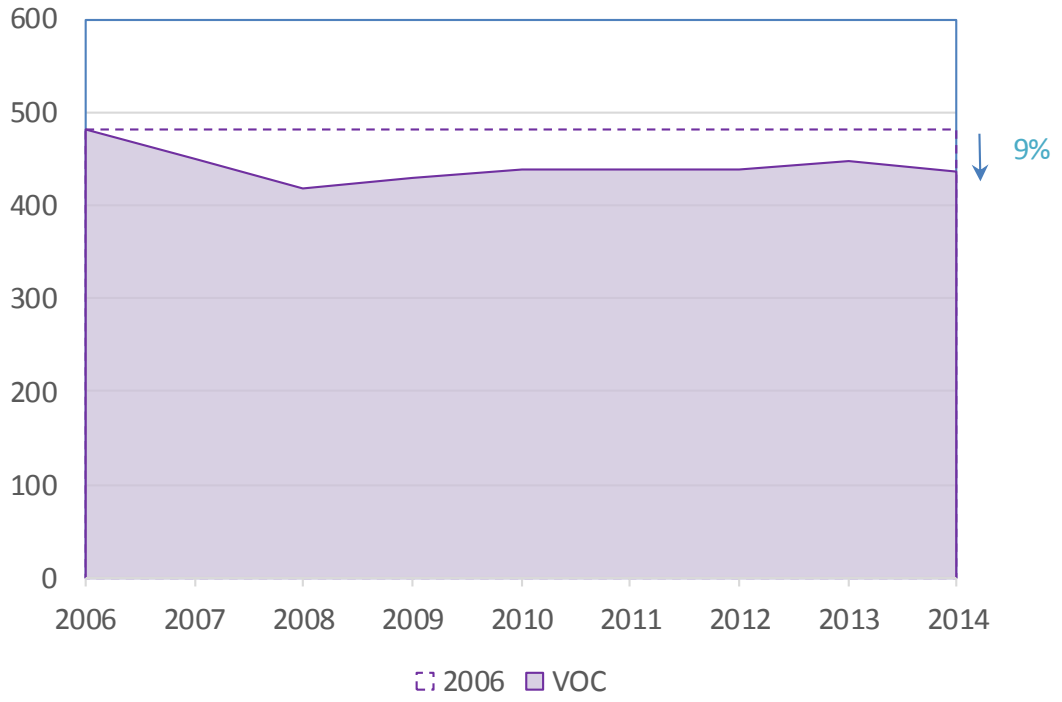


Figure 1.20: CO Emissions Trend

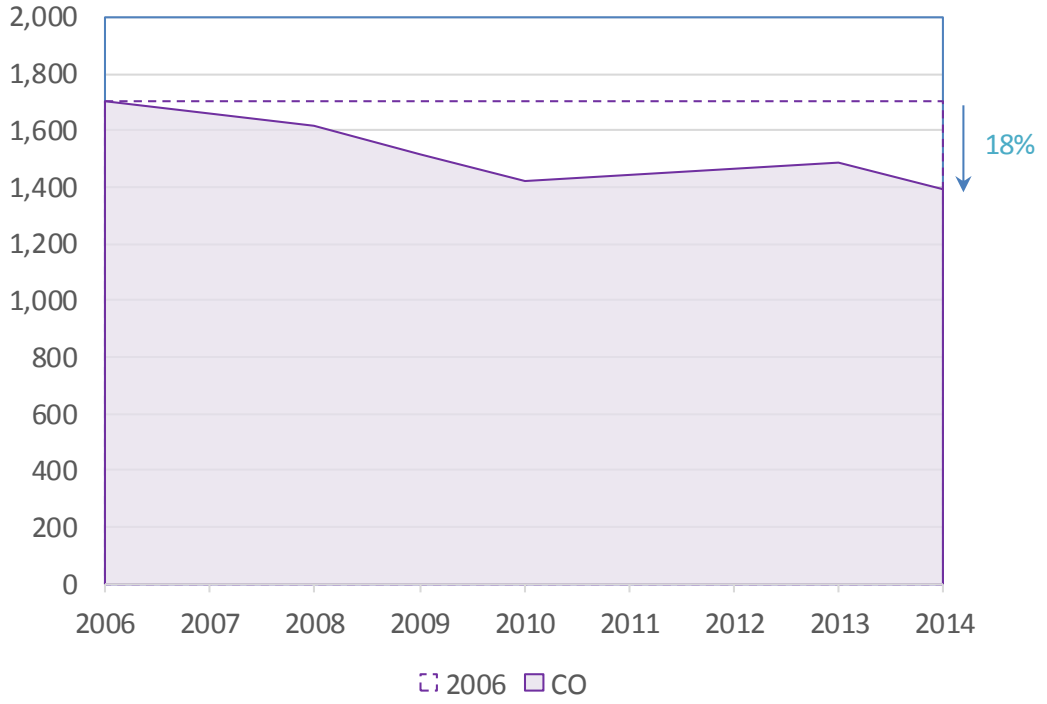


Figure 1.21: SO_2 Emissions Trend

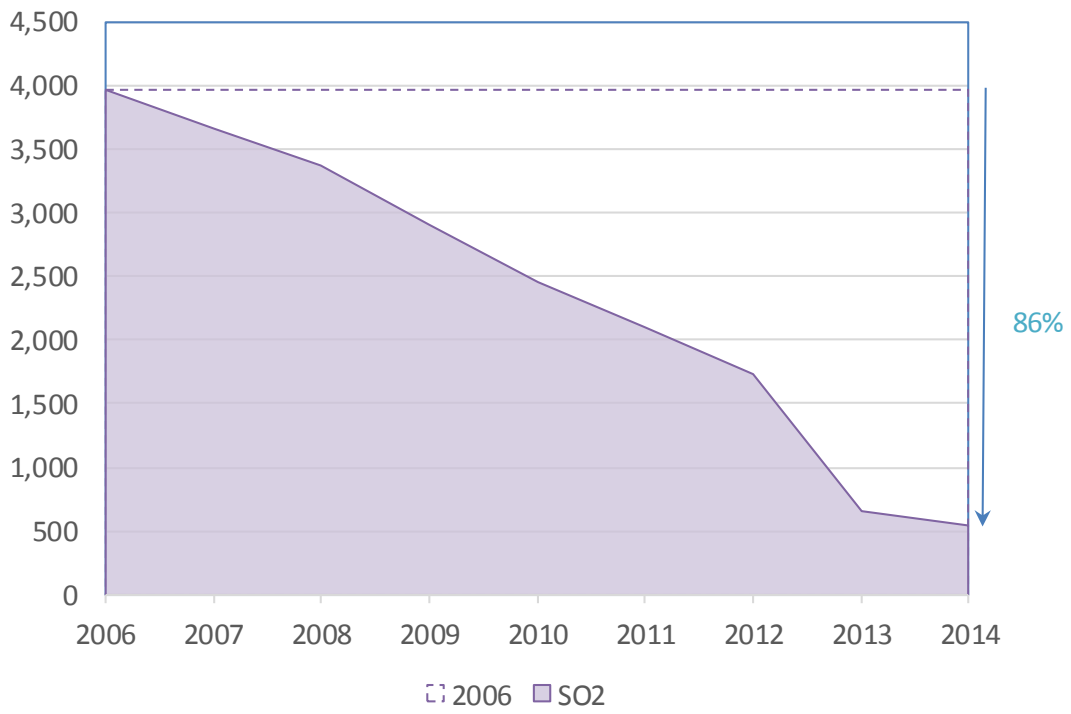


Figure 1.22: CO_2e Emissions Trend

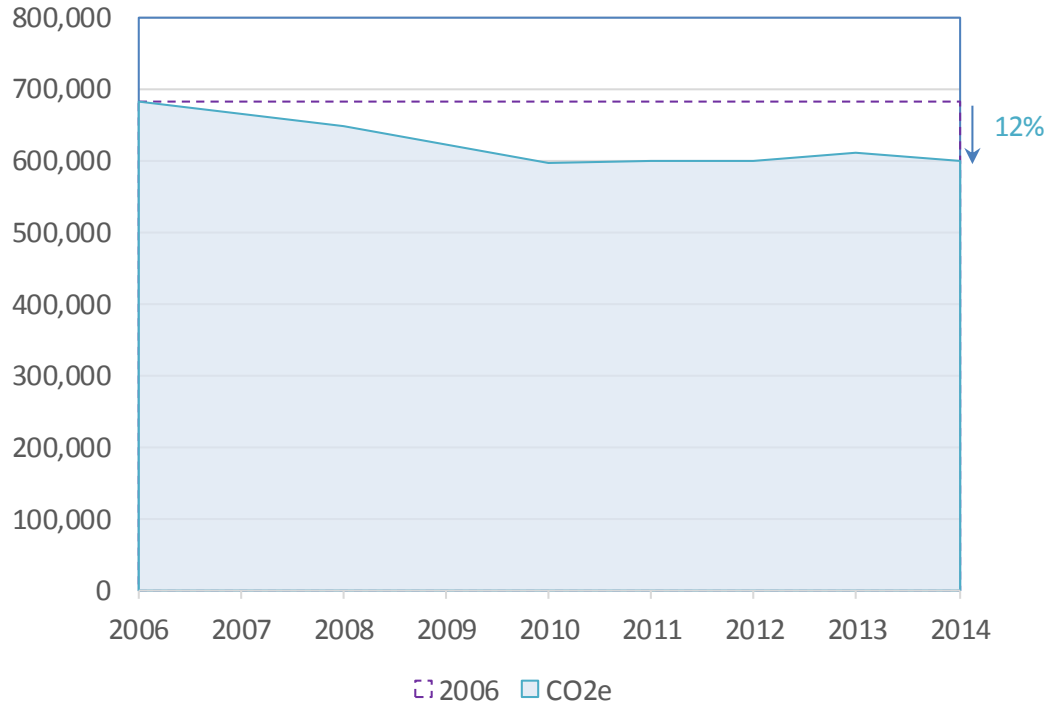
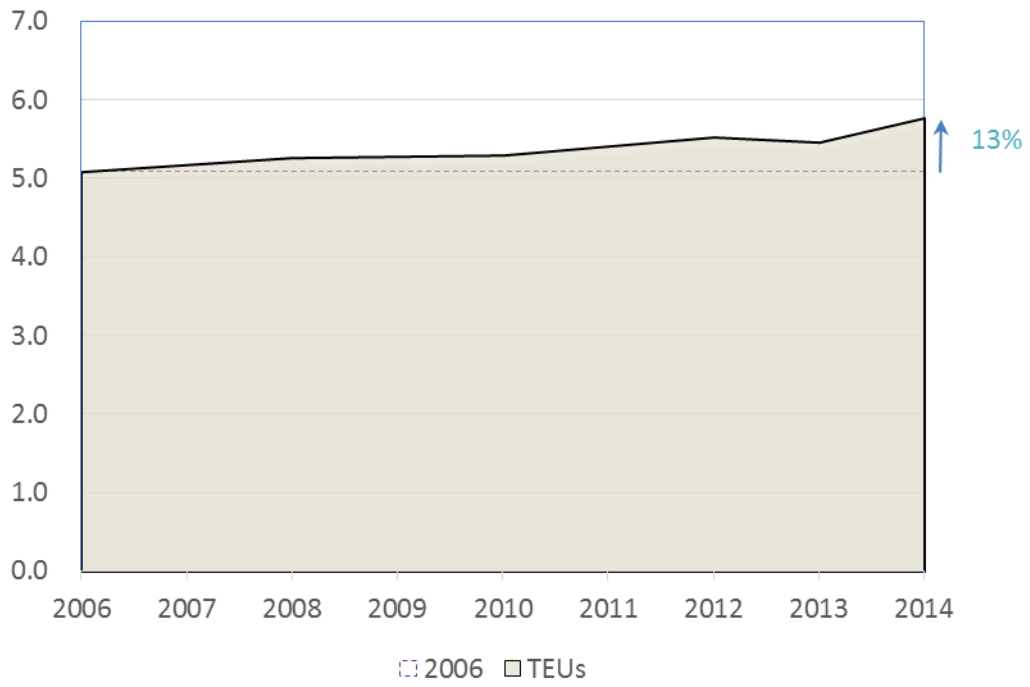


Figure 1.23: TEU Throughput Trend



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 eight privately operated Port Authority container and cruise 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;
- GCT New York, 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;
- GCT Bayonne, at the Port Jersey Port Authority Marine Terminal;
- Cape Liberty Cruise Terminals; and
- Brooklyn Cruise Terminals.

After an executive summary, the remainder of this section consists of the following subsections:

- 2.1 - Emission Estimates
- 2.2 - Cargo Handling Equipment Emission Comparisons
- 2.3 - Methodology
- 2.4 - Description of Cargo Handling Equipment

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.[9]

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	567,237	342,762	121,476	1,089,351	2,946,572	133,010	230,279,664
NYNJLINA	272,796	79,551	36,399	316,874	1,335,320	37,497	127,000,943
Cargo Handling Equipment	754	52	51	84	319	1.0	115,219
Percent of NYNJLINA Emissions	0.28%	0.07%	0.14%	0.03%	0.02%	0.003%	0.09%

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.

[9] Criteria pollutant emissions are primarily 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

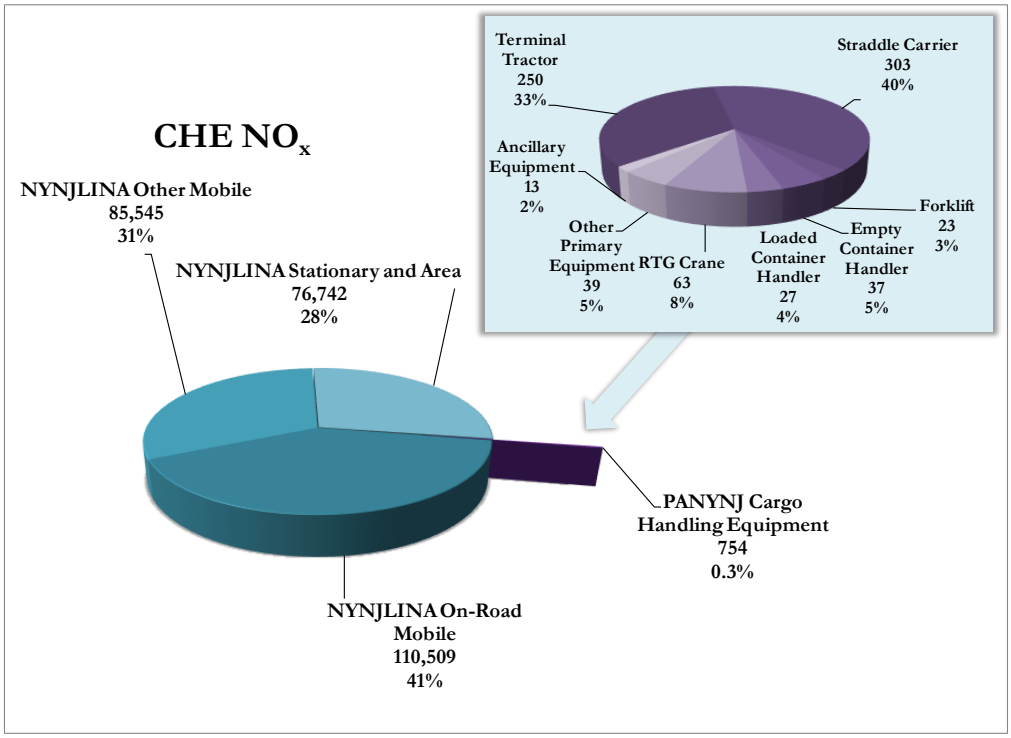


Figure ES2.2: Distribution and Comparison of PM_{10} from CHE, tpy and percent

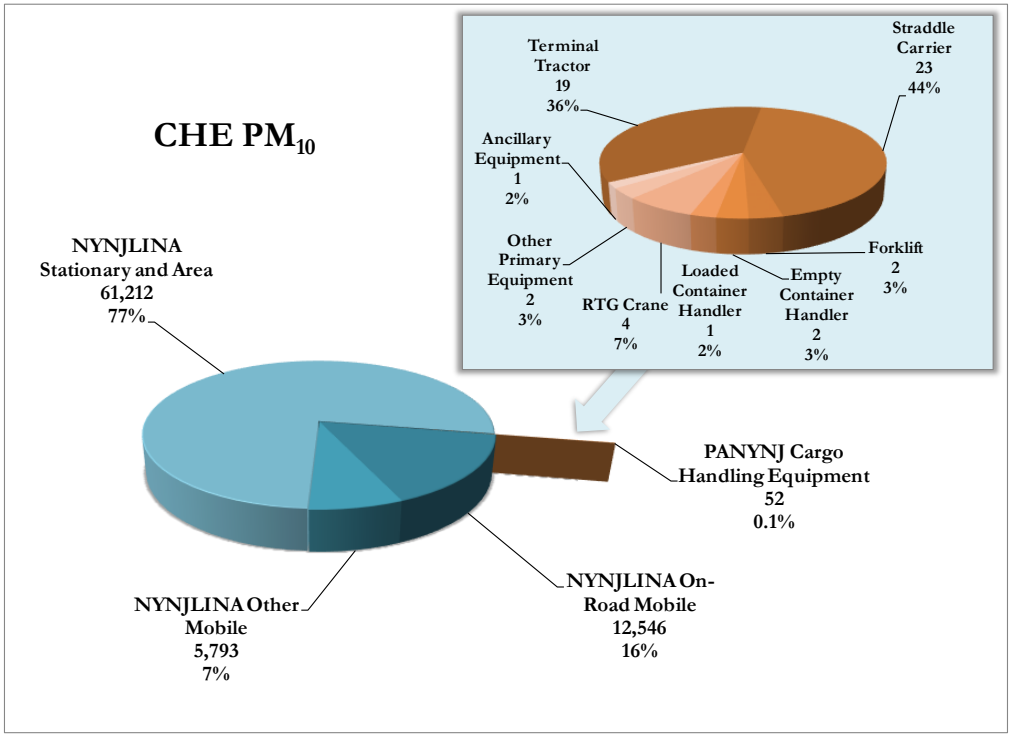


Figure ES2.3: Distribution and Comparison of $PM_{2.5}$ from CHE, tpy and percent

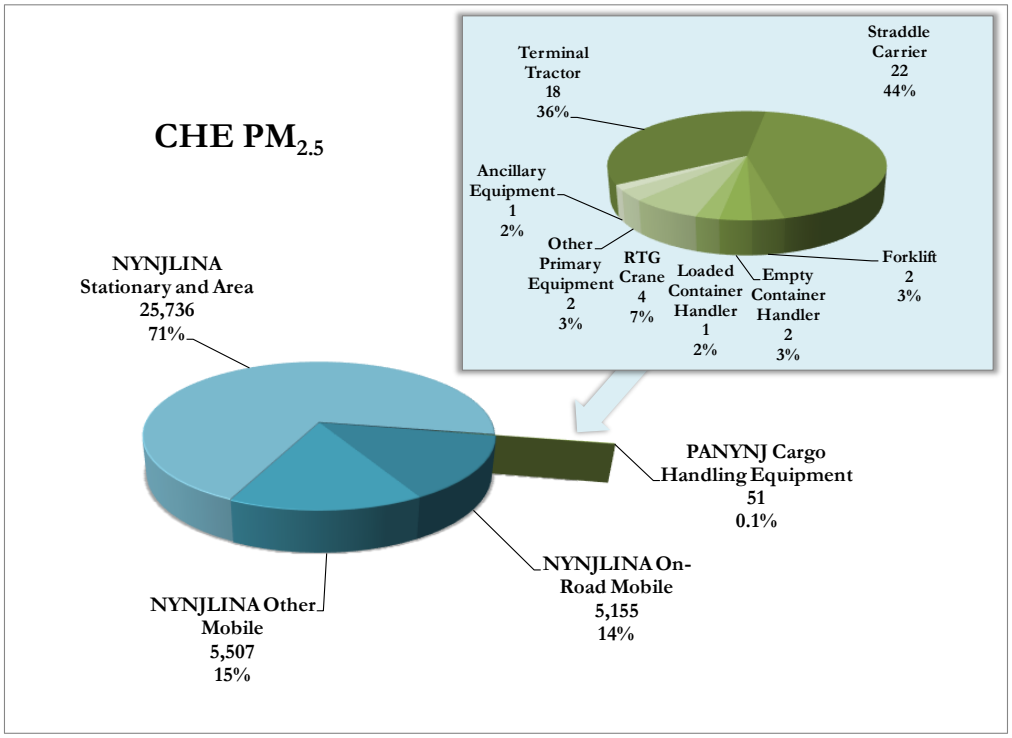


Figure ES2.4: Distribution and Comparison of VOC from CHE, tpy and percent

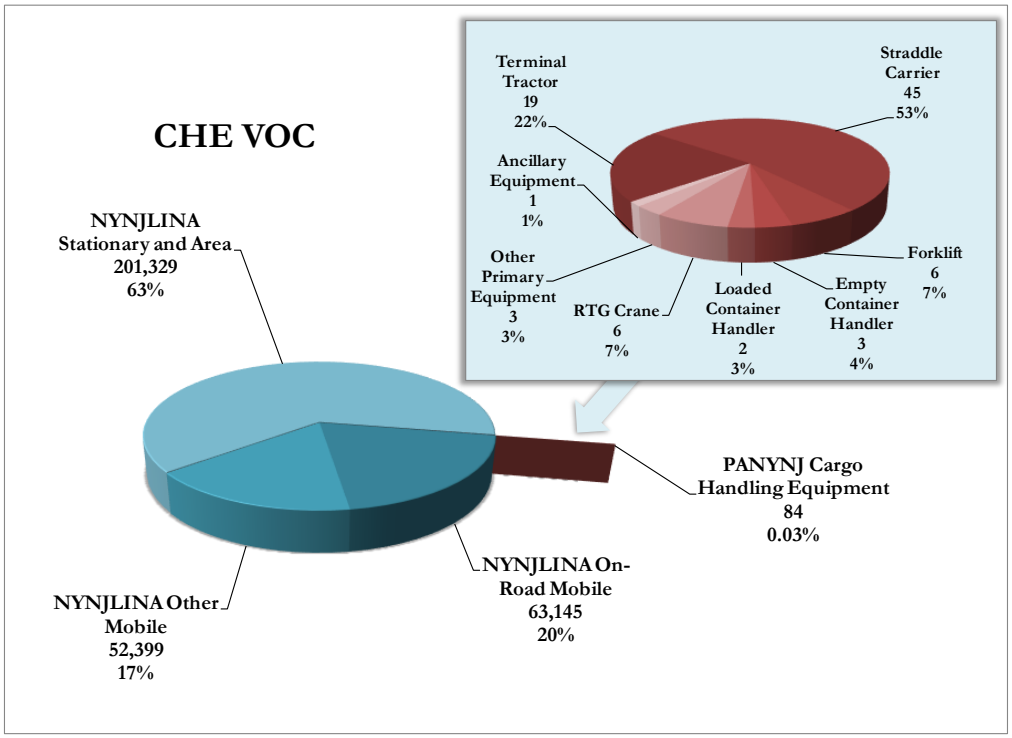


Figure ES2.5: Distribution and Comparison of CO from CHE, tpy and percent

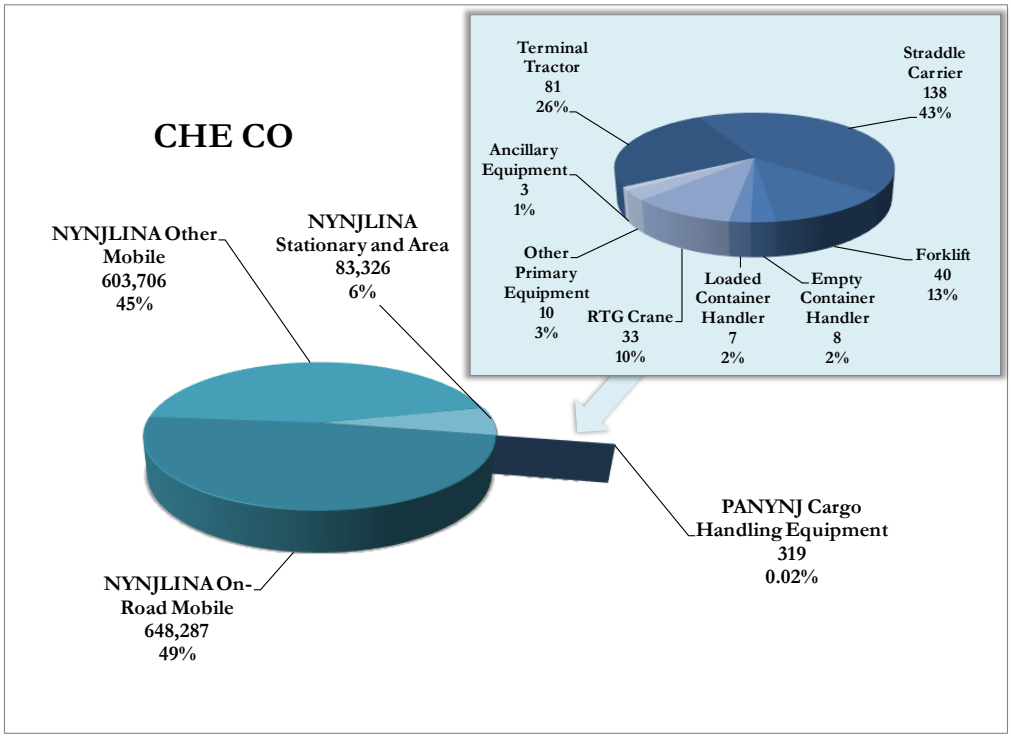


Figure ES2.6: Distribution and Comparison of SO_2 from CHE, tpy and percent

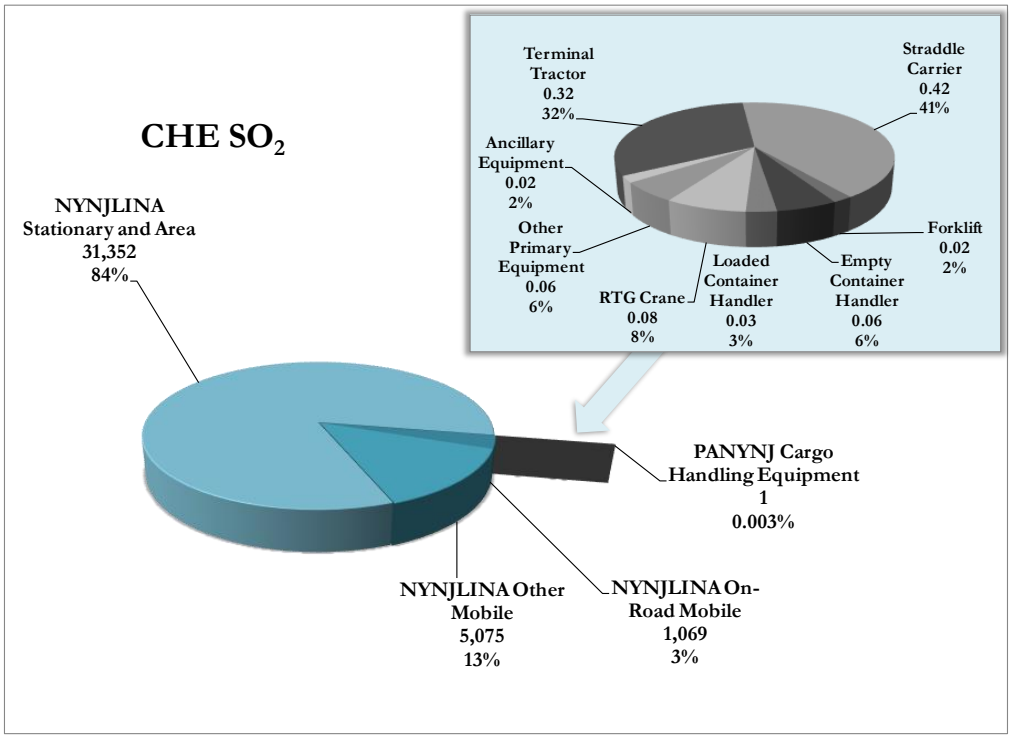
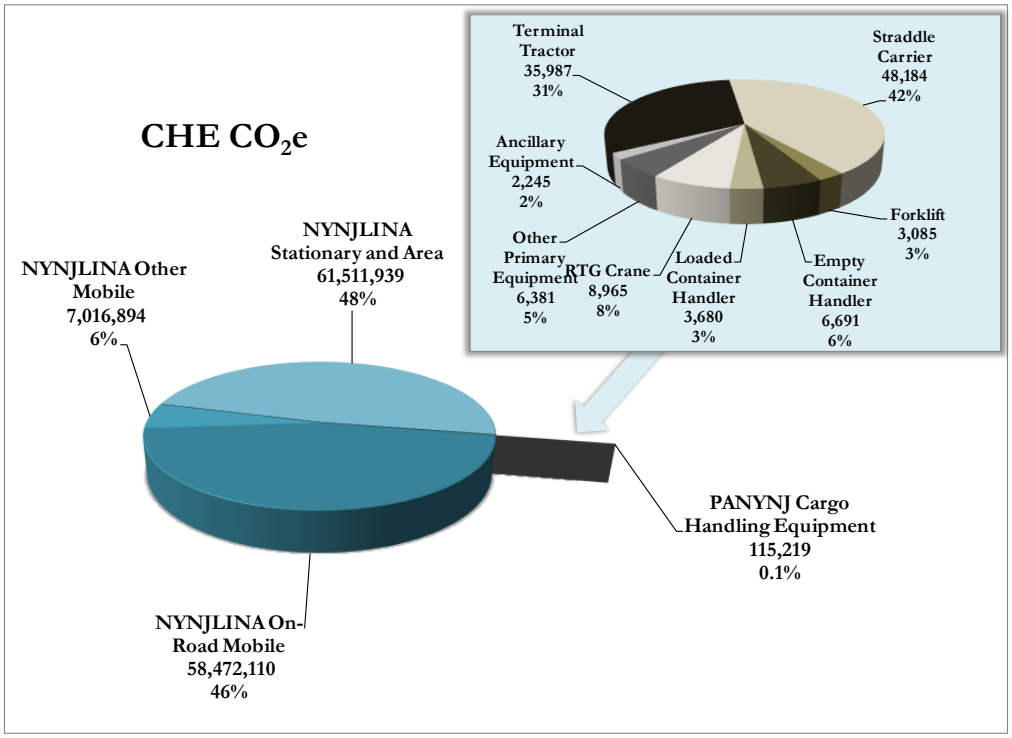


Figure ES2.7: Distribution of CO_2e equivalents from CHE, tpy and percent



2.1 Emission Estimates

This subsection presents the estimated emissions from cargo handling equipment operating at the terminals listed above. Table 2.1 presents emissions sorted by equipment type for all terminals combined. The equipment types are described later in this section.

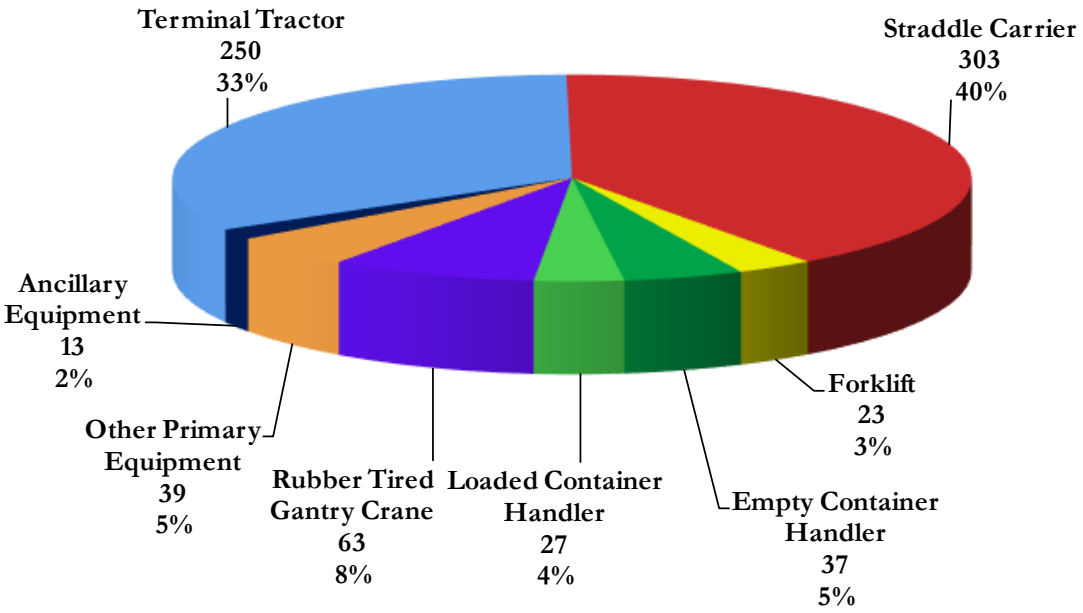
The emission estimates presented in this document are listed in several ways to provide as much information to the reader as possible. The emissions are presented by terminal type, by type of activity, and by county and state. Because of these different modes of display, the numerical values must be 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: CHE Emissions by Equipment Type, tpy

Equipment Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Terminal Tractor	250	18.7	18.2	18.5	81	0.32	35,987
Straddle Carrier	303	22.9	22.2	44.7	138	0.42	48,184
Forklift	23	1.7	1.6	5.9	40	0.02	3,085
Empty Container Handler	37	1.6	1.6	3.1	8	0.06	6,691
Loaded Container Handler	27	1.3	1.2	2	7	0.03	3,680
Rubber Tired Gantry Crane	63	3.6	3.5	6.2	33	0.08	8,965
Other Primary Equipment	39	1.6	1.6	2.5	10	0.06	6,381
Ancillary Equipment	13	0.9	0.8	1.2	3	0.02	2,245
Totals	**754**	**52**	**51**	**84**	**319**	**1.0**	**115,219**

As an example of the distribution of emissions among the various types of CHE, Figure 2.1 shows the distribution of NO_x emissions. Terminal tractors and straddle carriers make up the majority of emissions from CHE equipment, and the other pollutants show a similar distribution.

Figure 2.1: Distribution of NO_x Emissions for CHE



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.[10] This subsection also presents a comparison of 2014 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.

[10] 2011 and 2008 National Emission Inventory Databases, US EPA, as cited above.

2.2.1 Comparisons with County and Regional Emissions

Table 2.2 summarizes the 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 2.2, a series of tables and figures (Tables 2.3 – 2.9 and Figures 2.2 – 2.8) present 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 2.2: 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_2e
Bergen	NJ	0	0	0	0	0	0.0	0
Essex	NJ	62	5	5	8	36	0.1	15,566
Hudson	NJ	97	6	6	9	38	0.2	17,602
Middlesex	NJ	0	0	0	0	0	0.0	0
Monmouth	NJ	0	0	0	0	0	0.0	0
Union	NJ	538	37	36	62	210	0.7	72,588
New Jersey subtotal		**697**	**48**	**46**	**79**	**284**	**0.9**	**105,756**
Bronx	NY	0	0	0	0	0	0.0	0
Kings (Brooklyn)	NY	20	1	1	2	11	0.0	2,302
Nassau	NY	0	0	0	0	0	0.0	0
New York	NY	0	0	0	0	0	0.0	0
Orange	NY	0	0	0	0	0	0.0	0
Queens	NY	0	0	0	0	0	0.0	0
Richmond (Staten Island)	NY	37	3	3	4	24	0.1	7,161
Rockland	NY	0	0	0	0	0	0.0	0
Suffolk	NY	0	0	0	0	0	0.0	0
Westchester	NY	0	0	0	0	0	0.0	0
New York subtotal		**57**	**5**	**4**	**5**	**35**	**0.1**	**9,463**
TOTAL		**754**	**52**	**51**	**84**	**319**	**1.0**	**115,219**

Table 2.3: 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	15,763	0	0.0%
Essex	NJ	14,172	62	0.4%
Hudson	NJ	10,059	92	0.9%
Middlesex	NJ	15,574	0	0.0%
Monmouth	NJ	10,795	0	0.0%
Union	NJ	13,636	538	3.9%
New Jersey Subtotal		**79,999**	**692**	**0.9%**
Bronx	NY	9,912	0	0.0%
Kings (Brooklyn)	NY	19,011	20	0.1%
Nassau	NY	23,967	0	0.0%
New York	NY	33,400	0	0.0%
Orange	NY	8,857	0	0.0%
Queens	NY	29,220	0	0.0%
Richmond (Staten Island	NY	7,531	37	0.5%
Rockland	NY	5,494	0	0.0%
Suffolk	NY	39,142	0	0.0%
Westchester	NY	16,263	0	0.0%
New York Subtotal		**192,797**	**57**	**0.0%**
TOTAL		**272,796**	**749**	**0.3%**

Figure 2.2: Comparison of CHE NO_x Emissions with Overall NO_x Emissions by County, tpy

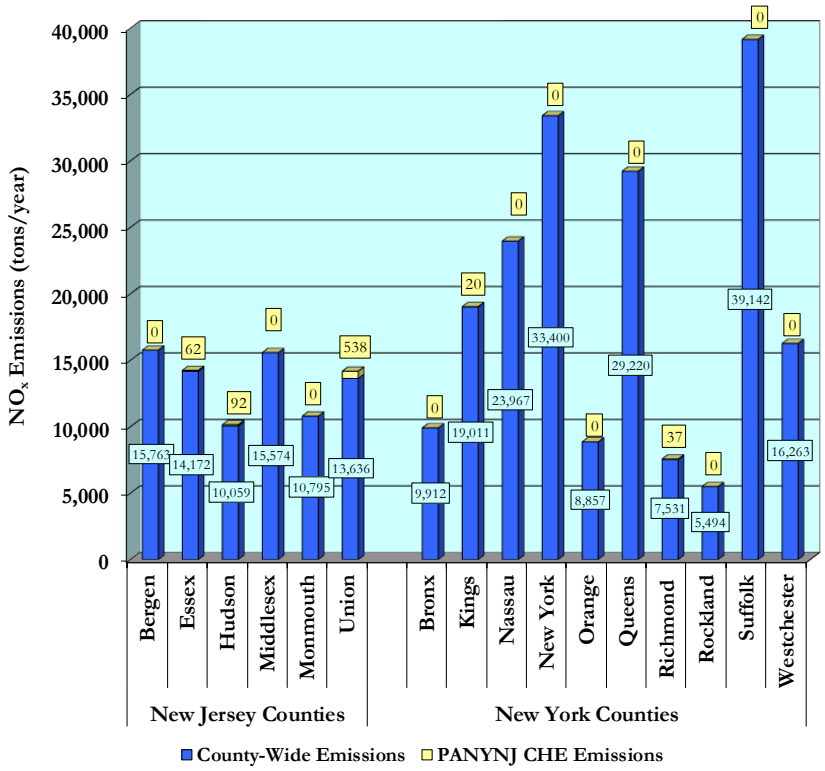


Table 2.4: Comparison of CHE PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	3,896	0.0	0.0%
Essex	NJ	2,631	4.7	0.2%
Hudson	NJ	1,641	5.6	0.3%
Middlesex	NJ	4,486	0.0	0.0%
Monmouth	NJ	3,406	0.0	0.0%
Union	NJ	2,761	37.0	1.3%
New Jersey Subtotal		**18,821**	**47**	**0.3%**
Bronx	NY	2,713	0.0	0.0%
Kings (Brooklyn)	NY	4,984	1.4	0.0%
Nassau	NY	6,975	0.0	0.0%
New York	NY	7,049	0.0	0.0%
Orange	NY	7,645	0.0	0.0%
Queens	NY	5,881	0.0	0.0%
Richmond (Staten Islanc	NY	1,972	3.3	0.2%
Rockland	NY	2,149	0.0	0.0%
Suffolk	NY	14,340	0.0	0.0%
Westchester	NY	7,023	0.0	0.0%
New York Subtotal		**60,730**	**5**	**0.01%**
TOTAL		**79,551**	**52**	**0.1%**

Figure 2.3: Comparison of CHE PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

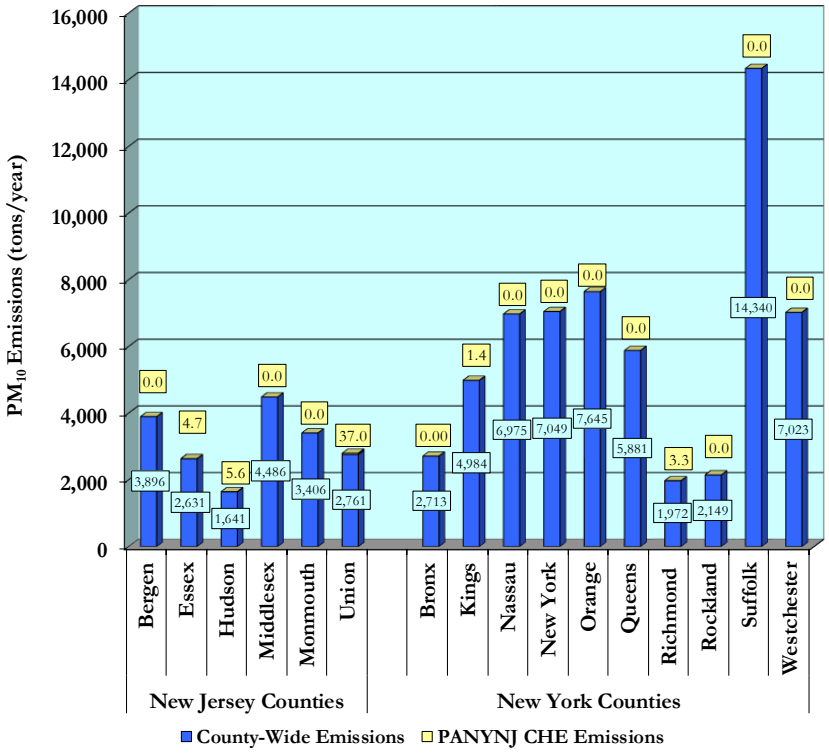


Table 2.5: Comparison of CHE $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	2,097	0.0	0.0%
Essex	NJ	1,627	4.6	0.3%
Hudson	NJ	1,105	5.4	0.5%
Middlesex	NJ	2,309	0.0	0.0%
Monmouth	NJ	1,635	0.0	0.0%
Union	NJ	1,704	35.9	2.1%
New Jersey Subtotal		**10,477**	**46**	**0.4%**
Bronx	NY	1,407	0.0	0.0%
Kings (Brooklyn)	NY	2,600	1.3	0.1%
Nassau	NY	2,984	0.0	0.0%
New York	NY	3,295	0.0	0.0%
Orange	NY	2,395	0.0	0.0%
Queens	NY	3,167	0.0	0.0%
Richmond (Staten Island)	NY	1,000	3.2	0.3%
Rockland	NY	827	0.0	0.0%
Suffolk	NY	5,705	0.0	0.0%
Westchester	NY	2,540	0.0	0.0%
New York Subtotal		**25,922**	**4**	**0.02%**
TOTAL		**36,399**	**50**	**0.14%**

Figure 2.4: Comparison of CHE $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

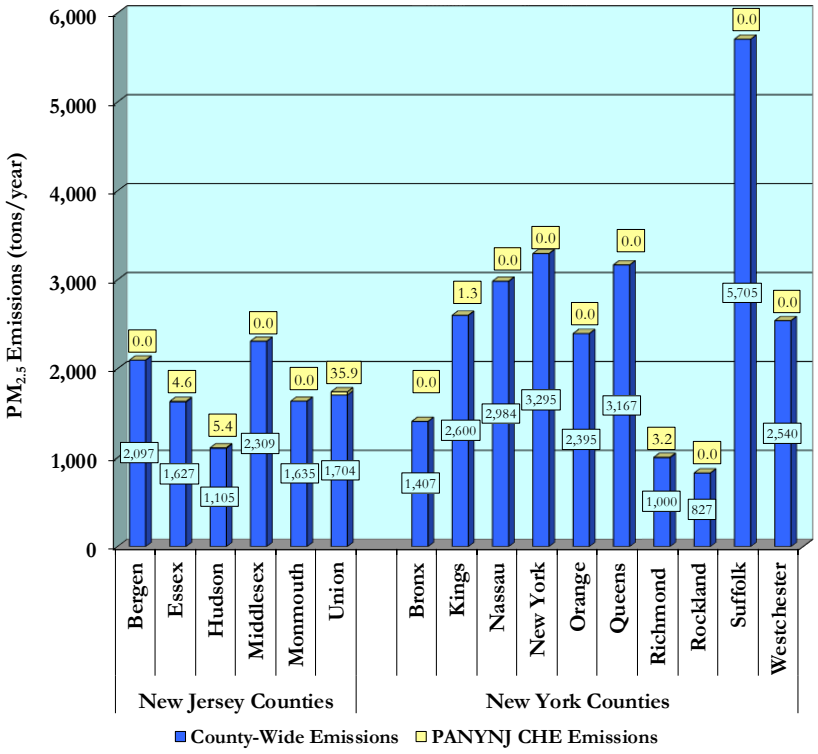


Table 2.6: Comparison of CHE VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	18,980	0.0	0.0%
Essex	NJ	14,151	8.0	0.1%
Hudson	NJ	9,429	8.5	0.1%
Middlesex	NJ	19,479	0.0	0.0%
Monmouth	NJ	19,080	0.0	0.0%
Union	NJ	12,608	62.0	0.5%
New Jersey Subtotal		**93,727**	**78**	**0.1%**
Bronx	NY	13,272	0.0	0.0%
Kings (Brooklyn)	NY	24,871	1.7	0.01%
Nassau	NY	27,629	0.0	0.0%
New York	NY	20,469	0.0	0.0%
Orange	NY	19,383	0.0	0.0%
Queens	NY	27,772	0.0	0.0%
Richmond (Staten Island)	NY	7,600	3.7	0.0%
Rockland	NY	8,861	0.0	0.0%
Suffolk	NY	49,647	0.0	0.0%
Westchester	NY	23,643	0.0	0.0%
New York Subtotal		**223,147**	**5**	**0.002%**
TOTAL		**316,874**	**84**	**0.03%**

Figure 2.5: Comparison of CHE VOC Emissions with Overall VOC Emissions by County, tpy

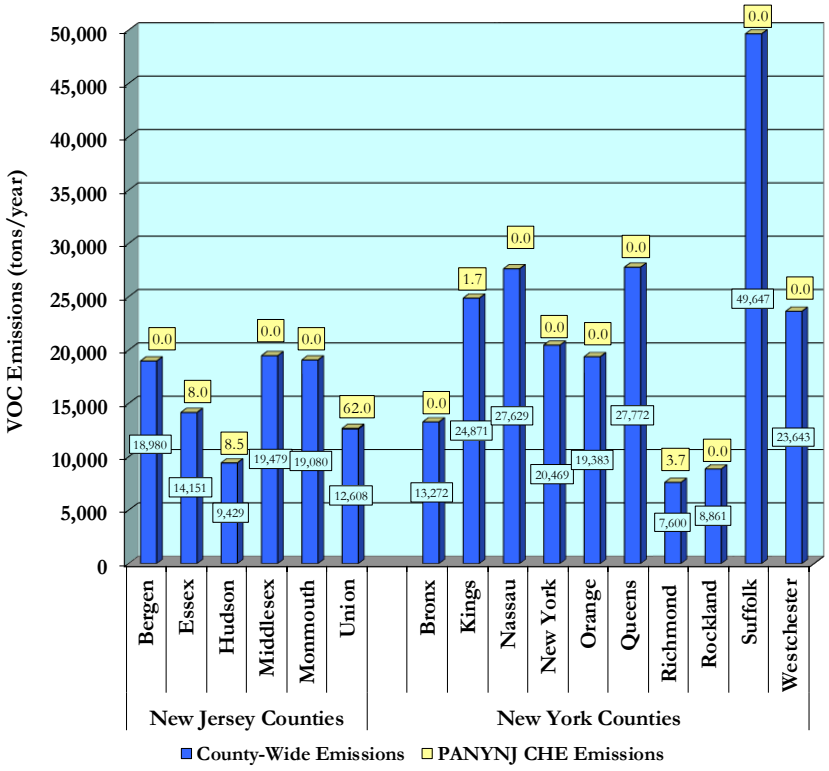


Table 2.7: Comparison of CHE CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	111,914	0.0	0.0%
Essex	NJ	64,014	35.8	0.1%
Hudson	NJ	36,789	33.9	0.1%
Middlesex	NJ	87,469	0.0	0.0%
Monmouth	NJ	71,524	0.0	0.0%
Union	NJ	53,352	209.6	0.4%
New Jersey Subtotal		**425,060**	**279**	**0.1%**
Bronx	NY	36,134	0.0	0.0%
Kings (Brooklyn)	NY	78,793	10.6	0.0%
Nassau	NY	143,985	0.0	0.0%
New York	NY	109,627	0.0	0.0%
Orange	NY	45,498	0.0	0.0%
Queens	NY	111,129	0.0	0.0%
Richmond (Staten Island	NY	32,985	24.4	0.1%
Rockland	NY	33,695	0.0	0.0%
Suffolk	NY	212,558	0.0	0.0%
Westchester	NY	105,856	0.0	0.0%
New York Subtotal		**910,259**	**35**	**0.00%**
TOTAL		**1,335,320**	**319**	**0.02%**

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

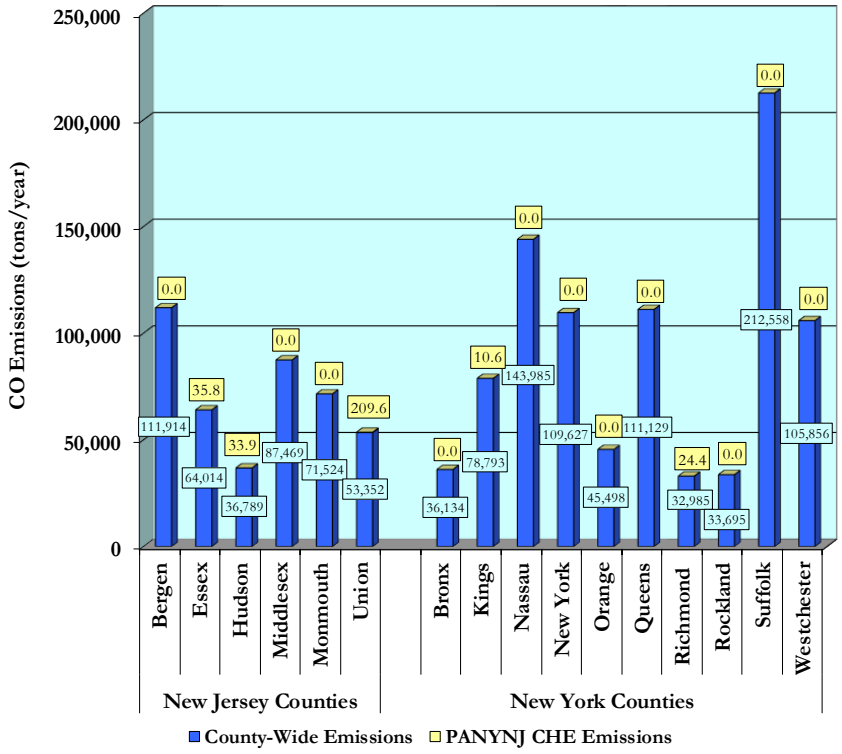


Table 2.8: Comparison of CHE SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	685	0.0	0.000%
Essex	NJ	1,226	0.1	0.010%
Hudson	NJ	1,840	0.1	0.008%
Middlesex	NJ	785	0.0	0.000%
Monmouth	NJ	687	0.0	0.000%
Union	NJ	1,583	0.7	0.041%
New Jersey Subtotal		**6,806**	**0.9**	**0.014%**
Bronx	NY	1,547	0.0	0.000%
Kings (Brooklyn)	NY	1,525	0.0	0.001%
Nassau	NY	2,563	0.0	0.000%
New York	NY	5,574	0.0	0.000%
Orange	NY	6,251	0.0	0.000%
Queens	NY	2,513	0.0	0.000%
Richmond (Staten Island)	NY	409	0.1	0.015%
Rockland	NY	297	0.0	0.000%
Suffolk	NY	7,875	0.0	0.000%
Westchester	NY	2,137	0.0	0.000%
New York Subtotal		**30,691**	**0.1**	**0.000%**
TOTAL		**37,497**	**1.0**	**0.003%**

Figure 2.7: Comparison of CHE SO_2 Emissions with Overall SO_2 Emissions by County, tpy

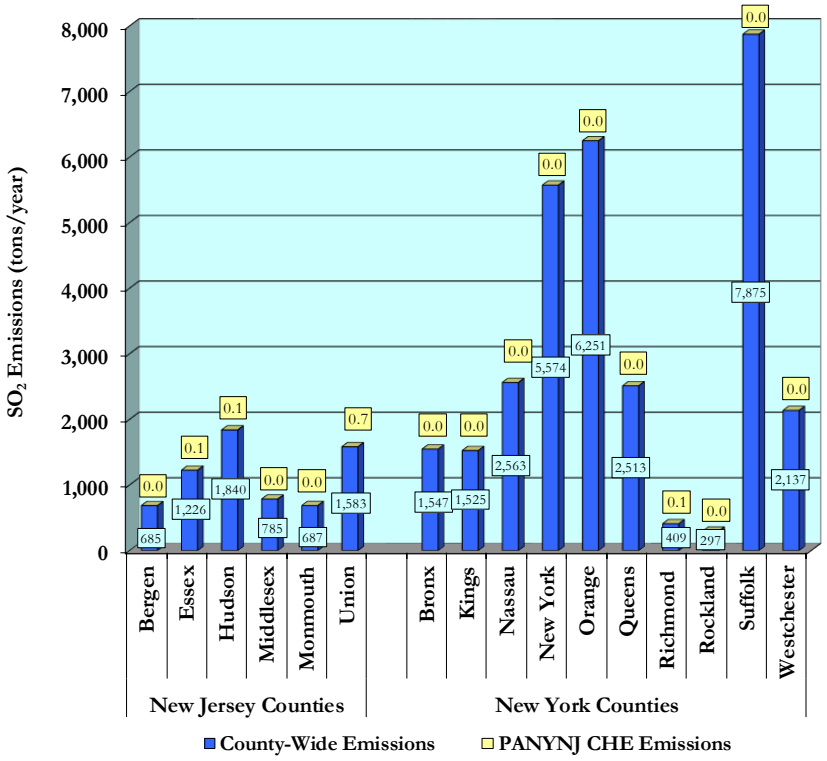
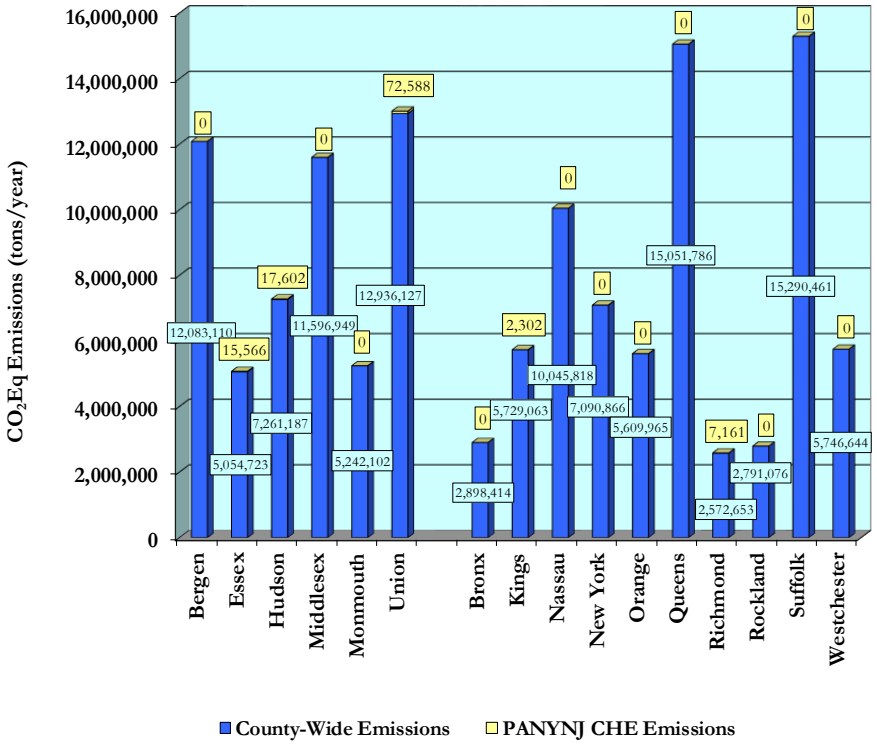


Table 2.9: Comparison of CHE CO_2 Emissions with Overall CO_2 Emissions by County, tpy

County	State	County-Wide Emissions	CHE Emissions in Inventory	Percent of Total
Bergen	NJ	12,083,110	0	0.00%
Essex	NJ	5,054,723	15,566	0.31%
Hudson	NJ	7,261,187	17,602	0.24%
Middlesex	NJ	11,596,949	0	0.00%
Monmouth	NJ	5,242,102	0	0.00%
Union	NJ	12,936,127	72,588	0.56%
New Jersey Subtotal		**54,174,197**	**105,756**	**0.20%**
Bronx	NY	2,898,414	0	0.00%
Kings (Brooklyn)	NY	5,729,063	2,302	0.04%
Nassau	NY	10,045,818	0	0.00%
New York	NY	7,090,866	0	0.00%
Orange	NY	5,609,965	0	0.00%
Queens	NY	15,051,786	0	0.00%
Richmond (Staten Islar	NY	2,572,653	7,161	0.28%
Rockland	NY	2,791,076	0	0.00%
Suffolk	NY	15,290,461	0	0.00%
Westchester	NY	5,746,644	0	0.00%
New York Subtotal		**72,826,745**	**9,463**	**0.01%**
TOTAL		**127,000,943**	**115,219**	**0.09%**

Figure 2.8: 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 2014 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. Compared to 2013, TEU throughput increased but overall there was a decrease in CHE emissions because the total work done by CHE, measured as total horsepower-hours, decreased in 2014 compared to 2013 and several older pieces of equipment were turned over to new models. 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 2.10 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 2014 estimates, emissions in tons per million TEUs, and the percentage differences in tons per million TEUs between the prior years and 2014.

Table 2.10: 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_2e	Million TEUs
Tons per year, with adjustments								
2014	754	52	51	84	319	1.0	115,219	5.772
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 2014 - tons per year								
2013 - 2014	-20%	-17%	-17%	-4%	-14%	-16%	-18%	6%
2012 - 2014	-23%	-21%	-21%	-5%	-16%	-16%	-14%	4%
2010 - 2014	-35%	-24%	-24%	-14%	-19%	-16%	-11%	9%
2008 - 2014	-35%	-29%	-29%	-15%	-19%	-95%	-10%	10%
2006 - 2014	-50%	-48%	-45%	-36%	-36%	-100%	-25%	13%
Tons per million TEU								
2014	131	9	9	15	55	0.2	19,962	
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 2014 - tons per million TEU								
2013 - 2014	-24%	-18%	-18%	-6%	-19%	0%	-22%	
2012 - 2014	-26%	-25%	-25%	-6%	-20%	0%	-17%	
2010 - 2014	-40%	-31%	-31%	-21%	-27%	0%	-18%	
2008 - 2014	-41%	-36%	-31%	-21%	-26%	-95%	-18%	
2006 - 2014	-56%	-55%	-50%	-42%	-43%	-99.6%	-34%	

The following figures graphically illustrate the changes in emissions, in tons per year, between the 2006 baseline emissions inventory and the 2014 update. The 2006 emissions are shown in each figure as a dashed line horizontal with the x axis, and the overall percent change between 2006 and 2014 is shown to the right of each chart, with an arrow indicating the direction of change in emissions. The units on the y-axis are tons per year.

Figure 2.9: NO_x Emissions Trend for CHE

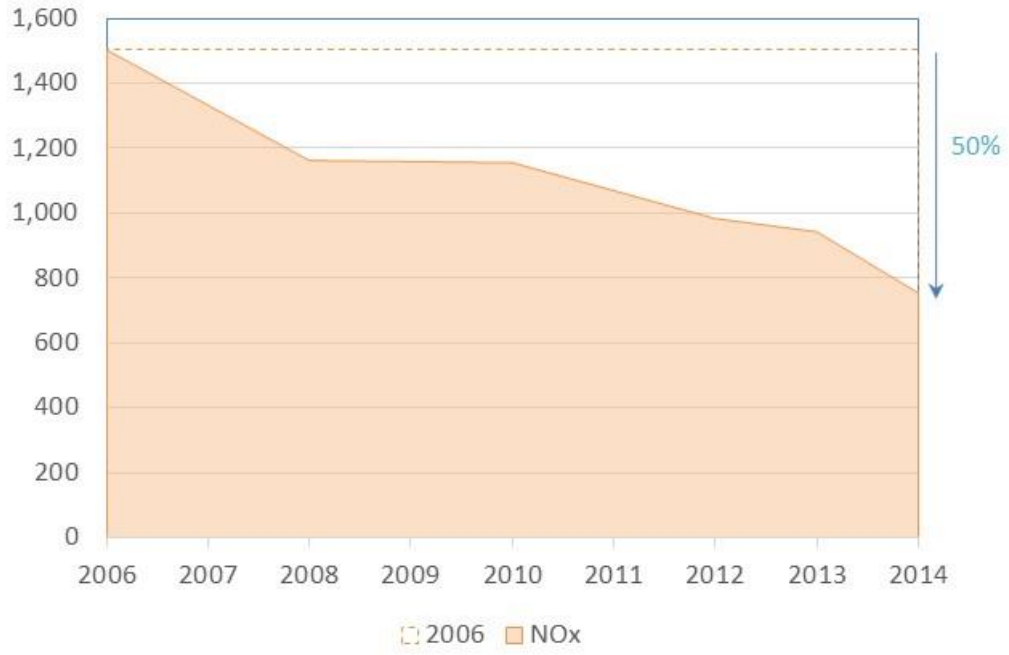


Figure 2.10: PM_{10} Emissions Trend for CHE

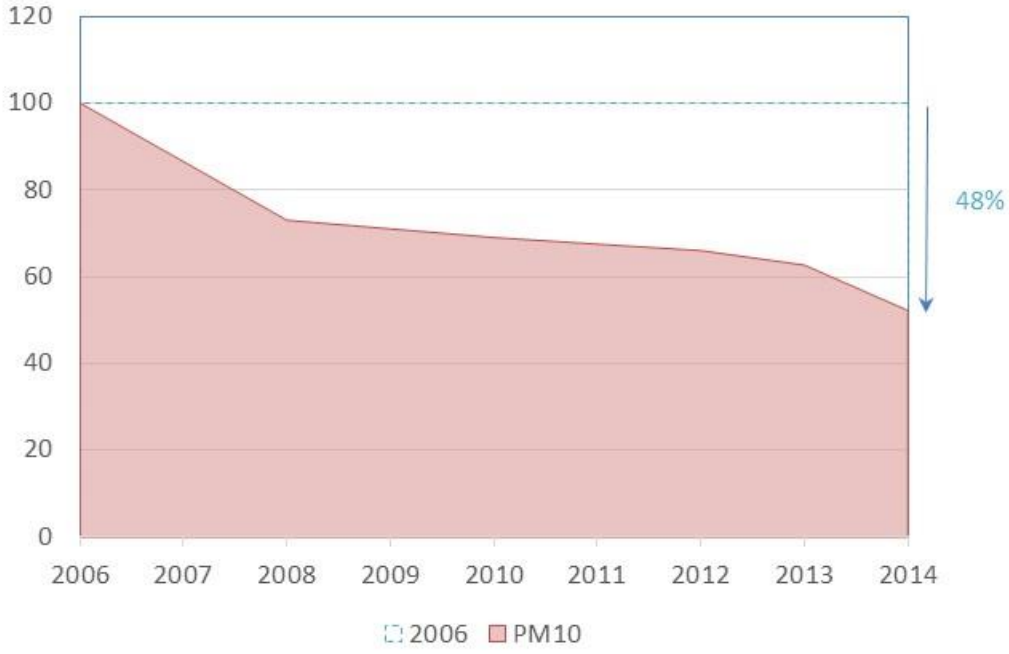


Figure 2.11: $PM_{2.5}$ Emissions Trend for CHE

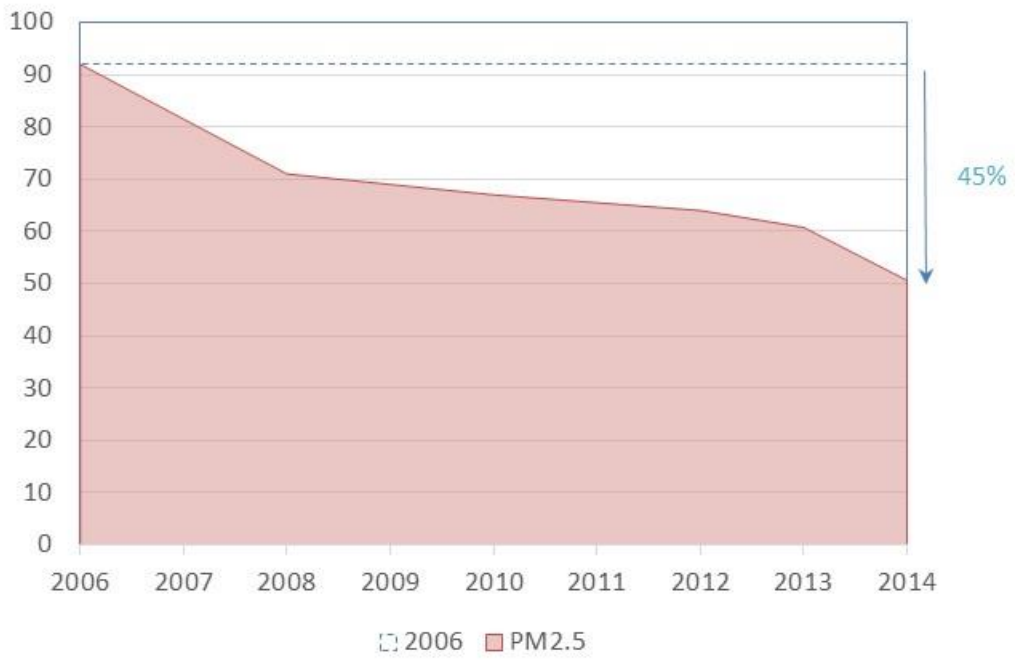


Figure 2.12: VOC Emissions Trend for CHE

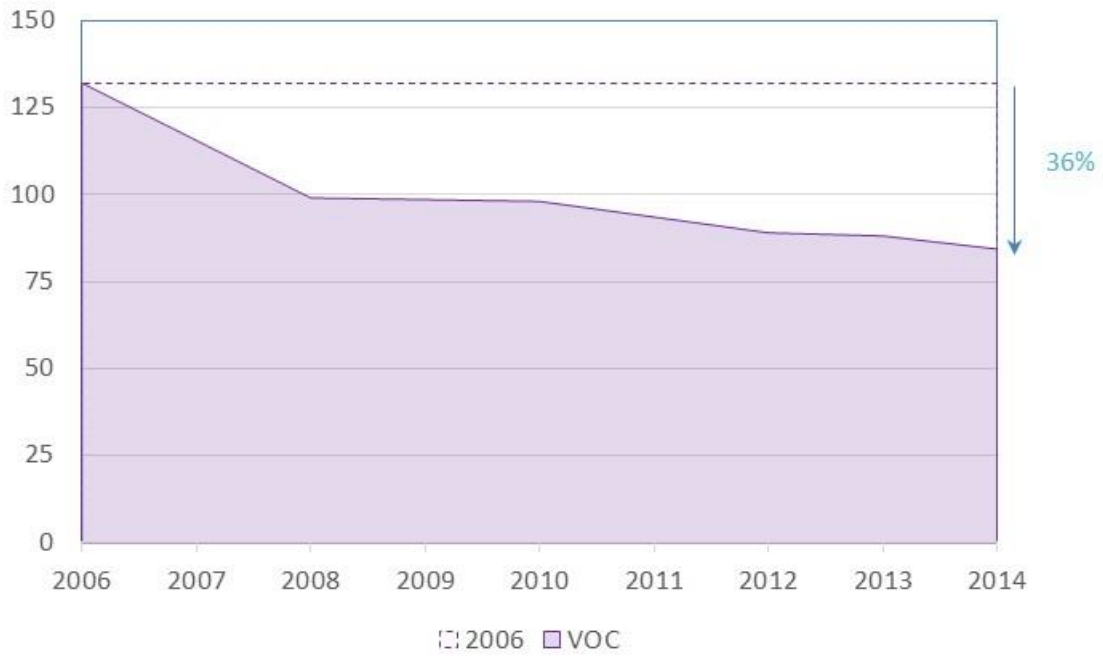


Figure 2.13: CO Emissions Trend for CHE

Figure 2.14: SO_2 Emissions Trend for CHE

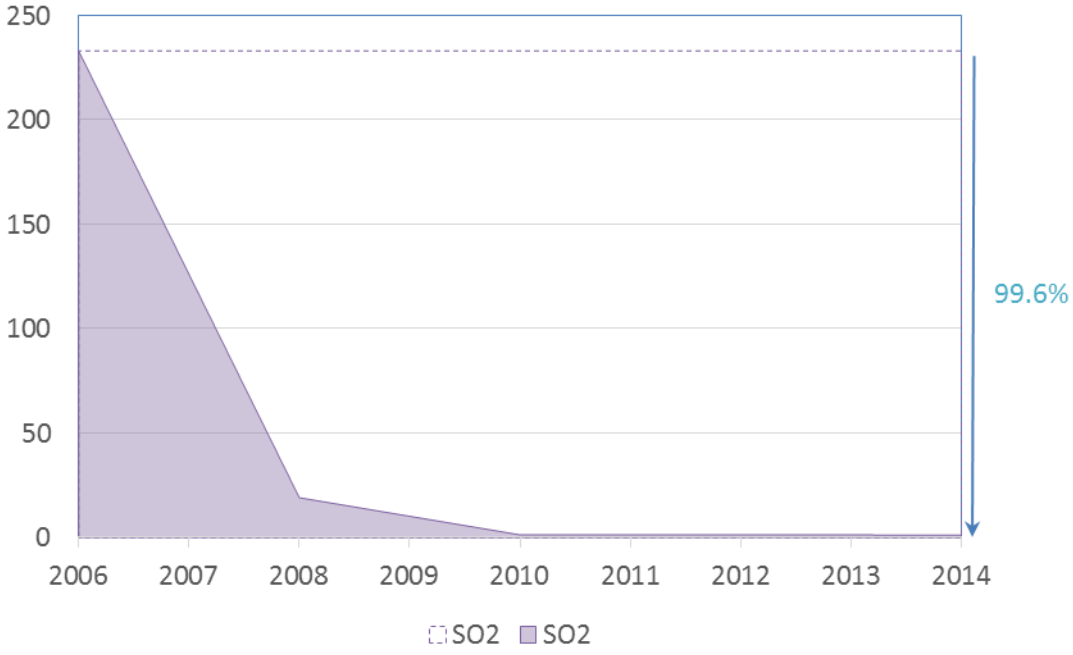
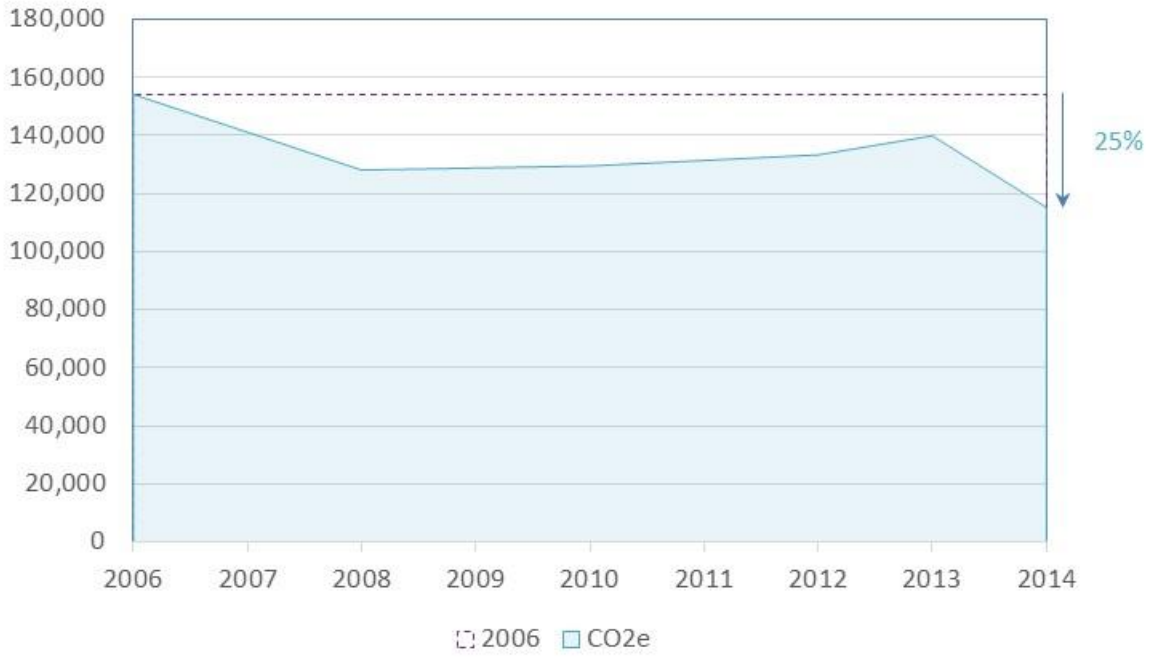


Figure 2.15: CO_2e Emissions Trend for CHE



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. Equipment lists were derived from information maintained by the container and cruise terminal operators. Data custody was maintained by a single point of contact outside the Port Authority to allay confidentiality concerns. In 2014, most of the terminal operators provided actual annual equipment hours.

2.3.2 Emission Estimating Model

Emissions were estimated using the NONROAD option of EPA's MOVES2014a emission estimating model.[11] To prepare for model input, the terminal equipment was stratified into equipment types recognized by the model. For example, cargo 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.

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

The cargo handling equipment identified by survey was categorized into the most closely corresponding MOVES2014a equipment type, as illustrated in Table 2.11, which presents equipment types by Source Classification Code (SCC), load factor, and MOVES2014 category common name.

Table 2.11: 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 2.12 lists the population of equipment identified at port facilities, listed by common name.

Table 2.12: MOVES/NONROAD Equipment Category Population List

NONROAD Category	2006 Count	2008 Count	2010 Count	2012 Count	2013 Count	2014 Count
Aerial lift	11	11	10	11	11	12
Crane	13	7	12	4	4	2
Diesel forklift	0	8	21	105	114	119
Propane forklift	87	108	93	83	83	93
Front end loader	13	7	4	4	0	0
Other industrial equipment	130	143	147	187	186	160
Other material handling equipment	260	293	297	303	307	329
Offroad truck	9	12	5	6	6	21
Signal board / light plant	12	12	12	12	12	12
Skid-steer Loader	0	0	0	0	2	2
Sweeper / scrubber	2	9	9	9	9	9
Terminal tractor	350	403	442	465	446	392
Totals	**887**	**1,013**	**1,052**	**1,189**	**1,180**	**1,151**

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

$$\mathbf{E = Power \times Activity \times LF \times EF \times FCF \times CF}$$

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.

For each calendar year, the model outputs emission factors in grams/hp-hr for each of the MOVES2014a equipment types by horsepower group 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.

The MOVES2014 model contains a load factor and default conditions for each source category as listed in Table 2.4. For calendar year 2014, the default sulfur content used in the model is 20 ppm[12]. Since ULSD fuel with a sulfur content of 15 ppm was used for CHE operated at the PANYNJ terminals, the emission factors for PM_{10}, $PM_{2.5}$, DPM and SO_2 from MOVES2014a were adjusted for the lower sulfur 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.

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

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).

The great majority of equipment is diesel powered, as illustrated in Figure 2.17. The inventory also includes 93 propane powered forklifts and 52 pieces of electric equipment. The electric equipment is not included in the equipment counts in the tables that follow because they do not contribute to emissions at the terminal facilities.

Figure 2.16: Equipment Distribution by Fuel Type

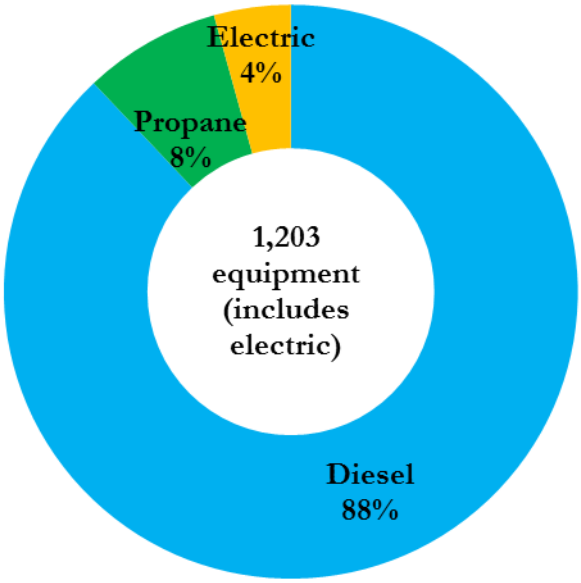


Table 2.13 summarizes the 2014 fleet characteristics of primary and ancillary non-road equipment, respectively, in terms of equipment count, and averages of model year, horsepower, and annual operating hours. As noted above, emissions were estimated using equipment-specific values for each piece of equipment.

Table 2.13: Cargo Handling Equipment Characteristics

Equipment Type	Count	Percent of Population	Average Model Year	Average hp	Average hrs/year
Primary Equipment					
Terminal Tractor	376	32.7%	2006	207	1,337
Straddle Carrier	275	23.9%	2006	231	3,430
Forklift	212	18.4%	2005	97	509
Empty Container Handler	67	5.8%	2008	197	2,036
Rubber Tired Gantry Crane	54	4.7%	2005	522	2,295
Loaded Container Handler	32	2.8%	2004	299	1,518
Stacker	23	2.0%	2004	239	949
Top Loader	17	1.5%	2008	363	1,337
Reach Stacker	14	1.2%	2006	324	1,993
Empty transport hustler	9	0.8%	2009	173	400
RORO Hustler	7	0.6%	2000	215	400
Chassis Flipper	5	0.4%	2002	156	1,000
Subtotal "Primary Equipment"	**1,091**	**94.8%**	**2006**	**213**	**1,784**
Ancillary Equipment					
Truck	17	1.5%	2013	na	1,050
Portable Light Set	12	1.0%	2001	50	500
Aerial Platform	10	0.9%	2005	47	360
Sweeper	9	0.8%	2001	90	300
Diesel Fuel Truck	4	0.3%	2005	243	600
Crane	2	0.2%	1983	925	485
Front End Loader	2	0.2%	1987	125	na
Skid Steer Loader	2	0.2%	2004	38	150
Manlift	2	0.2%	2001	162	na
Subtotal "Ancillary Equipment"	**60**	**5.2%**	**2004**	**89**	**564**
Total Population	**1,151**				

Figures 2.18 and 2.19 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 5% of the total equipment population. This equipment is listed separately from primary equipment in Table 2.13 and presented

visually in Figure 2.18. In addition to the "Ancillary" category, Figure 2.17 presents an additional category – "Other Primary Equipment" – which makes up 6% of all equipment; this category includes stackers and reach stackers, RORO and empty container hustlers, and chassis flippers. "Primary and "Ancillary" equipment is described in greater detail in the following subsections.

Figure 2.17: Population Distribution of Primary CHE, by Number and Percent

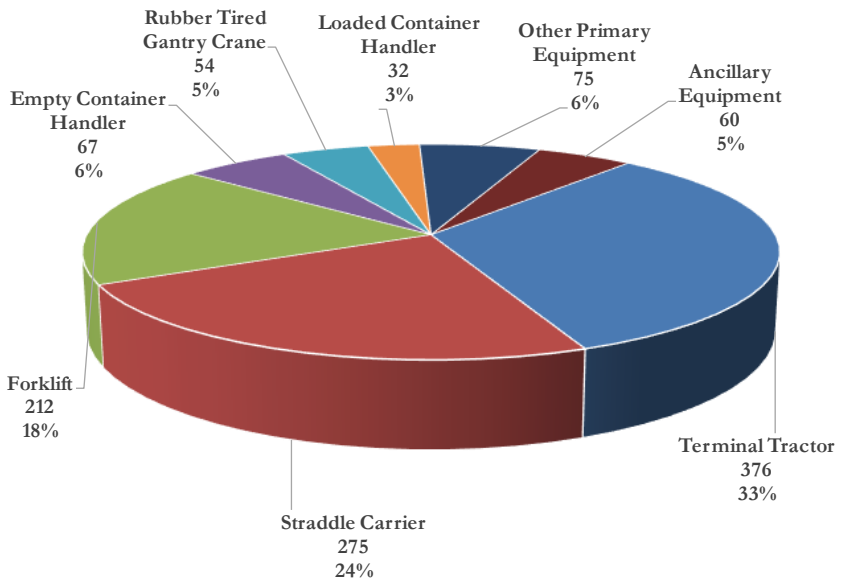
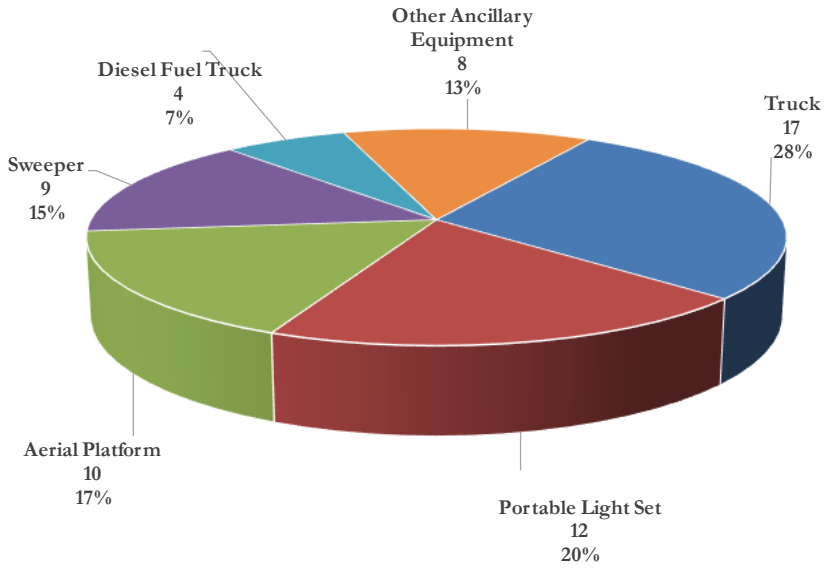


Figure 2.18: Population Distribution of Ancillary Equipment, by Number and Percent



2.4.1 Primary Cargo Handling Equipment

Primary cargo handling equipment is used directly in handling cargo. This equipment includes 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. Tables 2.14 through 2.16 present information on the model years, horsepower, and reported annual hours of operation of the various types of primary cargo handling equipment, listed in order of decreasing population. Figures 2.19 and 2.20 illustrate the model year distributions of terminal tractors and straddle carriers, the two most numerous types of equipment in the inventory.

Table 2.14: Model Year Characteristics of Primary CHE

Equipment Type	Average Model Year	Min Model Year	Max Model Year
Terminal Tractor	2006	2000	2014
Straddle Carrier	2006	1998	2014
Forklift	2005	1987	2013
Empty Container Handler	2008	1996	2014
RTG Crane	2005	2001	2014
Loaded Container Handler	2004	1991	2011
Stacker	2004	1999	2014
Top Loader	2008	2004	2011
Reach Stacker	2006	1999	2010
Empty Transport Hustler	2009	2007	2013
RORO Hustler	2000	1999	2000
Chassis Flipper	2002	1998	2006

Figure 2.19: Model Year Distribution of Terminal Tractors

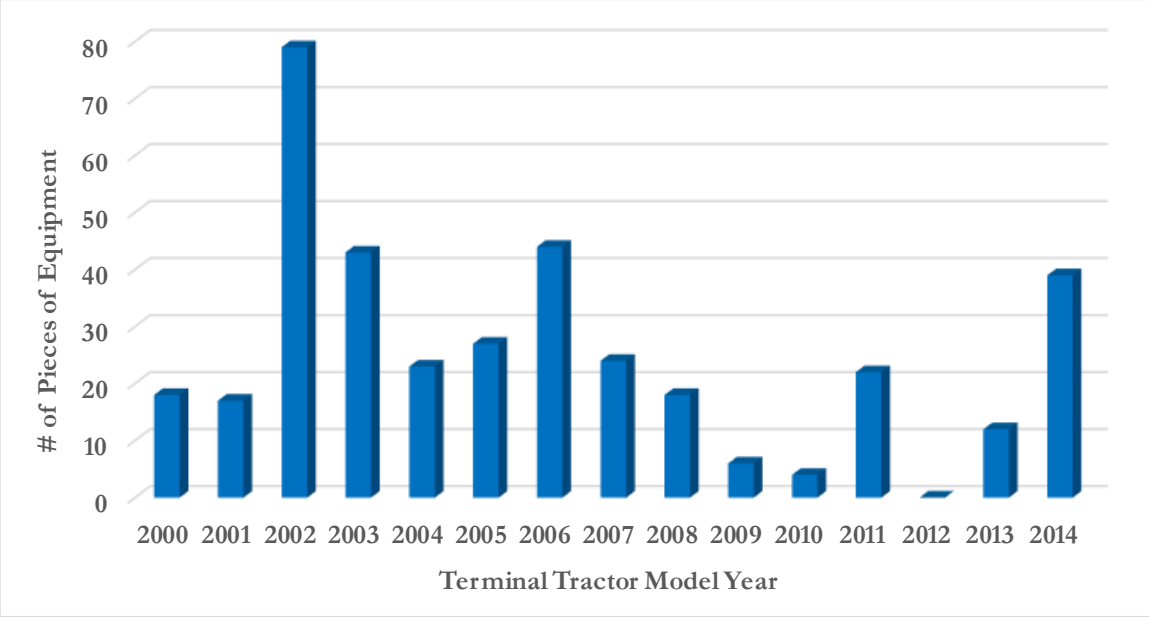


Figure 2.20: Model Year Distribution of Straddle Carriers

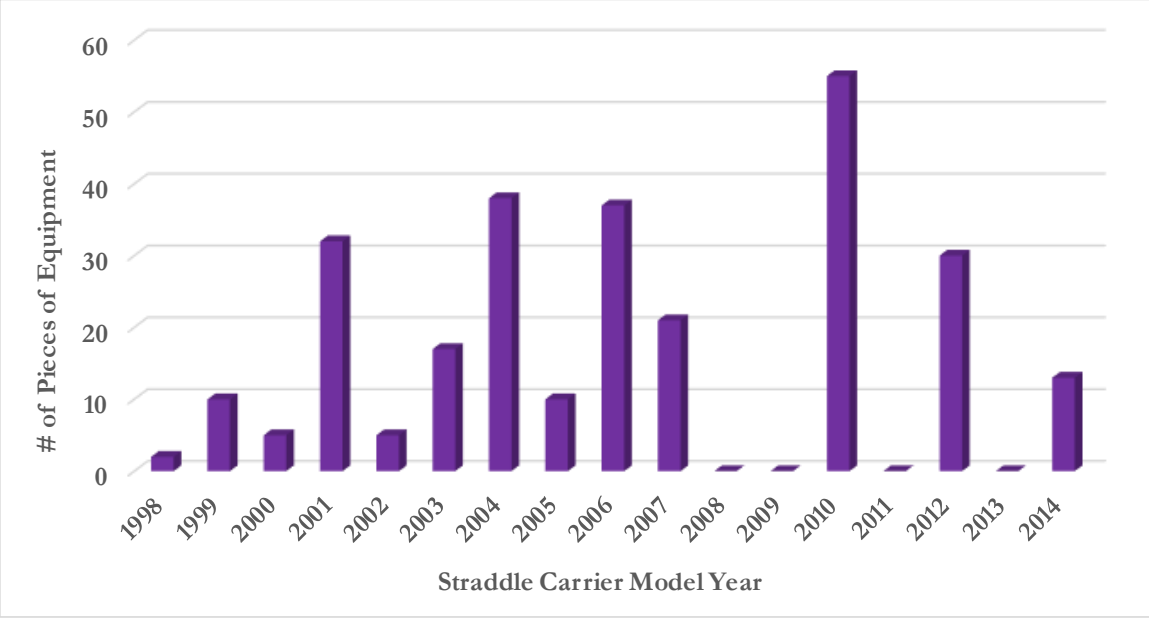


Table 2.15: Horsepower Characteristics of Primary CHE

Equipment Type	Average hp	Min hp	Max hp
Terminal Tractor	207	170	245
Straddle Carrier	231	184	394
Forklift	97	42	300
Empty Container Handler	197	160	240
RTG Crane	522	450	1,000
Loaded Container Handler	299	299	299
Stacker	239	152	350
Top Loader	363	330	365
Reach Stacker	324	225	365
Empty Transport Hustler	173	173	173
RORO Hustler	215	215	215
Chassis Flipper	156	152	160

Table 2.9 presents information on the reported annual operating hours of the various types of primary cargo handling equipment – the average, the lowest, and the highest.

Table 2.16: Reported Operating Hours of Primary CHE

Equipment Type	Average hrs/year	Min hrs/year	Max hrs/year
Terminal Tractor	1,380	0	4,135
Straddle Carrier	3,430	3,264	3,500
Forklift	509	1	2,892
Empty Container Handler	2,036	155	2,692
RTG Crane	2,295	0	4,477
Loaded Container Handler	1,518	0	4,704
Stacker	949	232	1,814
Top Loader	1,337	209	2,729
Reach Stacker	1,993	0	3,600
Empty Transport Hustler	400	400	400
RORO Hustler	400	400	400
Chassis Flipper	1,000	1,000	1,000

2.4.2 Ancillary Equipment

Ancillary equipment, or equipment not directly used to handle cargo, includes non-road trucks, portable light sets, aerial platforms, front end loaders, sweepers, and generators. Tables 2.17 through 2.19 present the distribution of characteristics of this ancillary equipment in terms of model year, horsepower rating, and annual operating hours, respectively, listed in order of decreasing population.

Table 2.17: Model Year Characteristics of Ancillary Equipment

Equipment Type	Average Model Year	Min Model Year	Max Model Year
Truck	2013	2013	2013
Portable Light Set	2001	2001	2001
Aerial Platform	2005	1998	2012
Sweeper	2001	1988	2008
Diesel Fuel Truck	2005	2002	2007
Crane	1983	1981	1984
Front End Loader	1987	1987	1987
Skid-steer Loader	2004	2004	2004
Manlift	2001	1998	2003

Table 2.18: Horsepower Characteristics of Ancillary Equipment

Truck	na	na	na
Portable Light Set	50	50	50
Aerial Platform	47	42	49
Sweeper	90	38	101
Diesel Fuel Truck	243	240	250
Crane	925	900	950
Front End Loader	125	125	125
Skid-steer Loader	38	38	38
Manlift	162	150	174

Table 2.19: Reported Operating Hours of Ancillary Equipment

Equipment Type	Average hrs/year	Min hrs/year	Max hrs/year
Truck	1,050	624	1,432
Portable Light Set	500	500	500
Aerial Platform	360	360	360
Sweeper	300	100	500
Diesel Fuel Truck	600	600	600
Crane	485	49	921
Front End Loader	na	na	na
Skid-steer Loader	150	150	150
Manlift	na	na	na

The following Figures 2.21 through 2.25 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 2.21: Example Yard Tractor

Figure 2.22: Example Straddle Carrier

Figure 2.23: Example Forklift

Figure 2.24: Example Top Loader

Figure 2.25: 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.

After an executive summary, the remainder of this section consists of the following subsections:

- 3.1 - Heavy-Duty Diesel Vehicle Emission Estimates
- 3.2 - Heavy-Duty Diesel Vehicle Emission Comparisons
- 3.3 - Heavy-Duty Diesel Vehicle Emission Calculation Methodology
- 3.4 - Description of Heavy-Duty Diesel Vehicles

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.[13]

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_2e
New York and New Jersey	567,237	342,762	121,476	1,089,351	2,946,572	133,010	230,279,664
NYNJLINA	272,796	79,551	36,399	316,874	1,335,320	37,497	127,000,943
Heavy-Duty Diesel Vehicles	2,383	126	116	158	673	2.7	292,960
Percent of NYNJLINA Emissions	0.87%	0.16%	0.32%	0.05%	0.05%	0.007%	0.23%

Because of changes to EPA's emission estimating models over time, the HDDV emission estimates presented above are not directly comparable to HDDV emission estimates presented in earlier emissions inventories. Comparable emission estimates are presented later in this section.

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.

[13] 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 ES3.1: Distribution and Comparison of NOx from HDDVs, tpy and percent

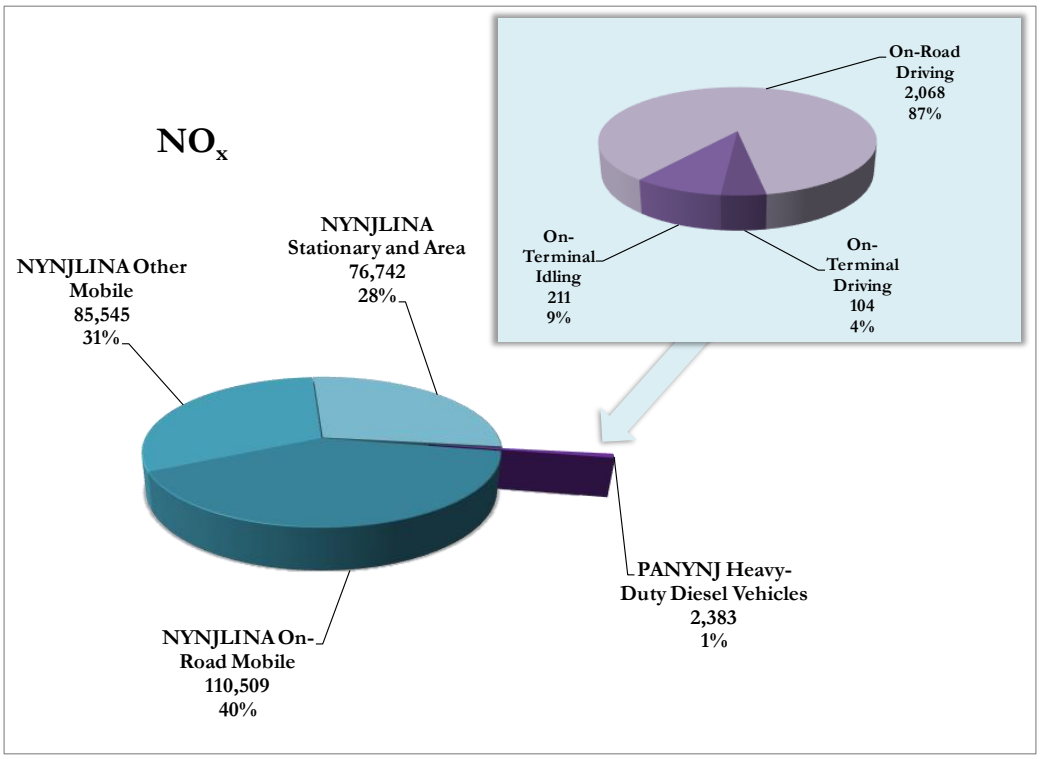


Figure ES3.2: Distribution and Comparison of PM10 from HDDVs, tpy and percent

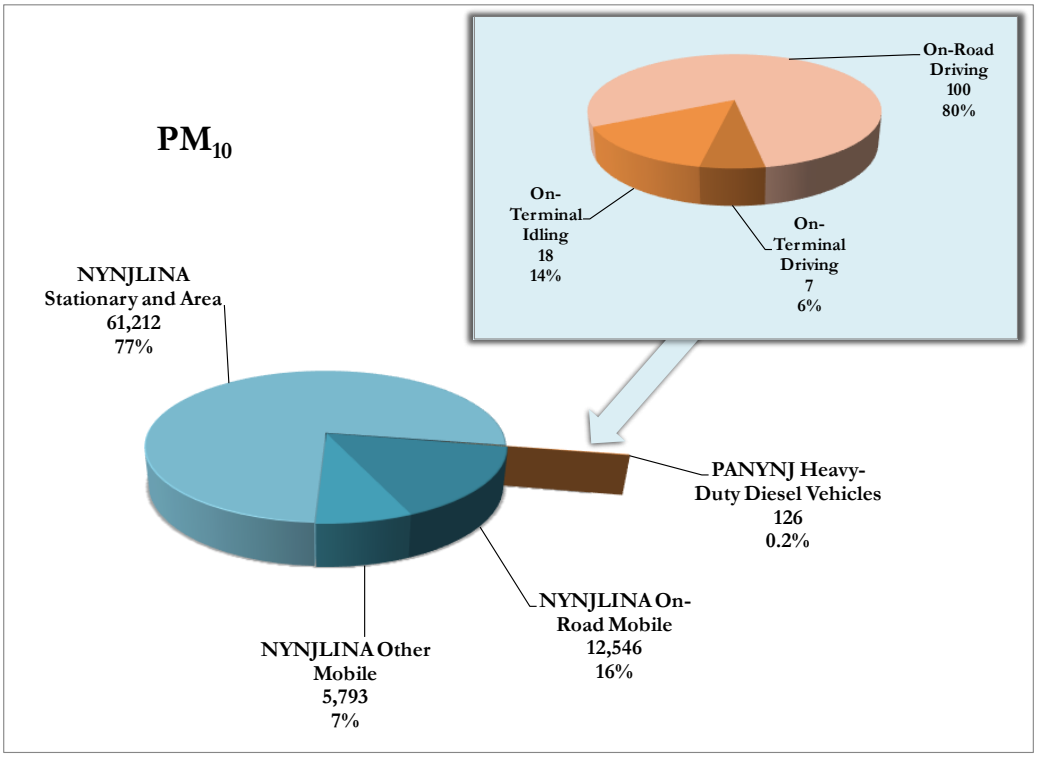


Figure ES3.3: Distribution and Comparison of PM2.5 from HDDVs, tpy and percent

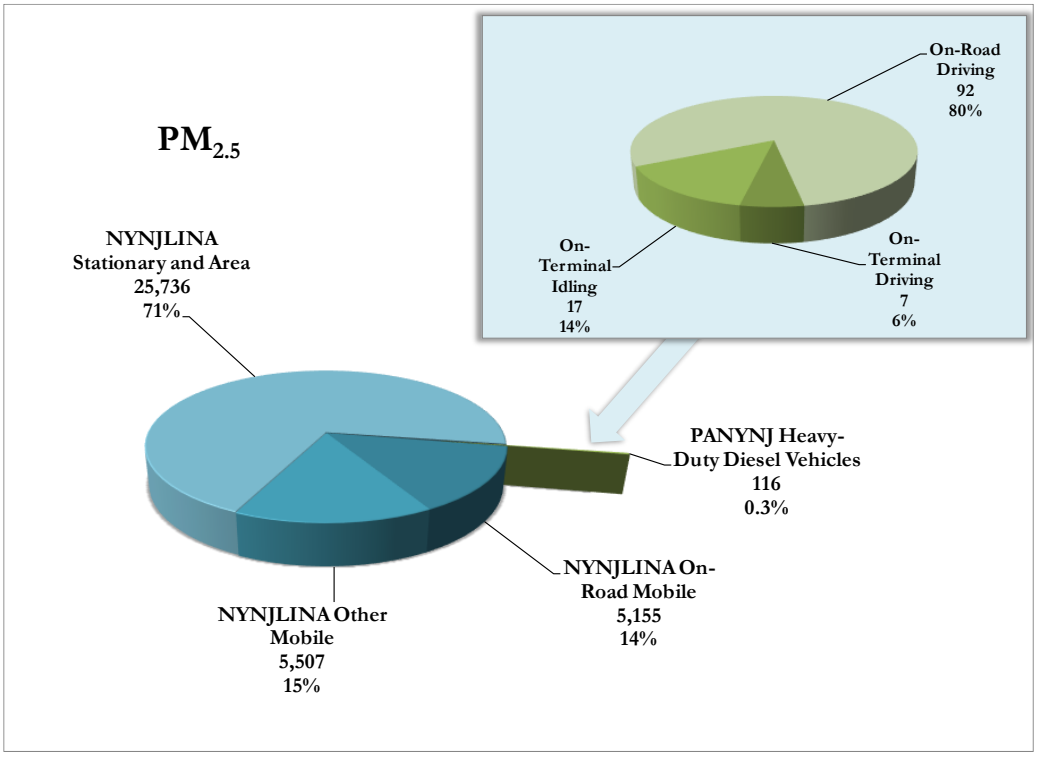


Figure ES3.4: Distribution and Comparison of VOC from HDDVs, tpy and percent

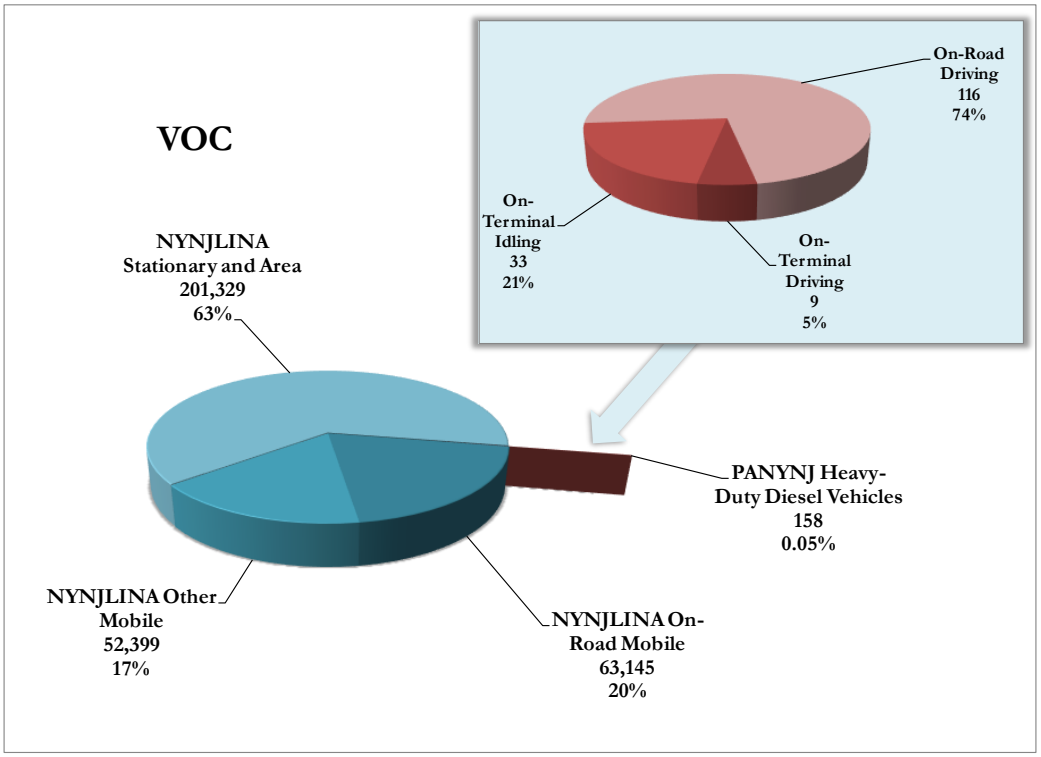


Figure ES3.5: Distribution and Comparison of CO from HDDVs, tpy and percent

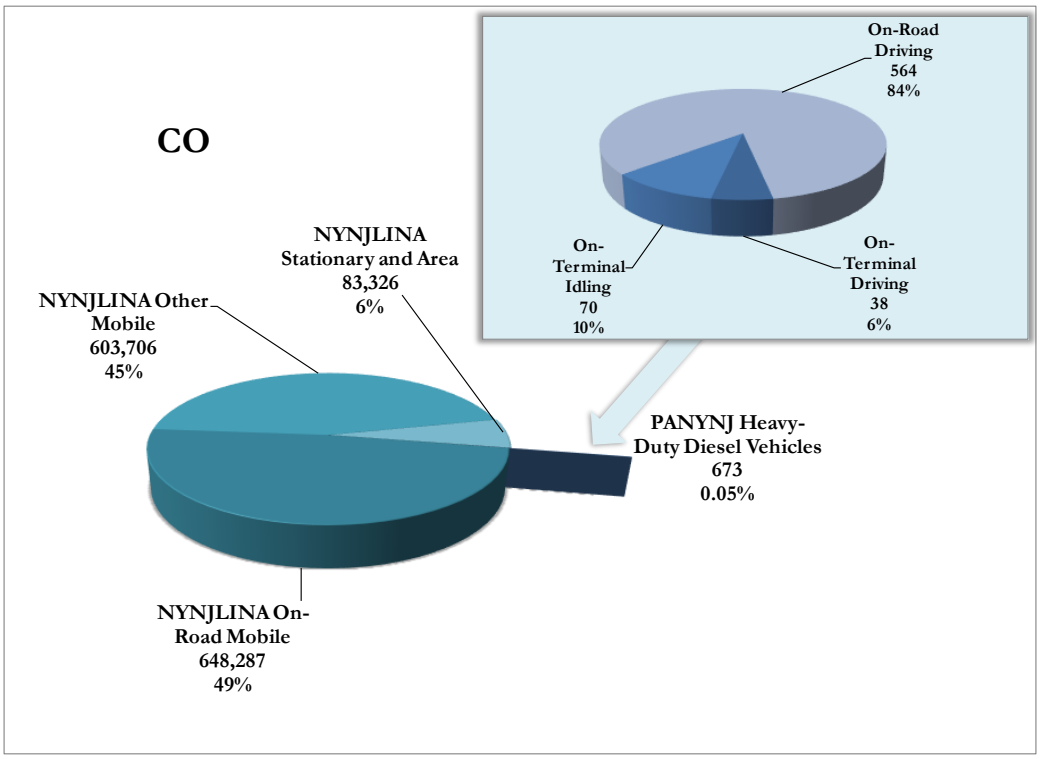


Figure ES3.6: Distribution and Comparison of SO_2 from HDDVs, tpy and percent

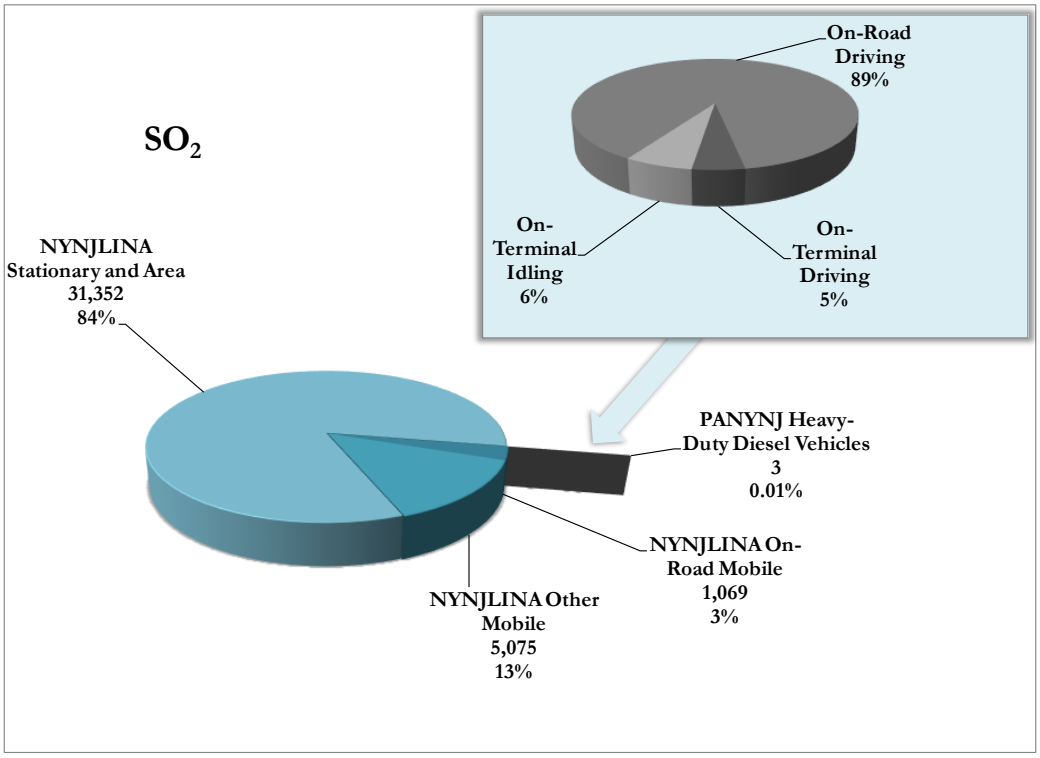
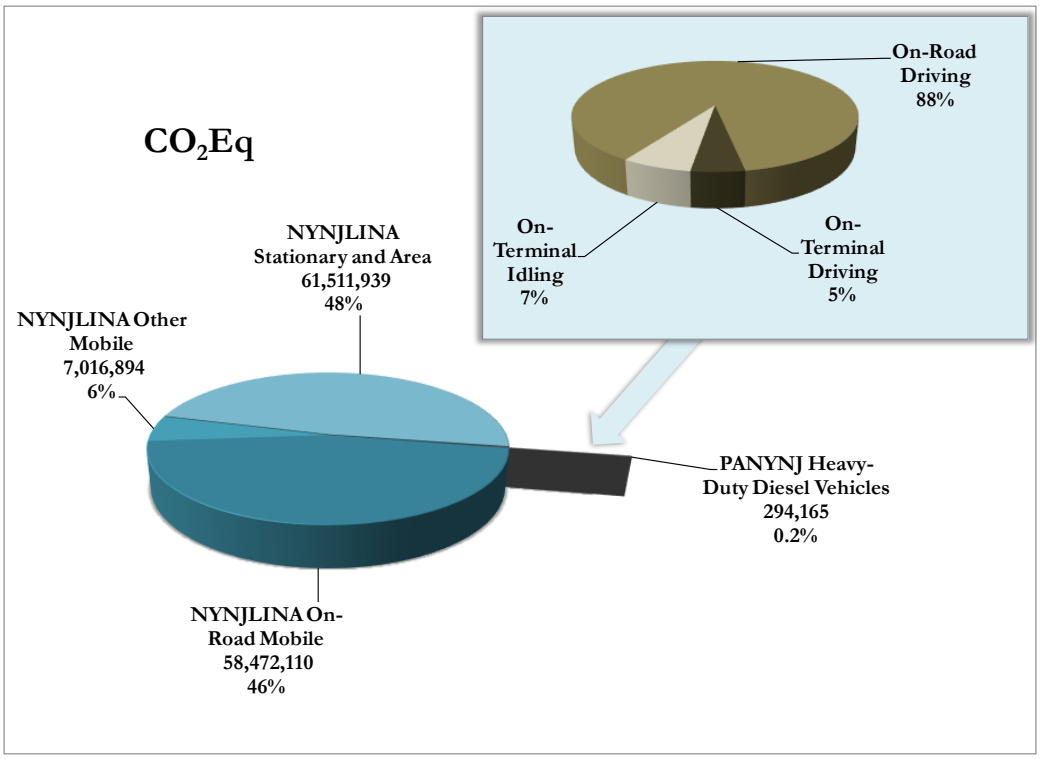


Figure ES3.7: Distribution of CO_2Eq Emissions from HDDVs, tpy and percent



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 HDDV emissions were estimated using the MOVES2014 emission estimating model. As such, the estimates are not comparable with estimates presented in previous emissions inventories before the 2013 inventory, which presents earlier year inventories normalized to the MOVES2014 emissions model. See section 3.2 below for a comparison of estimated 2014 emissions with 2013 and earlier year 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 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 are presented in Table 3.1. Table 3.2 present estimates of on-terminal idling emissions. Summaries of combined driving and idling emissions are presented in Table 3.3. As noted above, the estimates were prepared using the MOVES2014 model and are only comparable with prior-year estimates presented in the 2013 emissions inventory report.

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

Facility Type	VMT	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2e
Auto Terminals	10,531	0.2	0.02	0.01	0.0	0.1	0.000	31
Container Terminals	4,919,696	101.8	7.28	6.70	8.5	37.5	0.13	14,448
Warehouses	102,658	2.1	0.15	0.14	0.2	0.8	0.003	301
Overall Total	**5,032,885**	**104.2**	**7.45**	**6.85**	**8.7**	**38.3**	**0.13**	**14,781**

Table 3.2: Summary of HDDV On-Terminal Idling Emissions (tpy)

Facility Type	Idling Hours	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2e
Auto Terminals	89,030	22.2	0.6	0.5	5.4	8.8	0.01	912
Container Terminals	1,802,313	174	16	15	25	57	0.15	17,178
Warehouses	143,071	13.8	1.3	1.2	2.0	4.5	0.01	1,364
Overall Total	**2,034,414**	**210.5**	**18.2**	**16.7**	**32.9**	**70.0**	**0.17**	**19,454**

Table 3.3: Summary of Total HDDV On-Terminal Emissions (tpy)

Facility Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2e
Auto Terminals	22.4	0.6	0.5	5.4	8.9	0.01	943
Container Terminals	276	24	22	34	94	0.28	31,626
Warehouses	16.0	1.4	1.3	2.2	5.3	0.01	1,665
Overall Total	**314.7**	**25.6**	**23.6**	**41.5**	**108.4**	**0.30**	**34,234**

3.1.2 On-Road Emissions

Table 3.4 presents estimates of on-road, off-terminal emissions in tons per year (tpy) by state for the container terminal truck calls. As noted above, the estimates were prepared using the MOVES2014 model and are only comparable with prior-year estimates presented in the 2013 emissions inventory report. The geographical breakdown of these emissions by county is also presented in Section 3.2.

Table 3.4: Summary of HDDV On-Road Emissions by State (tpy)

State	VMT (thousands)	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2e
New Jersey	106,833	1,699	82.4	75.8	95.3	463.5	1.94	213,511
New York	23,226	369	17.9	16.5	20.7	100.8	0.42	46,419
Total	**130,059**	**2,068**	**100.3**	**92.3**	**116.0**	**564.2**	**2.36**	**259,930**

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 3.5. As noted above, the estimates were prepared using the MOVES2014 model and are only comparable with prior-year estimates presented in the 2013 emissions inventory report.

Table 3.5: Total Marine Terminal Emission Estimates, tpy

Activity Component	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2e
On-Terminal Driving	104	7.5	6.9	9	38	0.13	14,781
On-Terminal Idling	211	18	17	33	70	0.17	19,454
On-Road Driving	2,068	100	92	116	564	2.36	259,930
Totals	**2,383**	**126**	**116**	**158**	**673**	**2.67**	**294,165**

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.[14] 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.

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

This section also presents a comparison of 2014 heavy-duty truck emission estimates, prepared using the MOVES2014 model, with the results of earlier emissions inventories, prepared using MOVES2014 for 2013 and the now-outdated MOVES2010 and MOBILE6.2 models for calendar years 2012 and earlier. The 2012 and earlier emissions have been adjusted to reflect the relative differences in outputs between the models to make them comparable to the MOVES2014 results. As noted in the Introduction to this emissions inventory report, the MOVES2014 model version estimates different emission rates than did the MOVES2010 version[15] and MOBILE6.2. 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 GTC Bayonne during those earlier years, as discussed in the Introduction.

3.2.1 Comparisons with County and Regional Emissions

Table 3.6 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 3.7 through 3.13 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.

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

Table 3.6: Summary of Heavy-Duty Diesel Vehicle Emissions by County (on-terminal and on-road), tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2e
Bergen	NJ	136	6.6	6.1	8	37	0.16	17,136
Essex	NJ	663	34.2	31.5	43	187	0.74	81,840
Hudson	NJ	326	17.1	15.7	22	92	0.36	40,063
Middlesex	NJ	445	21.6	19.9	25	121	0.51	55,965
Monmouth	NJ	29	1.4	1.3	2	8	0.03	3,679
Union	NJ	400	25.8	23.8	35	122	0.43	47,639
New Jersey subtotal		**2,000**	**107**	**98**	**135**	**567**	**2.23**	**246,322**
Bronx	NY	39	1.9	1.8	2	11	0.04	4,937
Kings	NY	101	5.0	4.6	6	28	0.11	12,607
Nassau	NY	68	3.3	3.0	4	19	0.08	8,576
New York	NY	18	0.9	0.8	1	5	0.02	2,239
Orange	NY	41	2.0	1.8	2	11	0.05	5,188
Queens	NY	32	1.6	1.4	2	9	0.04	4,078
Richmond	NY	17	1.3	1.2	2	5	0.02	1,857
Rockland	NY	5	0.3	0.2	0	1	0.01	656
Suffolk	NY	23	1.1	1.0	1	6	0.03	2,941
Westchester	NY	38	1.8	1.7	2	10	0.04	4,762
New York subtotal		**383**	**19.2**	**17.7**	**23**	**105**	**0.43**	**47,842**
TOTAL		**2,383**	**126**	**116**	**158**	**673**	**2.67**	**294,165**

Table 3.7: 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	15,763	136	0.87%
Essex	NJ	14,172	663	4.68%
Hudson	NJ	10,059	326	3.24%
Middlesex	NJ	15,574	445	2.86%
Monmouth	NJ	10,795	29	0.27%
Union	NJ	13,636	400	2.93%
New Jersey Subtotal		**79,999**	**2,000**	**2.50%**
Bronx	NY	9,912	39	0.40%
Kings (Brooklyn)	NY	19,011	101	0.53%
Nassau	NY	23,967	68	0.28%
New York	NY	33,400	18	0.05%
Orange	NY	8,857	41	0.47%
Queens	NY	29,220	32	0.11%
Richmond (Staten Island)	NY	7,531	17	0.23%
Rockland	NY	5,494	5	0.10%
Suffolk	NY	39,142	23	0.06%
Westchester	NY	16,263	38	0.23%
New York Subtotal		**192,797**	**383**	**0.2%**
TOTAL		**272,796**	**2,383**	**0.87%**

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

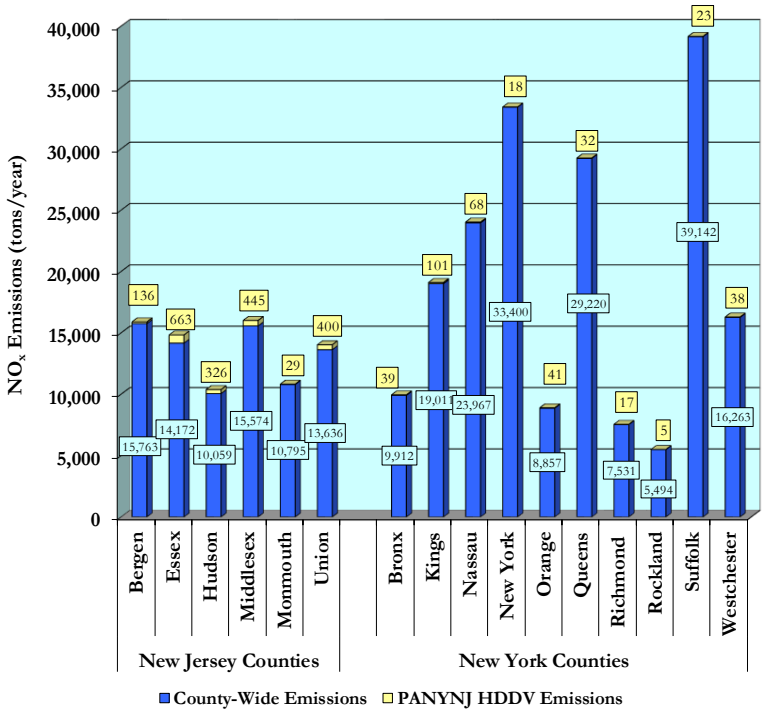


Table 3.8: Comparison of Heavy-Duty Diesel Vehicle PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	3,896	6.6	0.17%
Essex	NJ	2,631	34.2	1.30%
Hudson	NJ	1,641	17.1	1.04%
Middlesex	NJ	4,486	21.6	0.48%
Monmouth	NJ	3,406	1.4	0.042%
Union	NJ	2,761	25.8	0.9%
New Jersey Subtotal		**18,821**	**107**	**0.57%**
Bronx	NY	2,713	1.9	0.07%
Kings (Brooklyn)	NY	4,984	5.0	0.10%
Nassau	NY	6,975	3.3	0.047%
New York	NY	7,049	0.9	0.012%
Orange	NY	7,645	2.0	0.026%
Queens	NY	5,881	1.6	0.027%
Richmond (Staten Island)	NY	1,972	1.3	0.07%
Rockland	NY	2,149	0.3	0.012%
Suffolk	NY	14,340	1.1	0.008%
Westchester	NY	7,023	1.8	0.026%
New York Subtotal		**60,730**	**19**	**0.03%**
TOTAL		**79,551**	**126**	**0.16%**

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

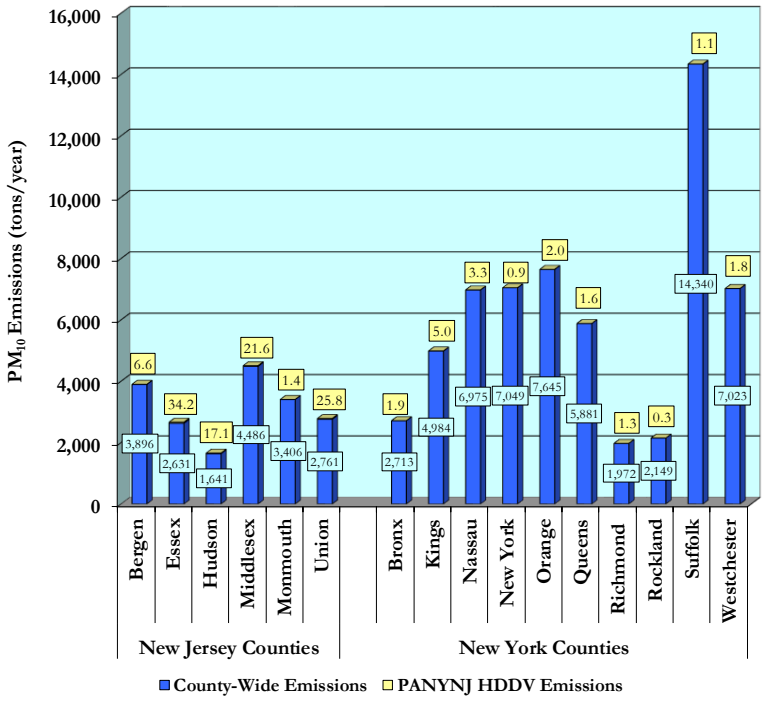


Table 3.9: Comparison of Heavy-Duty Diesel Vehicle $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	2,097	6.1	0.29%
Essex	NJ	1,627	31.5	1.93%
Hudson	NJ	1,105	15.7	1.42%
Middlesex	NJ	2,309	19.9	0.86%
Monmouth	NJ	1,635	1.3	0.08%
Union	NJ	1,704	23.8	1.39%
New Jersey Subtotal		**10,477**	**98**	**0.9%**
Bronx	NY	1,407	1.8	0.12%
Kings (Brooklyn)	NY	2,600	4.6	0.18%
Nassau	NY	2,984	3.0	0.10%
New York	NY	3,295	0.8	0.024%
Orange	NY	2,395	1.8	0.08%
Queens	NY	3,167	1.4	0.05%
Richmond (Staten Island)	NY	1,000	1.2	0.12%
Rockland	NY	827	0.2	0.028%
Suffolk	NY	5,705	1.0	0.02%
Westchester	NY	2,540	1.7	0.07%
New York Subtotal		**25,922**	**18**	**0.07%**
TOTAL		**36,399**	**116**	**0.32%**

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

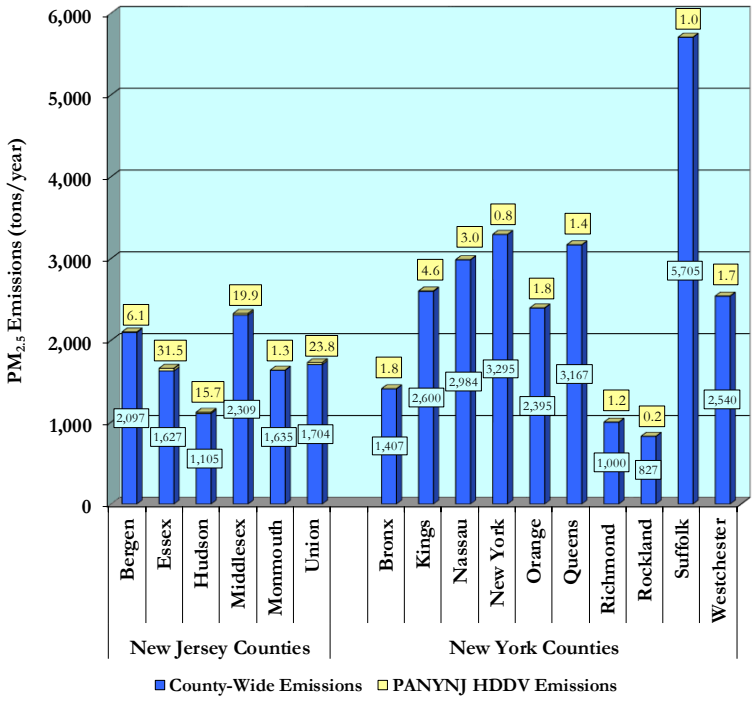


Table 3.10: Comparison of Heavy-Duty Diesel Vehicle VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	18,980	7.6	0.04%
Essex	NJ	14,151	43.3	0.31%
Hudson	NJ	9,429	21.8	0.23%
Middlesex	NJ	19,479	25.0	0.13%
Monmouth	NJ	19,080	1.6	0.009%
Union	NJ	12,608	35.5	0.28%
New Jersey Subtotal		**93,727**	**135**	**0.14%**
Bronx	NY	13,272	2.2	0.017%
Kings (Brooklyn)	NY	24,871	5.9	0.024%
Nassau	NY	27,629	3.8	0.014%
New York	NY	20,469	1.0	0.005%
Orange	NY	19,383	2.3	0.012%
Queens	NY	27,772	1.8	0.007%
Richmond (Staten Island)	NY	7,600	1.9	0.025%
Rockland	NY	8,861	0.3	0.003%
Suffolk	NY	49,647	1.3	0.003%
Westchester	NY	23,643	2.1	0.009%
New York Subtotal		**223,147**	**23**	**0.010%**
TOTAL		**316,874**	**158**	**0.05%**

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

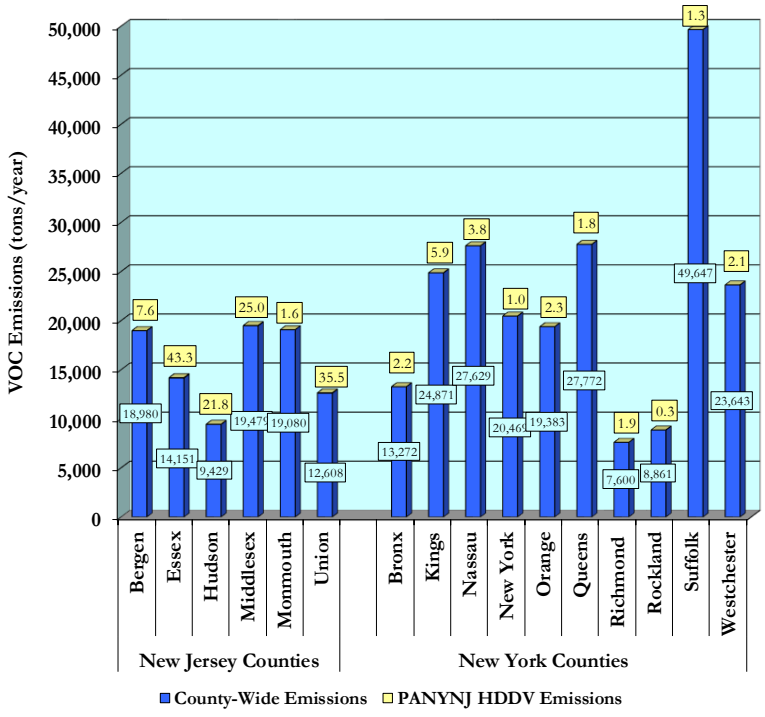


Table 3.11: Comparison of Heavy-Duty Diesel Vehicle CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	111,914	37.2	0.033%
Essex	NJ	64,014	186.8	0.292%
Hudson	NJ	36,789	92.1	0.250%
Middlesex	NJ	87,469	121.5	0.139%
Monmouth	NJ	71,524	8.0	0.011%
Union	NJ	53,352	121.7	0.228%
New Jersey Subtotal		**425,060**	**567**	**0.13%**
Bronx	NY	36,134	10.7	0.030%
Kings (Brooklyn)	NY	78,793	27.7	0.035%
Nassau	NY	143,985	18.6	0.013%
New York	NY	109,627	4.9	0.004%
Orange	NY	45,498	11.3	0.025%
Queens	NY	111,129	8.9	0.008%
Richmond (Staten Island)	NY	32,985	5.2	0.016%
Rockland	NY	33,695	1.4	0.004%
Suffolk	NY	212,558	6.4	0.003%
Westchester	NY	105,856	10.3	0.010%
New York Subtotal		**910,259**	**105**	**0.012%**
TOTAL		**1,335,320**	**673**	**0.05%**

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

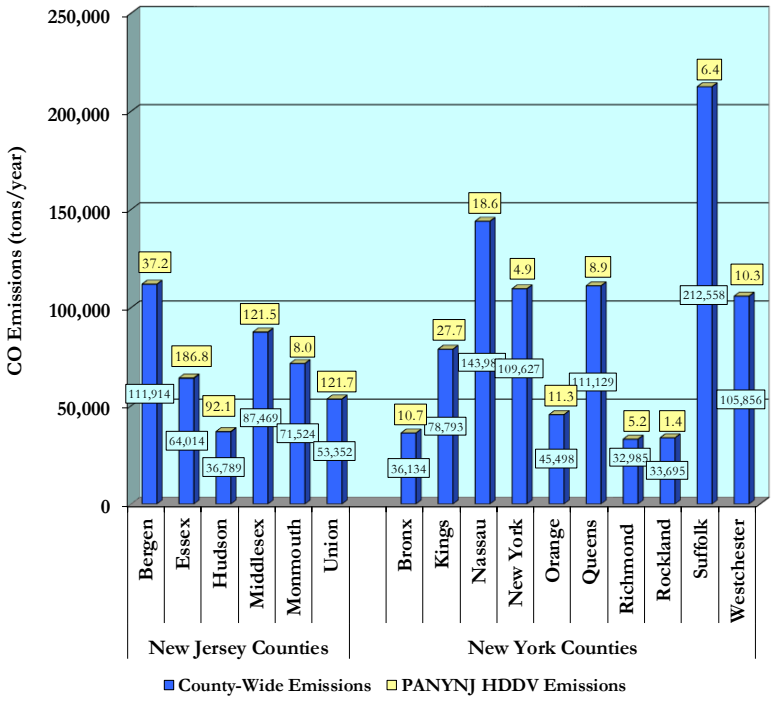


Table 3.12: Comparison of Heavy-Duty Diesel Vehicle SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	685	0.2	0.023%
Essex	NJ	1,226	0.7	0.061%
Hudson	NJ	1,840	0.4	0.020%
Middlesex	NJ	785	0.5	0.065%
Monmouth	NJ	687	0.0	0.005%
Union	NJ	1,583	0.4	0.027%
New Jersey Subtotal		**6,806**	**2.2**	**0.033%**
Bronx	NY	1,547	0.0	0.003%
Kings (Brooklyn)	NY	1,525	0.1	0.008%
Nassau	NY	2,563	0.1	0.003%
New York	NY	5,574	0.0	0.000%
Orange	NY	6,251	0.0	0.001%
Queens	NY	2,513	0.0	0.001%
Richmond (Staten Islar	NY	409	0.0	0.004%
Rockland	NY	297	0.0	0.002%
Suffolk	NY	7,875	0.0	0.000%
Westchester	NY	2,137	0.0	0.002%
New York Subtotal		**30,691**	**0.4**	**0.001%**
TOTAL		**37,497**	**2.7**	**0.007%**

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

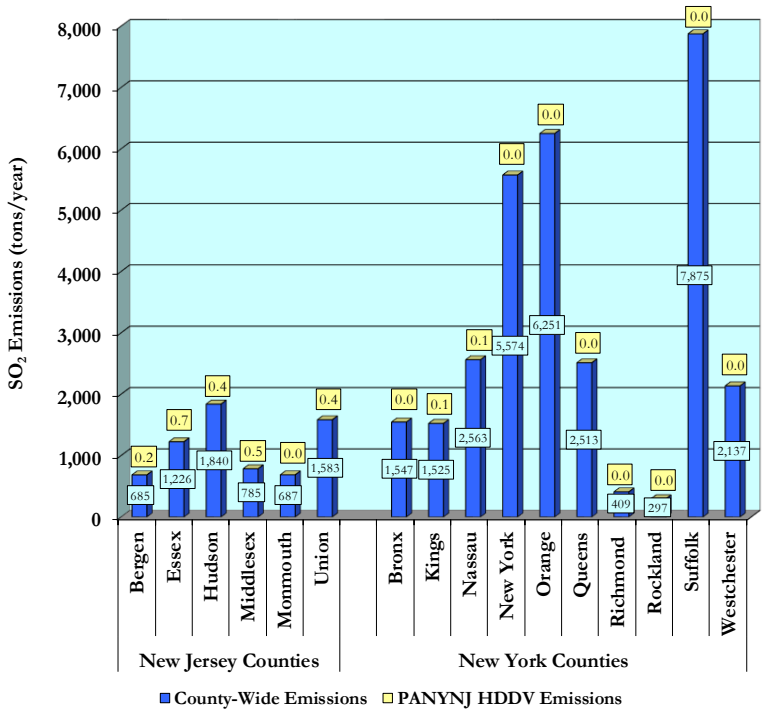
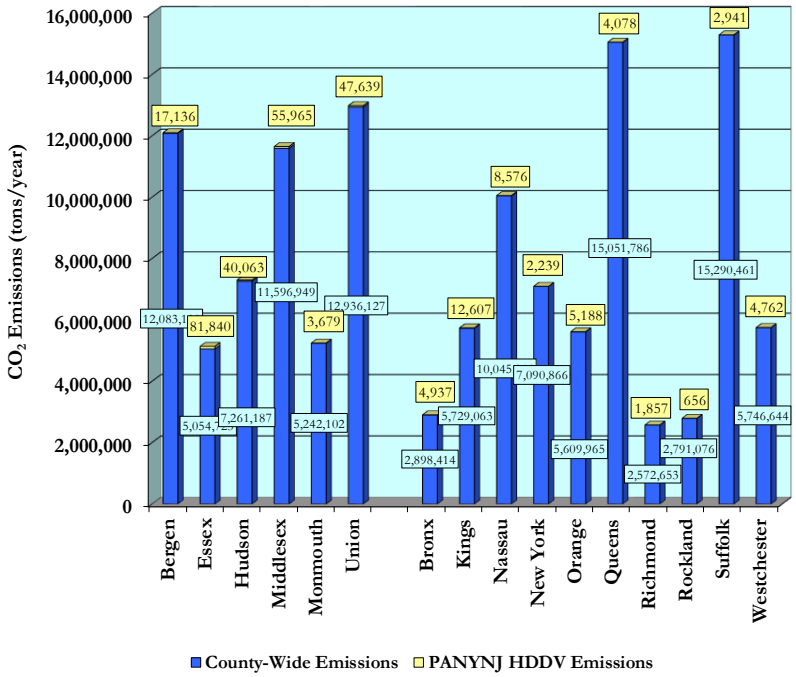


Table 3.13: Comparison of Heavy-Duty Diesel Vehicle CO_2e Emissions with Overall CO_2e Emissions by County, tpy

County	State	County-Wide Emissions	HDDV Emissions in Inventory	Percent of Total
Bergen	NJ	12,083,110	17,136	0.1%
Essex	NJ	5,054,723	81,840	1.6%
Hudson	NJ	7,261,187	40,063	0.6%
Middlesex	NJ	11,596,949	55,965	0.5%
Monmouth	NJ	5,242,102	3,679	0.1%
Union	NJ	12,936,127	47,639	0.4%
New Jersey Subtotal		**54,174,197**	**246,322**	**0.45%**
Bronx	NY	2,898,414	4,937	0.2%
Kings (Brooklyn)	NY	5,729,063	12,607	0.2%
Nassau	NY	10,045,818	8,576	0.1%
New York	NY	7,090,866	2,239	0.0%
Orange	NY	5,609,965	5,188	0.1%
Queens	NY	15,051,786	4,078	0.0%
Richmond (Staten Island)	NY	2,572,653	1,857	0.1%
Rockland	NY	2,791,076	656	0.0%
Suffolk	NY	15,290,461	2,941	0.0%
Westchester	NY	5,746,644	4,762	0.1%
New York Subtotal		**72,826,745**	**47,842**	**0.07%**
TOTAL		**127,000,943**	**294,164**	**0.23%**

Figure 3.7: Comparison of Heavy-Duty Diesel Vehicle CO_2e Emissions with Overall CO_2e 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 used for the 2013 and this 2014 emissions inventory. 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 differences 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 GTC Bayonne in the prior year estimates. The GTC Bayonne 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 through 2014 emissions inventories. HDDV emissions associated with GTC Bayonne 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 3.14. 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 through 2014 than in earlier years, discussed later in this section, shows up in the decreases of NO_x and PM compared with 2010 and earlier inventories. Continued renewal of the drayage truck fleet as a result of the Port Authority's truck program is expected to continue the decreases for at least a few years, 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 MOVES2014 model as were the 2013 and 2014 inventories, will provide a clearer picture of changes in emissions as a result of the changing drayage truck fleet. If the MOVES2014 model is amended in the future such that differing emission estimates are produced, further adjustments will be required at that time.

Table 3.14 presents the current 2014 emission estimates and the prior year estimates that have been adjusted for comparability with the 2014 estimates. The table also shows the percentage difference between each prior inventory's adjusted emissions and the 2014 estimates, emissions in tons per million TEUs, and the percentage differences in tons per million TEUs between the prior years and 2014.

Table 3.14: Comparison of 2014 HDDV Emissions with Prior Year Estimates, tons per year and percent

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e	Million TEUs
Tons per year, with adjustments								
2014	2,383	126	116	158	673	2.7	294,165	5.772
2013	2,521	155	147	177	746	2.7	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 2014 - tons per year								
2013 - 2014	-5%	-19%	-21%	-11%	-10%	-2%	0%	6%
2012 - 2014	-2%	-16%	-18%	-8%	-7%	3%	4%	4%
2010 - 2014	-8%	-34%	-33%	14%	6%	11%	3%	9%
2008 - 2014	-21%	-51%	-50%	0%	-20%	16%	6%	10%
2006 - 2014	-2%	-50%	-49%	24%	-12%	-91%	10%	13%
Tons per million TEU (adjusted)								
2014	413	22	20	27	117	0.46	50,964	
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 2014 - tons per million TEU								
2013 - 2014	-10%	-21%	-26%	-16%	-14%	-8%	-5%	
2012 - 2014	-7%	-19%	-23%	-13%	-11%	-2%	-1%	
2010 - 2014	-16%	-39%	-39%	4%	-3%	2%	-6%	
2008 - 2014	-27%	-55%	-55%	-10%	-26%	5%	-4%	
2006 - 2014	-13%	-56%	-56%	8%	-23%	-92%	-3%	

The following figures graphically illustrate the changes in emissions, in tons per year, between the 2006 baseline emissions inventory and the 2014 update. The 2006 emissions are shown in each figure as a dashed line horizontal with the x axis, and the overall percent change between 2006 and 2014 is shown to the right of each chart, with an arrow indicating the direction of change in emissions. The units on the y-axis are tons per year. Inventories were developed for even numbered years between 2006 and 2012, so for the intervening odd-numbered years the charts have been prepared by interpolating between even numbered years. The inventories became annual starting with the 2012 update.

Figure 3.8: NO_x Emissions Trend for HDDV

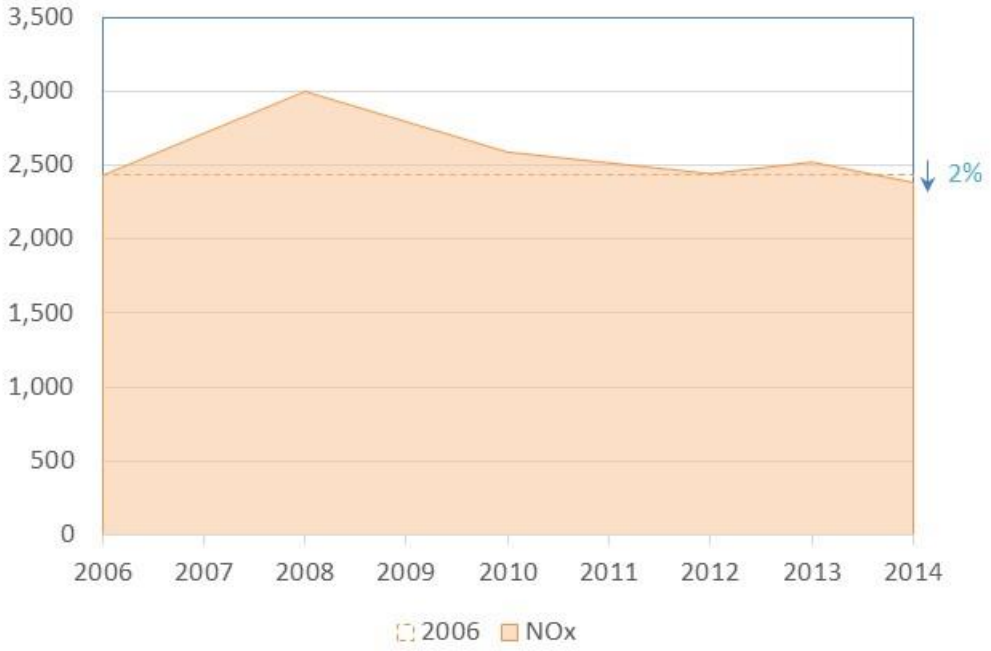


Figure 3.9: PM_{10} Emissions Trend for HDDV

Figure 3.10: $PM_{2.5}$ Emissions Trend for HDDV

Figure 3.11: VOC Emissions Trend for HDDV

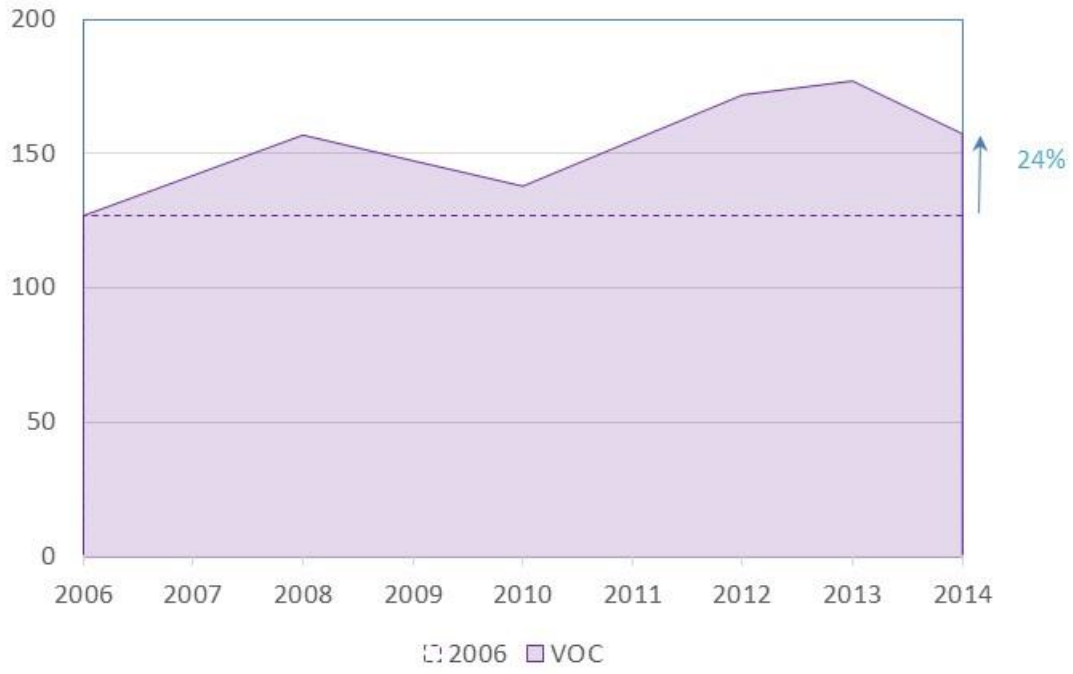


Figure 3.12: CO Emissions Trend for HDDV

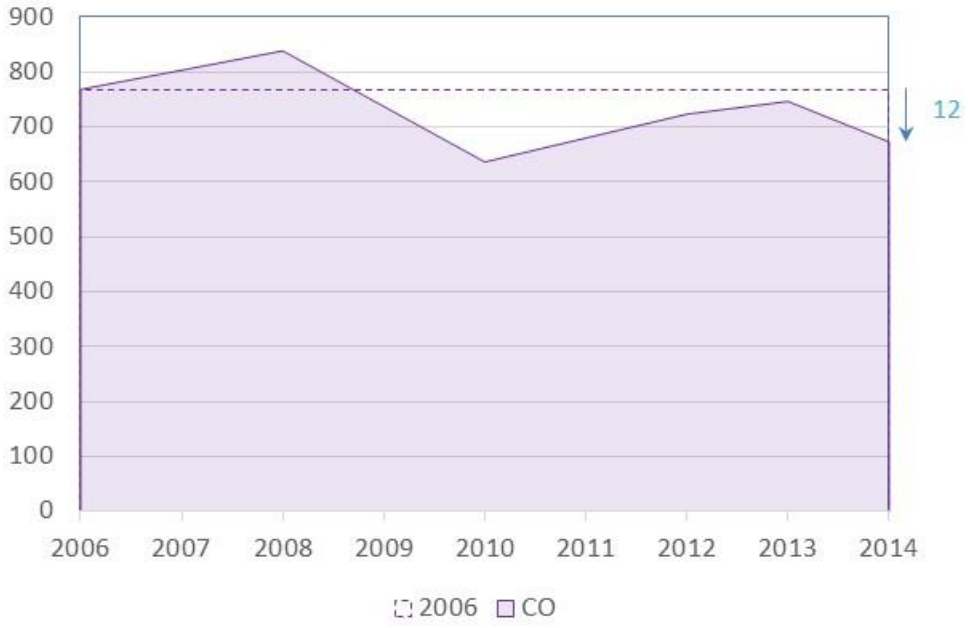


Figure 3.13: SO_2 Emissions Trend for HDDV

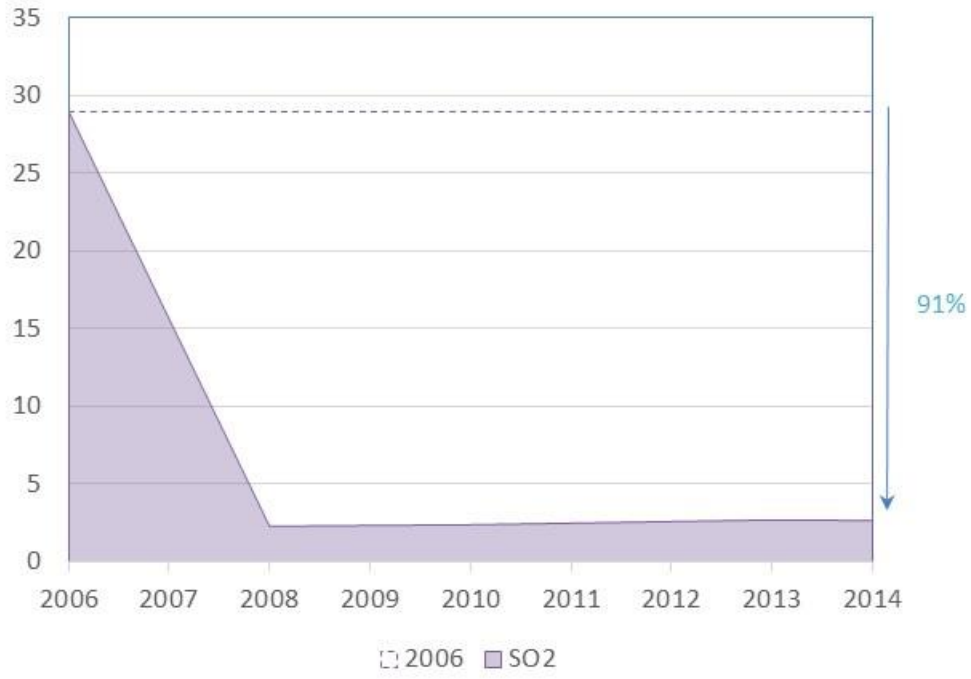
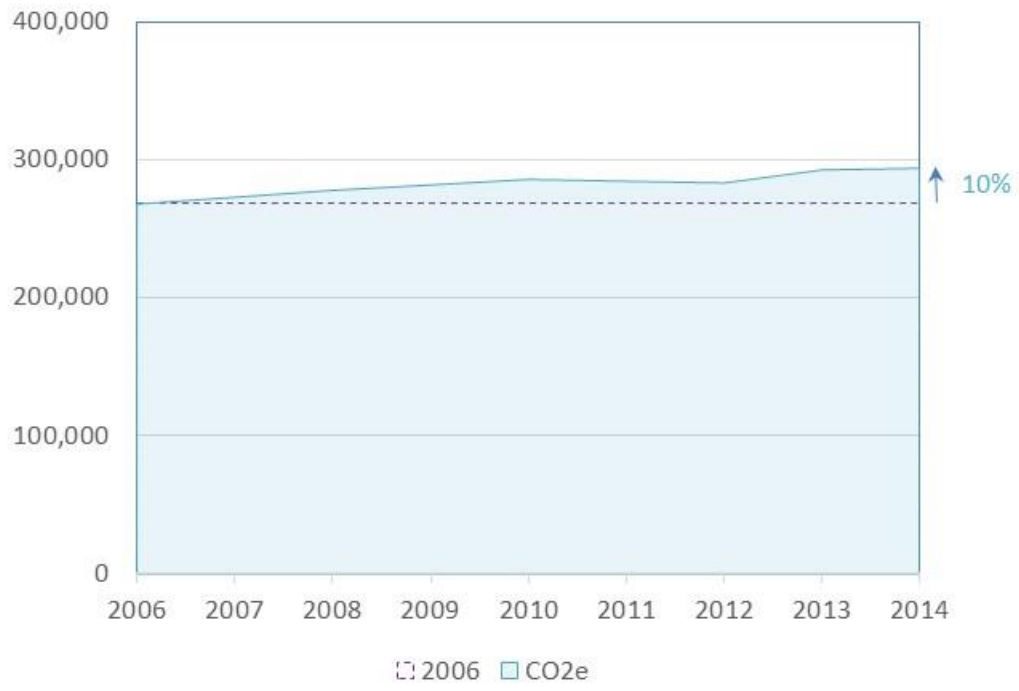


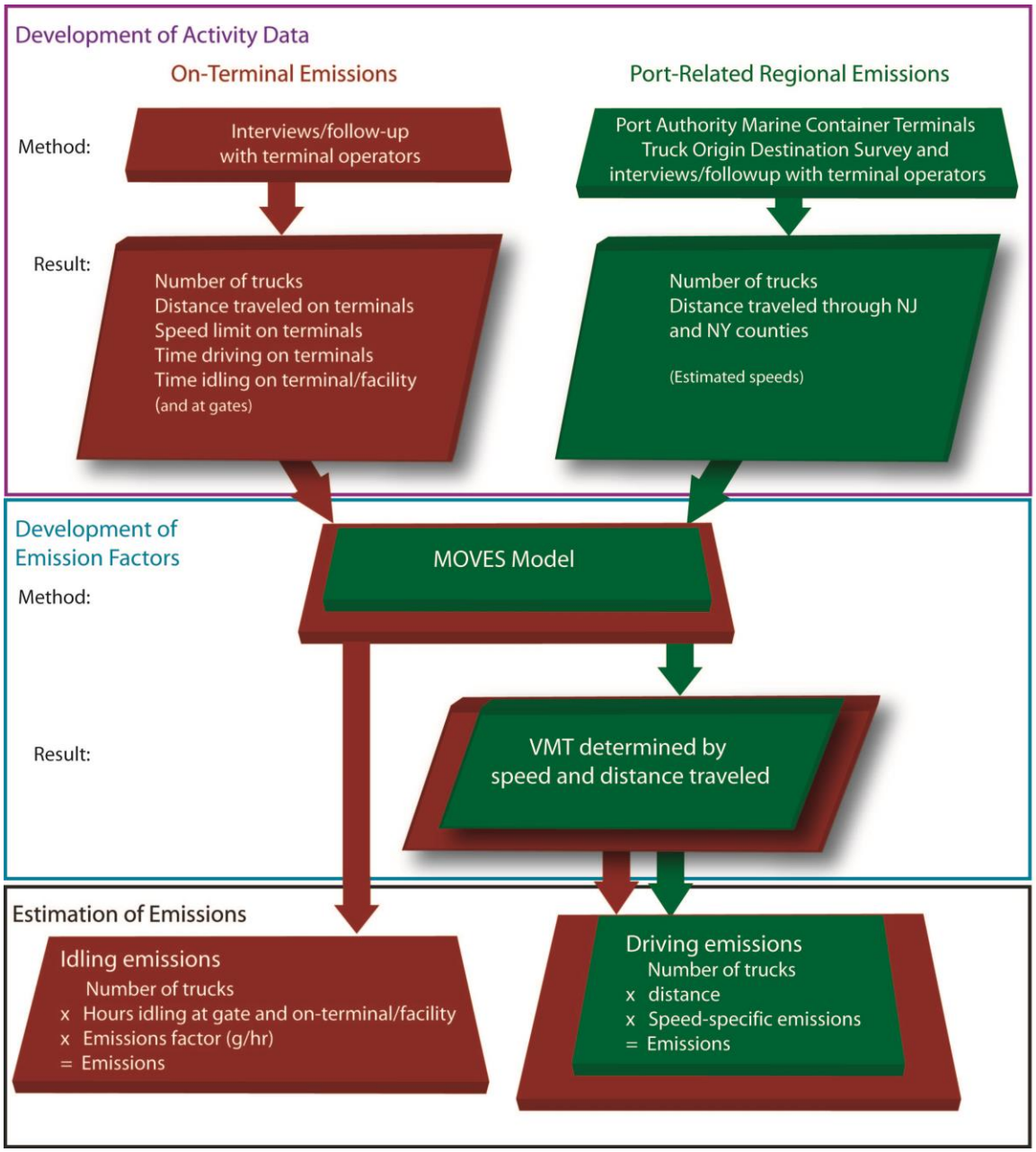
Figure 3.14: CO_2e Emissions Trend for HDDV



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 3.15 illustrates this process in a flow diagram for on-terminal and off-terminal activity.

Figure 3.15: 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 3.15 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 3.15: Summary of Reported On-Terminal Operating Characteristics

Maritime Operation	Annual Trips	Vehicle Miles Traveled	Average Speed (mph)	Average Idling Time (hours)
Auto-Handling Facilities	59,236	10,531	5	1.5
Container Terminals	3,995,668	4,919,696	15	0.5
Warehouses	211,240	102,658	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[16] was used for the 2014 emissions inventory update to estimate travel distance characteristics in developing the on-road emission estimates. Since annual gate counts and on-terminal activity information were collected for each of the six container terminals, 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.

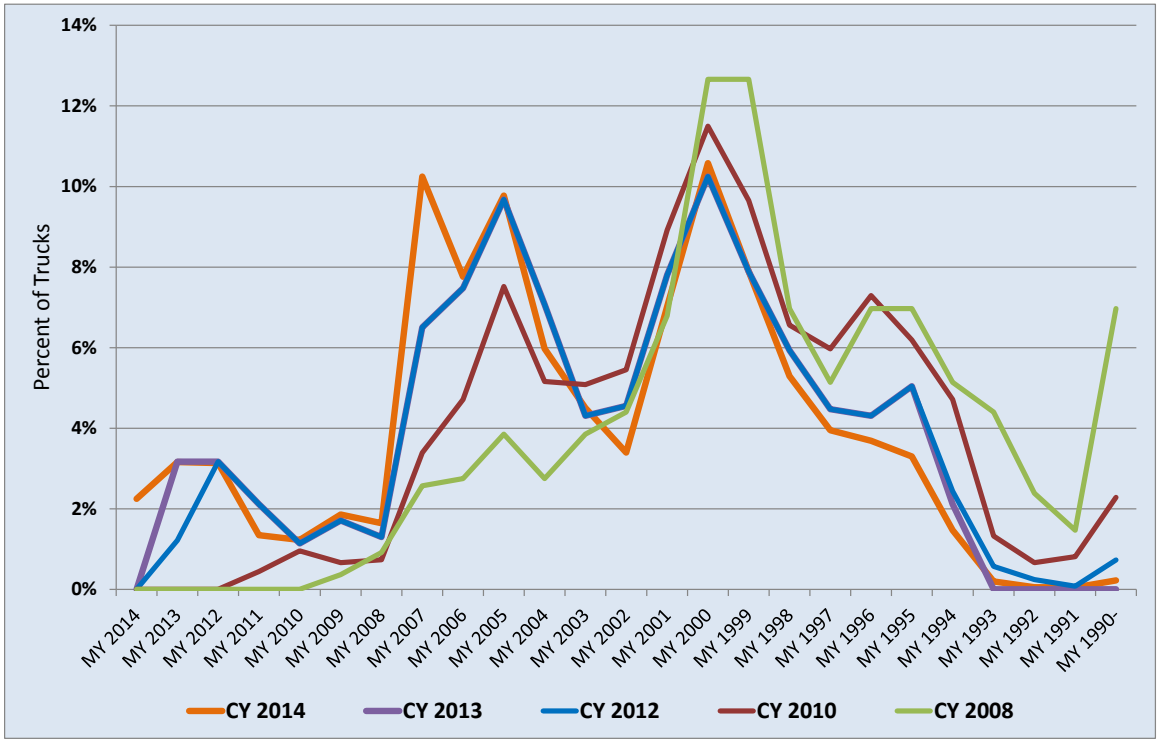
[16] Port Authority Marine Container Terminals – Truck Origin-Destination Survey 2005. Vollmer, November 2005 draft report, revised 2/27/2006

Model Year Distribution

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. A model year distribution characterizes the percentage that each model year makes up of the total number of terminal visits during the inventory year. The distribution is used to develop emission factors that appropriately reflect the specific mixture of model years in the trucks that called at the terminals.

The container terminals at the Port Authority marine terminals are in the process of implementing 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 valuable source of information about the distribution of truck model years in Port goods movement service that has been used to replace the periodic surveys that were conducted in 2008, 2010, and 2012. 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. The RFID system was not fully operational throughout 2014 but 2.15 million truck visits were recorded during the year, a sufficient number to allow development of a model year distribution representing 2014. Figure 3.16 illustrates the model year distributions developed for the trucks serving the Port Authority terminals for the emissions inventories for calendar years 2014, 2013, 2012, 2010, and 2008. This figure shows the gradual turnover to newer trucks and the elimination of older trucks from among the vehicles calling at the terminals.

Figure 3.16: Model Year Distribution



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):

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

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

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

The MOVES2014-derived driving and idling emission factors for Class 8 HDDVs used in the emission estimates are presented in Table 3.16.

Table 3.16: 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)	87.818	8.226	7.568	12.825	28.536	0.076	8,640	0.000	0.270
Extended Idle (g/hr)	226.355	5.690	5.235	54.597	90.116	0.081	9,099	0.000	7.664
On-Terminal (g/mi) (15 mph avg. speed)	18.780	1.343	1.236	1.566	6.907	0.024	2,663	0.000	0.042
On-Road (g/mi) MOVES highway/local	14.427	0.700	0.644	0.809	3.936	0.016	1,812	0.002	0.020

The extended idling emission rates shown in Table 3.16 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 3.17 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 3.17: 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	30,711	0.25	1.45	7,678	44,531	Yes
Automobile	15,525	0.10	1.56	1,553	24,219	Yes
Automobile	13,000	0.10	1.56	1,300	20,280	Yes
Container	1,463,505	1.50	0.47	2,195,258	680,530	No
Container	845,859	1.00	0.54	845,859	452,534	No
Container	723,704	1.60	0.39	1,157,927	282,245	No
Container	668,221	1.00	0.38	668,221	253,924	No
Container	236,897	0.10	0.46	23,690	107,788	No
Container	57,482	0.50	0.44	28,741	25,292	No
Warehouse	80,000	0.25	2.31	20,000	64,800	No
Warehouse	52,000	0.05	1.75	2,600	31,720	No
Warehouse	40,000	1.50	2.52	60,000	35,200	No
Warehouse	22,500	0.20	0.99	4,500	7,875	No
Warehouse	7,800	1.50	0.23	11,700	624	No
Warehouse	3,120	0.25	0.48	780	530	No
Warehouse	3,120	0.90	1.30	2,808	1,404	No
Warehouse	2,700	0.10	0.98	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:

Table 3.18: 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. Global Container Terminal New York at Howland Hook Marine Terminal 5. Red Hook Container Terminal, LLC secondary barge depot at Port Newark 6. Global Terminal Bayonne 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 3.17 is an illustration of a container truck transporting a container in a container terminal, while Figure 3.18 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 3.17: HDDV with Container

Figure 3.18: 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.

Following an executive summary. the remainder of this section consists of the following subsections:

- 4.1 - Locomotive Emission Estimates
- 4.2 - Locomotive Emission Comparisons
- 4.3 – Locomotive Emission Calculation methodology
- 4.4 - Description of 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.[17]

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_2e
New York and New Jersey	567,237	342,762	121,476	1,089,351	2,946,572	133,010	230,279,664
NYNJLINA	272,796	79,551	36,399	316,874	1,335,320	37,497	127,000,943
Railroad Locomotives	274	10	9	20	53	0.2	18,382
Percent of NYNJLINA Emissions	0.10%	0.01%	0.02%	0.006%	0.004%	0.001%	0.01%

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.

[17] 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 %

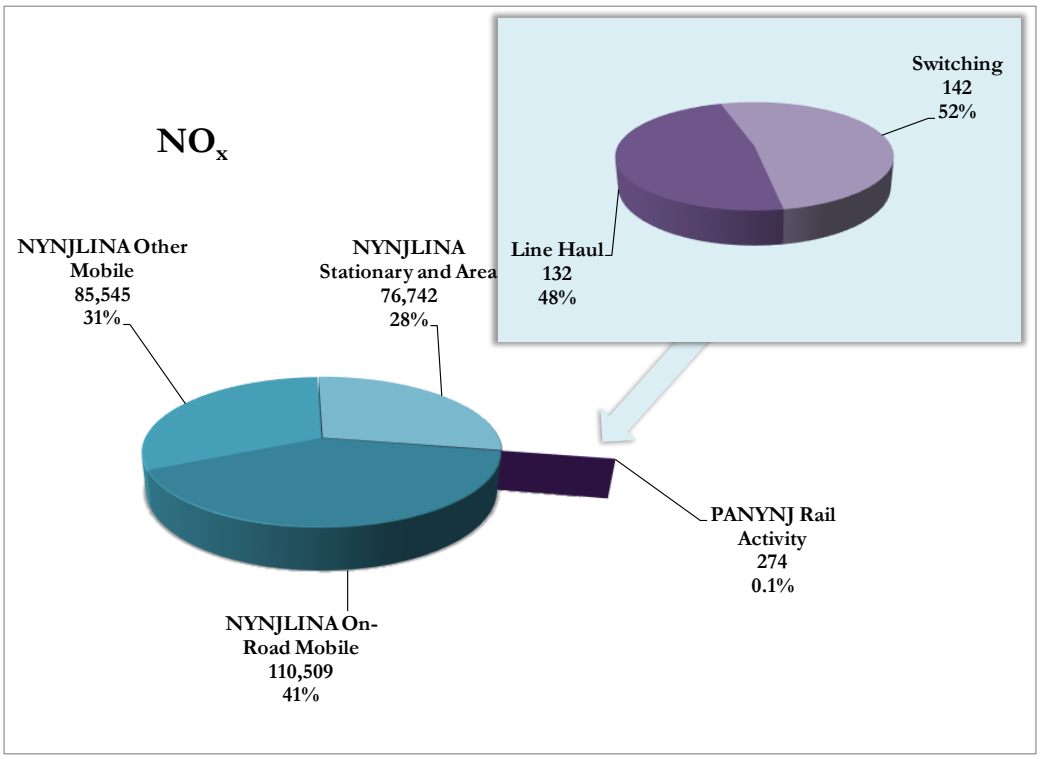


Figure ES4.2: Distribution and Comparison of PM_{10} from Locomotives, tpy and %

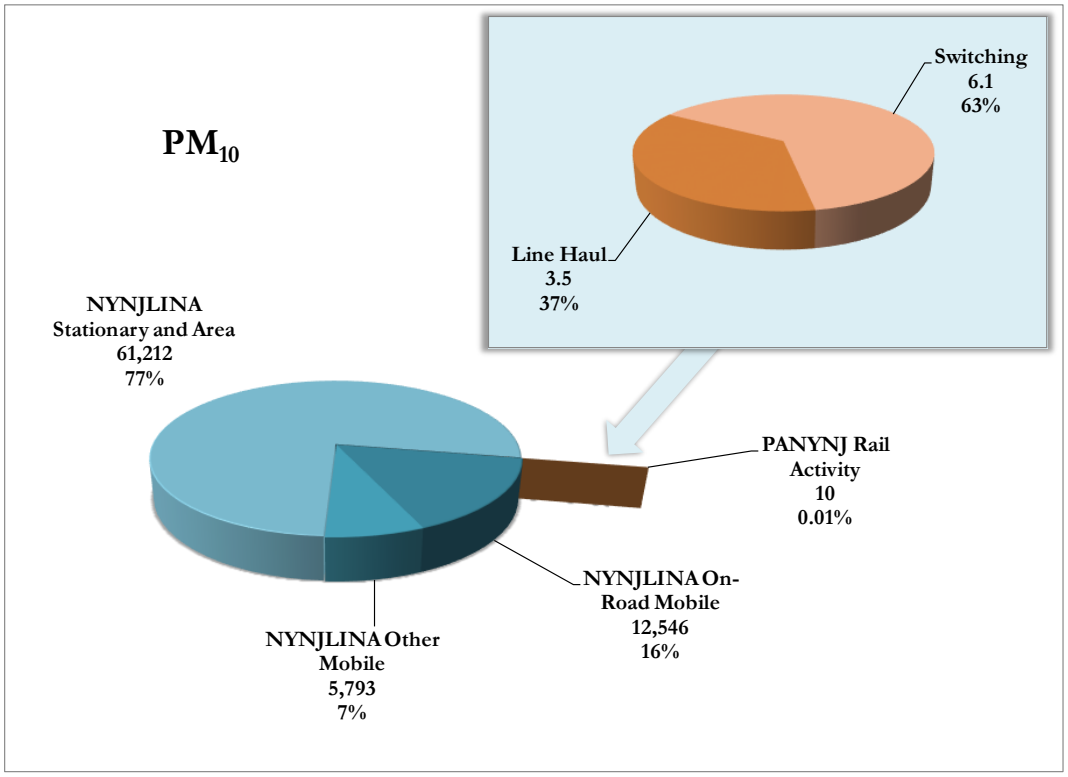


Figure ES4.3: Distribution and Comparison of $PM_{2.5}$ from Locomotives, tpy and %

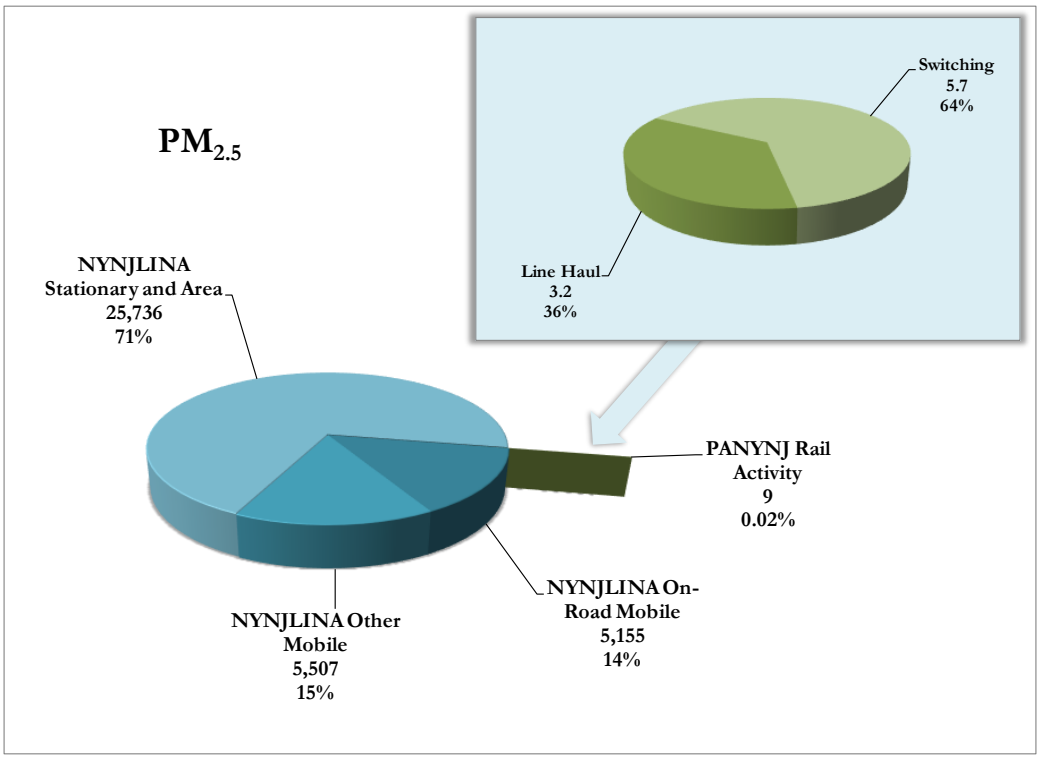


Figure ES4.4: Distribution and Comparison of VOC from Locomotives, tpy and %

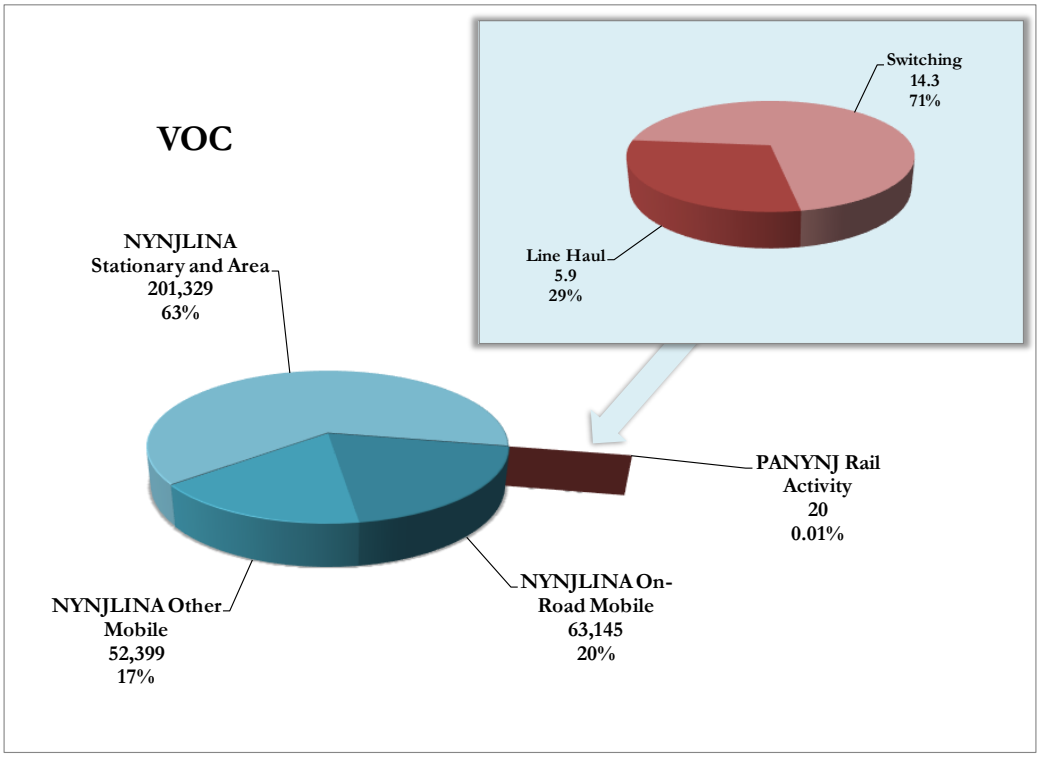


Figure ES4.5: Distribution and Comparison of CO from Locomotives, tpy and %

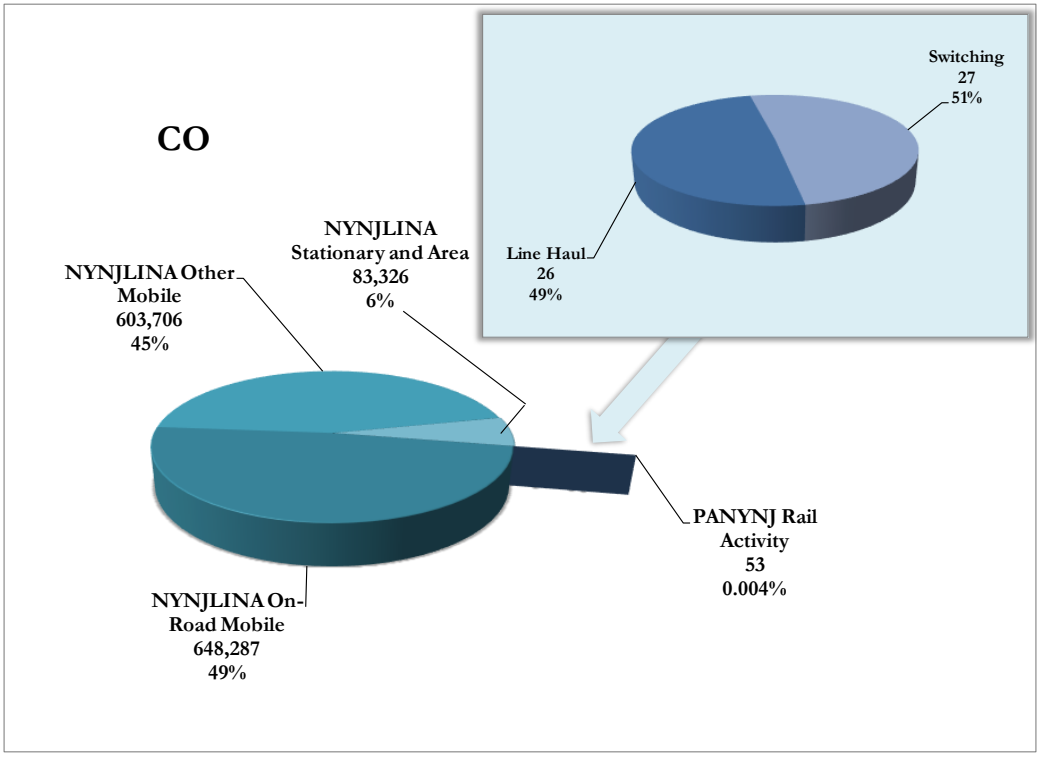


Figure ES4.6: Distribution and Comparison of SO_2 from Locomotives, tpy and %

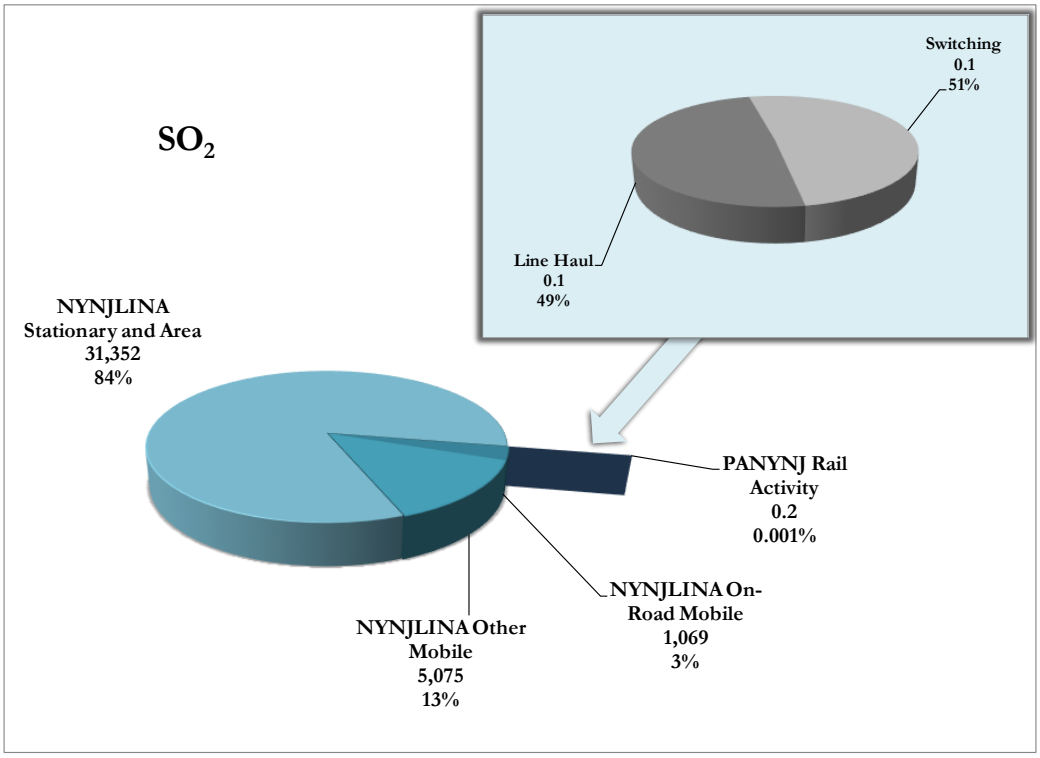
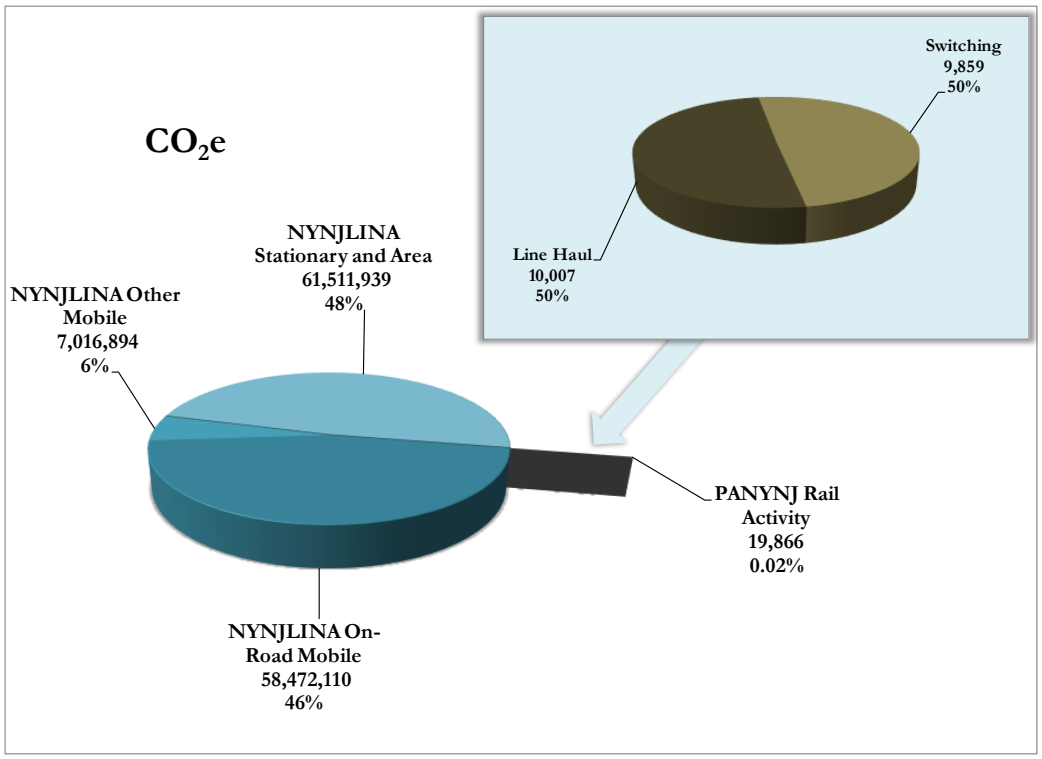


Figure ES4.7: Distribution of CO_2e from Locomotives, tpy and %



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 switching emissions.

Table 4.1: Locomotive Emission Estimates, tons per year

	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
New Jersey subtotal	215	7.9	7.3	17	41	0.2	15,330
New York subtotal	59	1.7	1.6	3	12	0.0	4,536
Total	**274**	**9.6**	**8.9**	**20**	**53**	**0.2**	**19,866**

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 2014 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.[18] 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.

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

Table 4.2 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 4.2: Summary of Locomotive Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	28.9	0.8	0.7	1.3	5.7	0.0	2,200
Essex	NJ	104.3	4.3	4.0	10.0	19.4	0.1	7,229
Hudson	NJ	28.1	0.8	0.7	1.3	5.4	0.0	2,070
Middlesex	NJ	5.1	0.1	0.1	0.2	1.0	0.0	387
Monmouth	NJ	0.0	0.0	0.0	0.0	0.0	0.0	0
Union	NJ	48.6	1.9	1.7	4.1	9.2	0.0	3,445
New Jersey subtotal		**215**	**7.9**	**7.3**	**17**	**41**	**0.2**	**15,330**
Bronx	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Kings (Brooklyn)	NY	2.7	0.10	0.09	0.20	0.40	0.00	147
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	9.7	0.4	0.4	1.0	2.3	0.0	865
Rockland	NY	46.3	1.2	1.1	2.1	9.1	0.0	3,524
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		**59**	**1.7**	**1.6**	**3**	**12**	**0.0**	**4,536**
Total		**274**	**9.6**	**8.9**	**20**	**53**	**0.2**	**19,866**

Table 4.3: 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	15,763	29	0.18%
Essex	NJ	14,172	104	0.74%
Hudson	NJ	10,059	28	0.28%
Middlesex	NJ	15,574	5.1	0.03%
Monmouth	NJ	10,795	0.0	0.00%
Union	NJ	13,636	49	0.36%
New Jersey Subtotal		**79,999**	**215**	**0.27%**
Bronx	NY	9,912	0.0	0.00%
Kings (Brooklyn)	NY	19,011	2.7	0.01%
Nassau	NY	23,967	0.0	0.00%
New York	NY	33,400	0.0	0.00%
Orange	NY	8,857	0.0	0.00%
Queens	NY	29,220	0.0	0.00%
Richmond (Staten Isld)	NY	7,531	9.7	0.13%
Rockland	NY	5,494	46	0.84%
Suffolk	NY	39,142	0.0	0.00%
Westchester	NY	16,263	0.0	0.00%
New York Subtotal		**192,797**	**59**	**0.03%**
TOTAL		**272,796**	**274**	**0.10%**

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

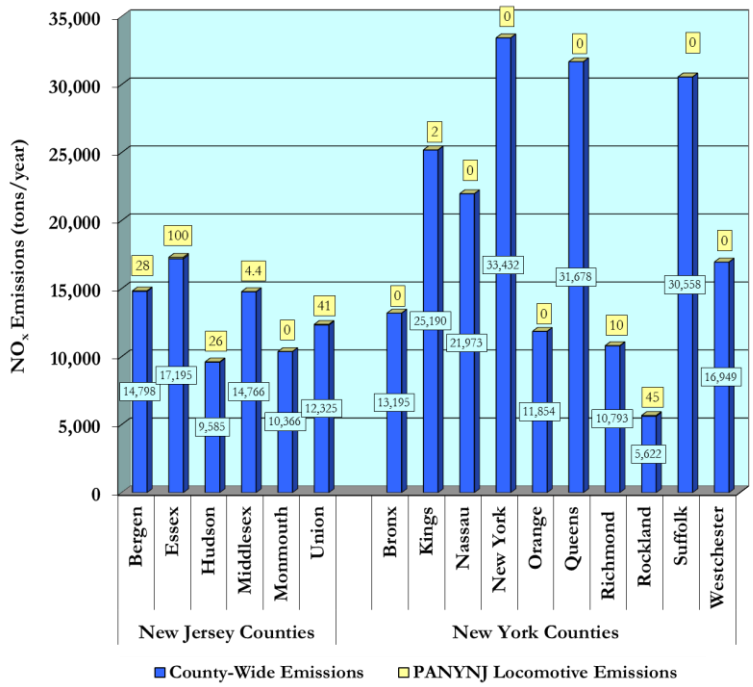


Table 4.4: Comparison of Locomotive PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	3,896	0.8	0.02%
Essex	NJ	2,631	4.3	0.16%
Hudson	NJ	1,641	0.8	0.05%
Middlesex	NJ	4,486	0.1	0.003%
Monmouth	NJ	3,406	0	0%
Union	NJ	2,761	1.9	0.07%
New Jersey Subtotal		**18,821**	**8**	**0.04%**
Bronx	NY	2,713	0	0%
Kings (Brooklyn)	NY	4,984	0	0%
Nassau	NY	6,975	0	0%
New York	NY	7,049	0	0%
Orange	NY	7,645	0	0%
Queens	NY	5,881	0	0%
Richmond (Staten Isld)	NY	1,972	0	0%
Rockland	NY	2,149	1.2	0.06%
Suffolk	NY	14,340	0	0%
Westchester	NY	7,023	0	0%
New York Subtotal		**60,730**	**2**	**0.003%**
TOTAL		**79,551**	**10**	**0.01%**

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

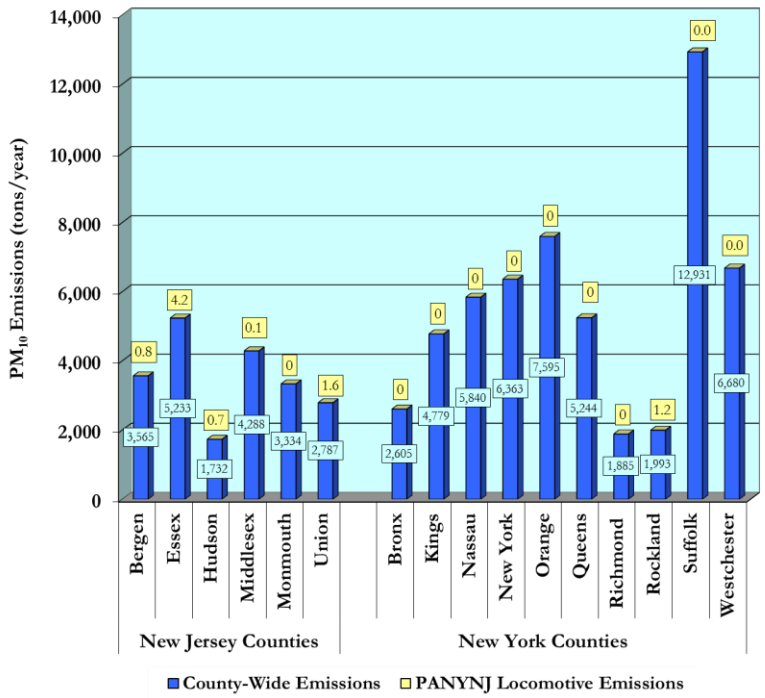


Table 4.5: Comparison of Locomotive $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	2,097	0.7	0.03%
Essex	NJ	1,627	4.0	0.25%
Hudson	NJ	1,105	0.7	0.06%
Middlesex	NJ	2,309	0.1	0.01%
Monmouth	NJ	1,635	0	0%
Union	NJ	1,704	1.7	0.10%
New Jersey Subtotal		**10,477**	**7**	**0.1%**
Bronx	NY	1,407	0	0%
Kings (Brooklyn)	NY	2,600	0	0%
Nassau	NY	2,984	0	0%
New York	NY	3,295	0	0%
Orange	NY	2,395	0	0%
Queens	NY	3,167	0	0%
Richmond (Staten Isld)	NY	1,000	0	0%
Rockland	NY	827	1.1	0.14%
Suffolk	NY	5,705	0	0%
Westchester	NY	2,540	0	0%
New York Subtotal		**25,922**	**2**	**0.01%**
TOTAL		**36,399**	**9**	**0.02%**

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

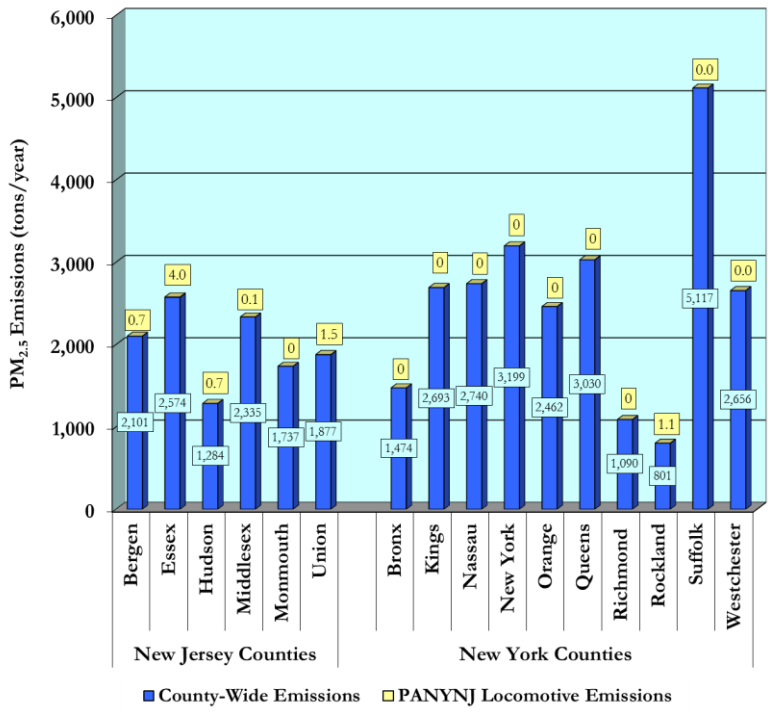


Table 4.6: Comparison of Locomotive VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	18,980	1.3	0.007%
Essex	NJ	14,151	10.0	0.071%
Hudson	NJ	9,429	1.3	0.014%
Middlesex	NJ	19,479	0.2	0.001%
Monmouth	NJ	19,080	0	0%
Union	NJ	12,608	4.1	0.03%
New Jersey Subtotal		**93,727**	**17**	**0.02%**
Bronx	NY	13,272	0	0%
Kings (Brooklyn)	NY	24,871	0	0%
Nassau	NY	27,629	0	0%
New York	NY	20,469	0	0%
Orange	NY	19,383	0	0%
Queens	NY	27,772	0	0%
Richmond (Staten Isld)	NY	7,600	1	0%
Rockland	NY	8,861	2.1	0.024%
Suffolk	NY	49,647	0	0%
Westchester	NY	23,643	0	0%
New York Subtotal		**223,147**	**3**	**0.001%**
TOTAL		**316,874**	**20**	**0.006%**

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

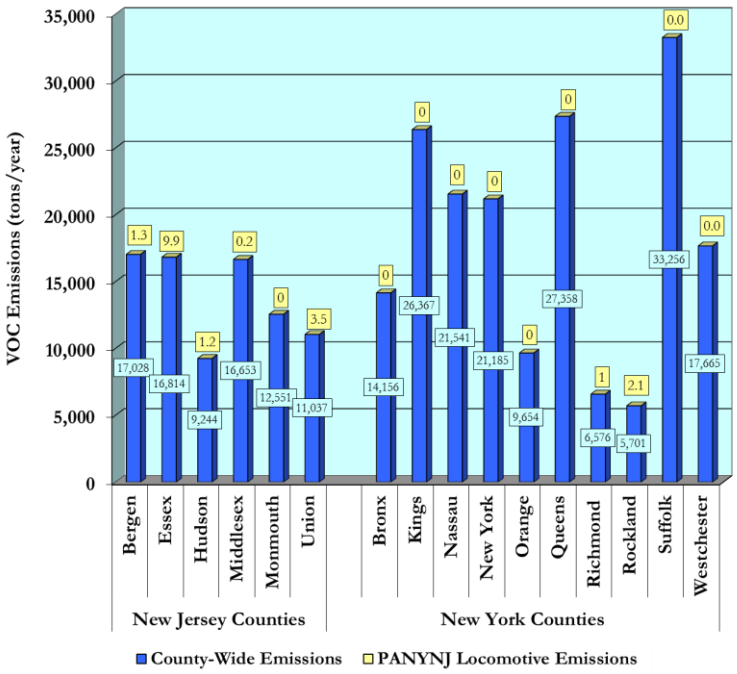


Table 4.7: Comparison of Locomotive CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	111,914	5.7	0.005%
Essex	NJ	64,014	19.4	0.030%
Hudson	NJ	36,789	5.4	0.015%
Middlesex	NJ	87,469	1.0	0.0011%
Monmouth	NJ	71,524	0.0	0.00%
Union	NJ	53,352	9.2	0.02%
New Jersey Subtotal		**425,060**	**41**	**0.010%**
Bronx	NY	36,134	0.0	0.000%
Kings (Brooklyn)	NY	78,793	0.4	0.001%
Nassau	NY	143,985	0.0	0.000%
New York	NY	109,627	0.0	0.000%
Orange	NY	45,498	0.0	0.000%
Queens	NY	111,129	0.0	0.000%
Richmond (Staten Isld)	NY	32,985	2.3	0.007%
Rockland	NY	33,695	9.1	0.027%
Suffolk	NY	212,558	0.0	0.000%
Westchester	NY	105,856	0.0	0.000%
New York Subtotal		**910,259**	**12**	**0.0013%**
TOTAL		**1,335,320**	**53**	**0.004%**

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

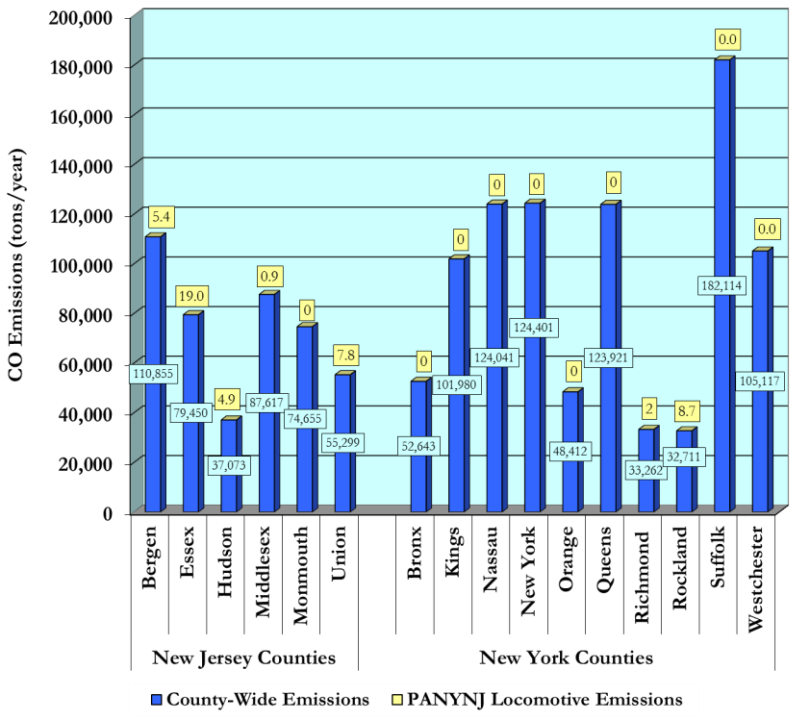


Table 4.8: Comparison of Locomotive SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	685	0.0	0.003%
Essex	NJ	1,226	0.1	0.006%
Hudson	NJ	1,840	0.0	0.001%
Middlesex	NJ	785	0.0	0.001%
Monmouth	NJ	687	0.0	0.000%
Union	NJ	1,583	0.0	0.002%
New Jersey Subtotal		**6,806**	**0.2**	**0.002%**
Bronx	NY	1,547	0.0	0.000%
Kings (Brooklyn)	NY	1,525	0.0	0.000%
Nassau	NY	2,563	0.0	0.000%
New York	NY	5,574	0.0	0.000%
Orange	NY	6,251	0.0	0.000%
Queens	NY	2,513	0.0	0.000%
Richmond (Staten Isld)	NY	409	0.0	0.002%
Rockland	NY	297	0.0	0.011%
Suffolk	NY	7,875	0.0	0.000%
Westchester	NY	2,137	0.0	0.000%
New York Subtotal		**30,691**	**0.0**	**0.000%**
TOTAL		**37,497**	**0.2**	**0.0005%**

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

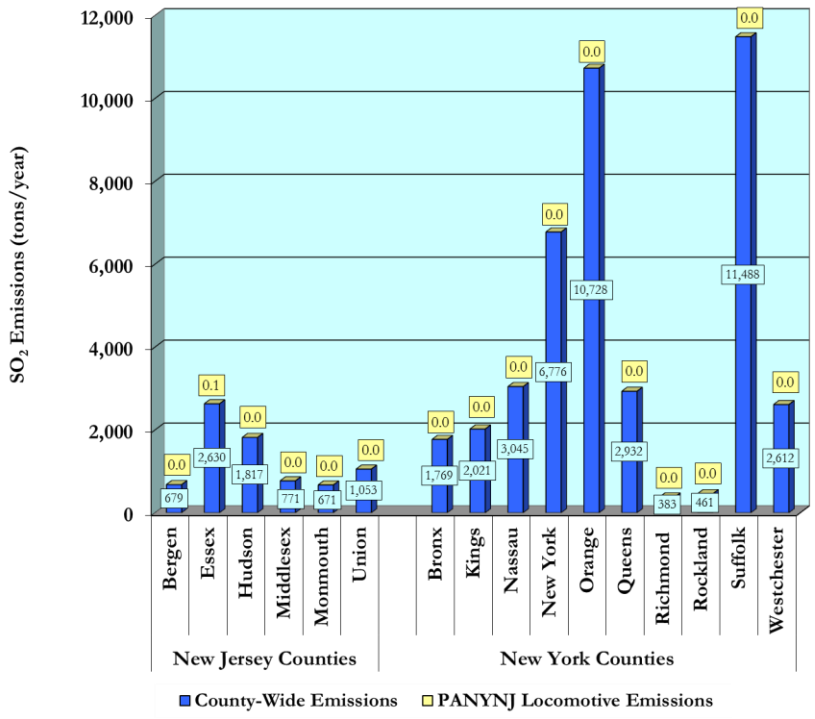
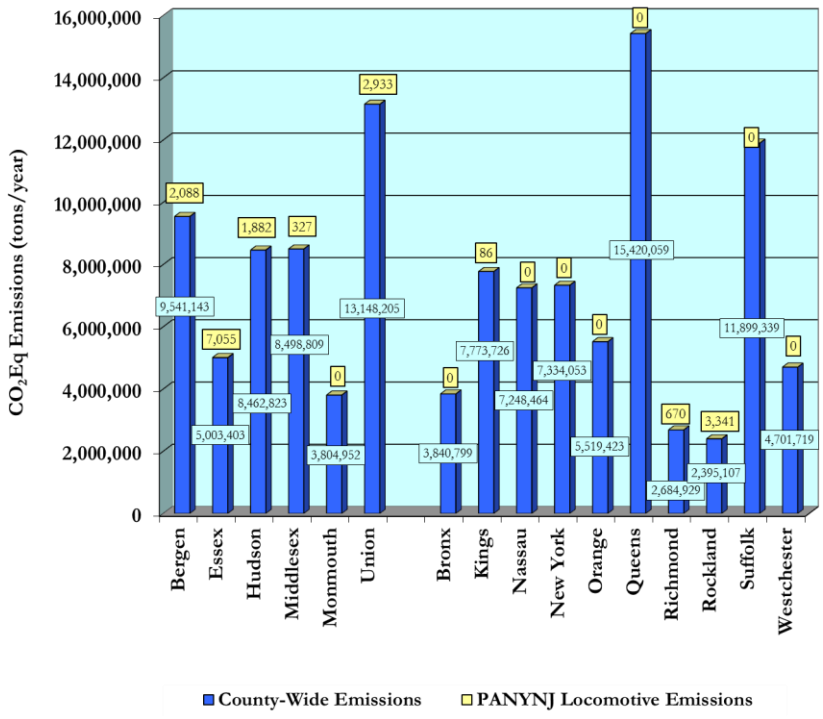


Table 4.9: Comparison of Locomotive CO_2e Emissions with Overall CO_2e Emissions by County, tpy

County	State	County-Wide Emissions	Locomotive Emissions in Inventory	Percent of Total
Bergen	NJ	12,083,110	2,200	0.02%
Essex	NJ	5,054,723	7,229	0.14%
Hudson	NJ	7,261,187	2,070	0.03%
Middlesex	NJ	11,596,949	387	0.00%
Monmouth	NJ	5,242,102	0	0.00%
Union	NJ	12,936,127	3,445	0.03%
New Jersey Subtotal		**54,174,197**	**15,330**	**0.03%**
Bronx	NY	2,898,414	0	0.00%
Kings (Brooklyn)	NY	5,729,063	147	0.00%
Nassau	NY	10,045,818	0	0.00%
New York	NY	7,090,866	0	0.00%
Orange	NY	5,609,965	0	0.00%
Queens	NY	15,051,786	0	0.00%
Richmond (Staten Isld)	NY	2,572,653	865	0.03%
Rockland	NY	2,791,076	3,524	0.13%
Suffolk	NY	15,290,461	0	0.00%
Westchester	NY	5,746,644	0	0.00%
New York Subtotal		**72,826,745**	**4,536**	**0.01%**
TOTAL		**127,000,943**	**19,866**	**0.02%**

Figure 4.7: Comparison of Locomotive CO_2e Emissions with Overall CO_2e Emissions by County, tpy



4.2.2 Comparisons with Prior Year Emission Estimates

Table 4.10 presents the annual locomotive emissions as estimated in the respective emissions inventories, the percentage difference between each prior inventory's emissions and the 2014 estimates, emissions in tons per million on-dock lifts, and the percentage differences in tons per million on-dock lifts between the prior years and 2014. 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. The figures following the summary table graphically illustrate the changes in emissions, in tons per year, between the 2006 baseline emissions inventory and the 2014 update. The 2006 emissions are shown in each figure as a dashed line horizontal with the x axis, and the overall percent change between 2006 and 2014 is shown to the right of each chart, with an arrow indicating the direction of change in emissions. The units on the y-axis are tons per year. Inventories were developed for even numbered years between 2006 and 2012, so for the intervening odd-numbered years the charts have been prepared by interpolating between even numbered years. The inventories became annual starting with the 2012 update.

Table 4.10: Comparison of 2014 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_2e	On-dock Lifts
Tons per year								
2014	274	10	9	20	53	0.2	19,866	465,405
2013	257	9	9	19	49	0.2	18,382	425,784
2012	266	9	9	20	49	1.3	18,458	433,481
2010	261	9	9	20	46	3.8	17,364	376,770
2008	268	10	9	20	45	4	17,183	377,827
2006	286	10	9	20	44	32	14,710	338,884
Percent change relative to 2014 - tons per year								
2013 - 2014	6%	5%	4%	7%	7%	-5%	8%	9%
2012 - 2014	3%	2%	-1%	1%	7%	-85%	8%	7%
2010 - 2014	5%	5%	2%	1%	14%	-95%	14%	24%
2008 - 2014	2%	-1%	-1%	1%	17%	-95%	16%	23%
2006 - 2014	-4%	-6%	-5%	1%	19%	-99%	35%	37%
Tons per million on-dock lifts								
2014	588	21	19	44	113	0.4	42,685	
2013	604	22	20	45	115	0.5	43,172	
2012	614	22	21	46	113	3	42,581	
2010	693	24	23	53	122	10	46,086	
2008	709	26	24	53	119	10	45,478	
2006	844	30	28	59	130	94	43,407	
Percent change relative to 2014 - tons per million on-dock lifts								
2013 - 2014	-3%	-5%	-5%	-2%	-2%	-20%	-1%	
2012 - 2014	-4%	-5%	-10%	-4%	0%	-87%	0%	
2010 - 2014	-15%	-13%	-17%	-17%	-7%	-96%	-7%	
2008 - 2014	-17%	-19%	-21%	-17%	-5%	-96%	-6%	
2006 - 2014	-30%	-30%	-32%	-25%	-13%	-100%	-2%	

Figure 4.8: NO_x Emissions Trend for Locomotives

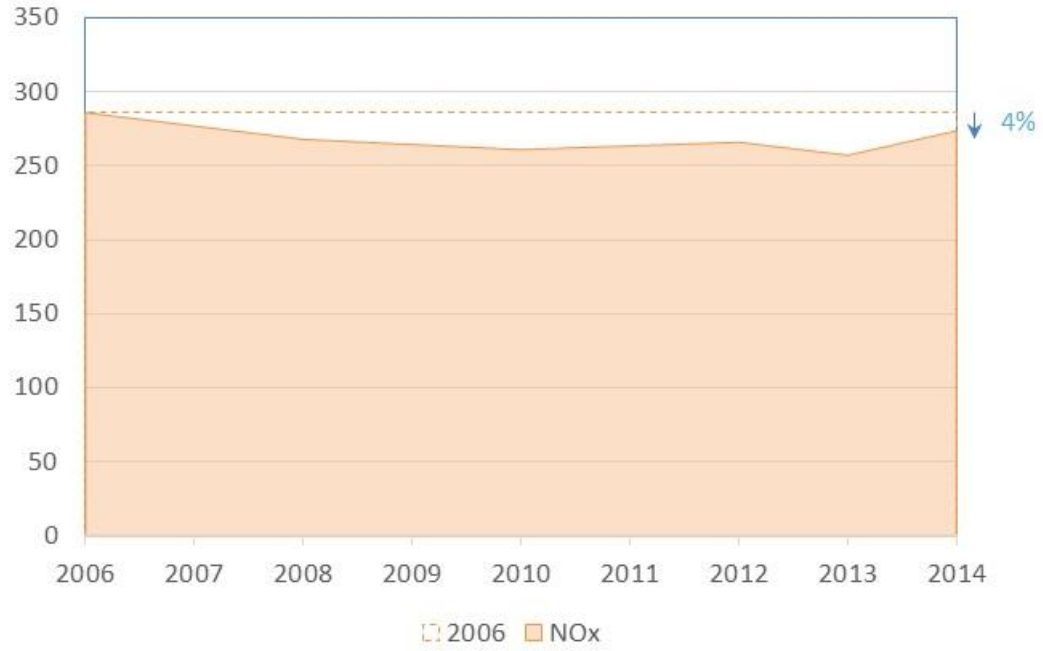


Figure 4.9: PM_{10} Emissions Trend for Locomotives

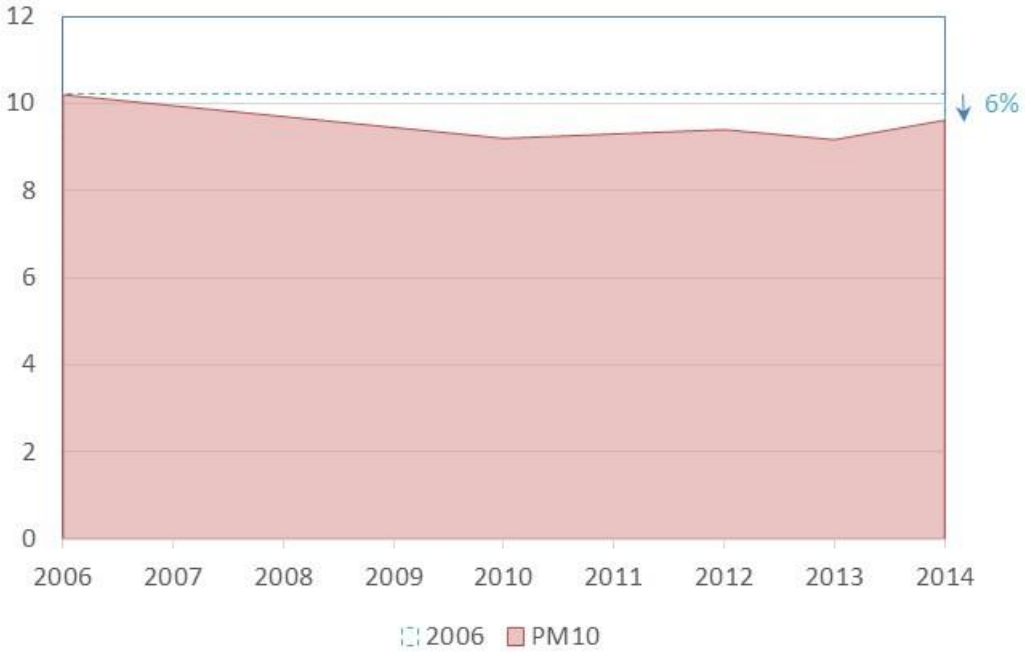


Figure 4.10: $PM_{2.5}$ Emissions Trend for Locomotives

Figure 4.11: VOC Emissions Trend for Locomotives

Figure 4.12: CO Emissions Trend for Locomotives

Figure 4.13: SO_2 Emissions Trend for Locomotives

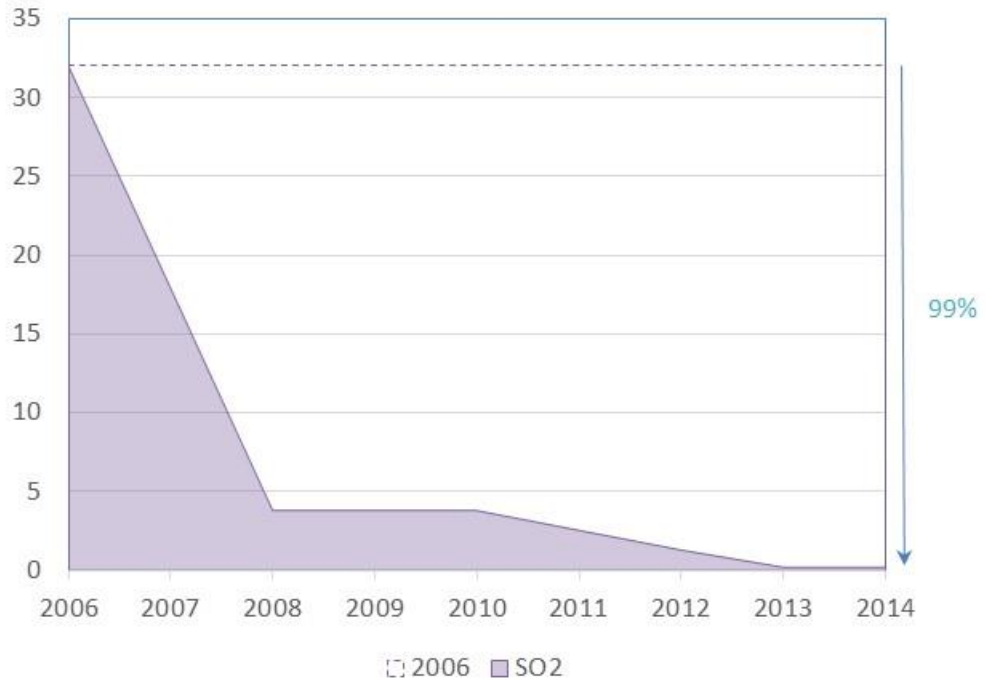
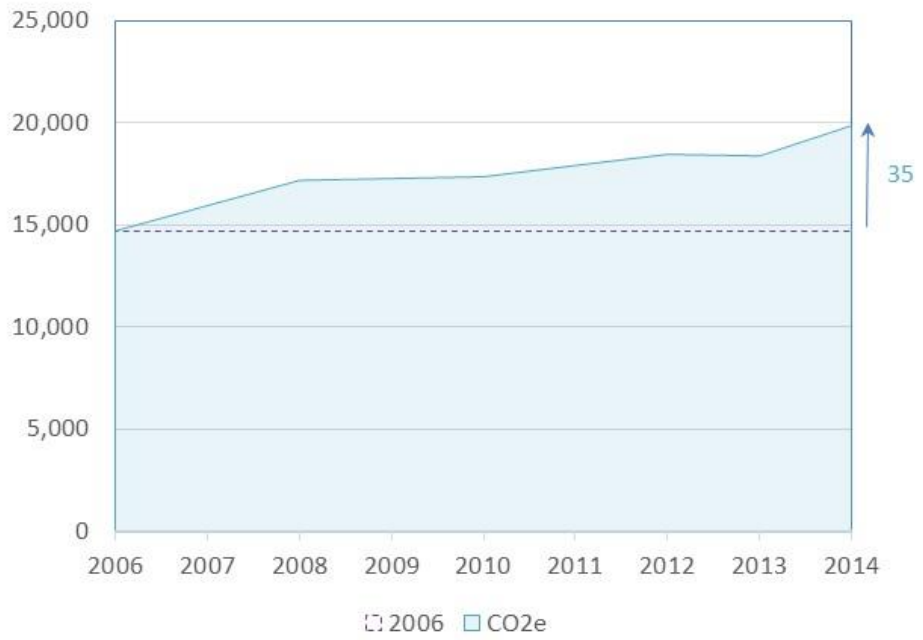
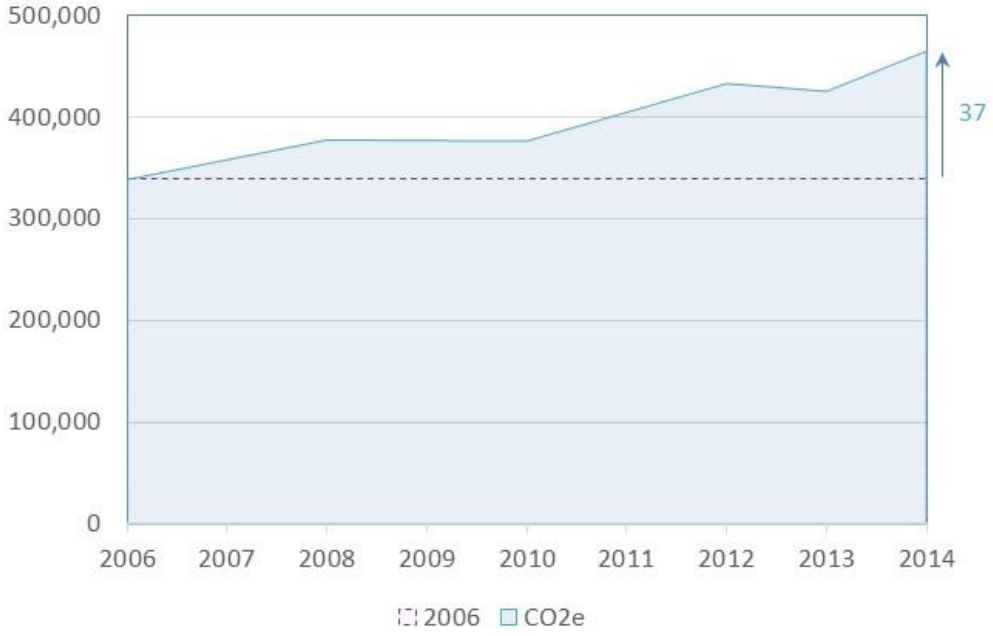


Figure 4.14: CO_2 Emissions Trend for Locomotives



To illustrate the change in the amount of cargo transported by rail over the time period covered by the foregoing figures, Figure 4.15 presents the change in on-dock rail volume in number of lifts (containers) for the period 2006-2014. It can be seen that the increase in GHG emissions represented by CO_2e follows, but is slightly less than, the increase in the number of containers moved by rail over that period of time.

Figure 4.15: On-Dock Rail Trend for Locomotives, lifts per year



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,[19] 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, which 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, VOCs, CO) come from an EPA publication[20] 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 15 ppm in 2014. The emission factors for N_2O and CH_4 were obtained from an EPA publication on greenhouse gases.[21]

[19] Information provided by PANYNJ by email 3 December 2013.
[20] "Emission Factors for Locomotives," EPA-420-F-09-025, Office of Transportation and Air Quality, April 2009
[21] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2013; April 2015; Table A- 108: Emission Factors for CH4 and N2O Emissions from Non-Highway Mobile Combustion (g gas/kg fuel).

The emission factors for line haul locomotives are presented in Table 4.11.

Table 4.11: 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	135	3.6	3.3	6.1	26.7	0.10	10,186	0.25	0.79
g/hp-hr	6.5	0.17	0.16	0.29	1.28	0.00	489	0.012	0.038

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.[22]

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 4.12 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 4.12: 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	20	28	12	20	16
Length of 5-platform car, feet	300	300	300	300	300	300
Length of cargo, feet	8,400	6,000	8,400	3,600	6,000	4,800
Length of 1 locomotive, feet	70	70	70	70	70	70
# of locomotives per train	2	2	2	1	2	2
Total locomotive length, feet	140	140	140	140	140	140
Total train length	**8,540**	**6,140**	**8,540**	**3,740**	**6,140**	**4,940**

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.

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

Table 4.13 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 4.13. 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 4.13: 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	400	560	240	400	320
Average "density"	95%	95%	95%	95%	95%	95%
TEUs per train (adjusted)	532	380	532	228	380	304
Average TEUs per container:	1.73	1.73	1.73	1.73	1.73	1.73
Containers per train (average)	**308**	**220**	**308**	**132**	**220**	**176**

Table 4.14 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 4.13). The total estimated number of containers moved by the train configurations described above (and shown below in Table 4.14) corresponds to the reported actual 2014 on-dock rail throughput to within approximately two tenths of a percent (estimated total of 464,464, actual 465,405). 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 4.14: 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	112,112	80,080	112,112	34,320	80,080	45,760
Total estimated containers:	**304,304**			**160,160**		

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 2014 submittals of an annual report known as the "R-1."[23] 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 4.15. In addition to average car weight, Table 4.15 lists the average number of railcars per train, estimated by multiplying the number of 5-platfom cars (shown in Table 4.15) 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 4.15.

Table 4.15: Line-Haul Train Gross Weight

Parameters	Q159 Outbound	Q162 Outbound	Q112 Inbound	25V Outbound	23M Outbound	24V Inbound
Platforms per train (average)	140	100	140	60	100	80
Gross tons per platform	84	84	84	84	84	84
Gross weight of train	**11,705**	**8,361**	**11,705**	**5,016**	**8,361**	**6,688**

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 **11.56 million gross tons** for the railroad whose trains are represented by the left three columns in the previous tables, and approximately **6.09 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 4.16. Fuel consumption in each county was estimated by multiplying the ton-miles by the factor of 1.12 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.

[23] *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2014* (Norfolk Southern Railroad) and *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2014* (CSX Transportation, Inc.).

Table 4.16: Line Haul Locomotive Ton-Mile and Fuel Use Estimates

County	Track Mileage	Thousand Gross Ton-Miles	Gallons Fuel
North Route			
Essex	3	34,692,950	38,856
Hudson	13	150,336,118	168,376
Bergen	15	173,464,751	194,281
Rockland	24	277,543,602	310,849
South Route			
Essex	5	30,432,413	34,084
Union	15	91,297,238	102,253
Middlesex	5	30,432,413	34,084
Total	80	788,199,484	882,783

The last step is to apply the emission factors (Table 4.11) 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 2013 and 2014. 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, 465,000 containers moved by rail in 2014 divided by 426,000 containers moved by rail in 2013 results in a growth factor of 1.09 or a 9% increase in throughput; this was multiplied by the 2013 operating hours estimate of 43,417 for a 2014 estimate of 47,325 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.[24] 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.

[24] 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 4.17. The switching locomotives operated 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. The container terminal that operates a single switcher on terminal has upgraded their locomotive to a Tier 4 engine, so the Tier 4 emission factors have been used for that locomotive's emissions.

Table 4.17: 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	55	1.9	1.8	4.4	8.1	7.00	2,957	0.07	0.22
g/hp-hr	12.6	0.44	0.40	1.01	1.83	0.01	672	0.017	0.05
Tier 1 emission factors									
g/gal	150	6.5	6.1	15.3	27.7	0.10	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
Tier 4 emission factors									
g/gal	15	0.2	0.2	1.2	27.7	0.10	10,182	0.26	0.76
g/hp-hr	1.0	0.015	0.015	0.08	1.83	0.01	672	0.017	0.05

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 2014 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 2014 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 4.16 illustrates a typical older switching locomotive, while Figure 4.17 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 4.18 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 4.16: Example Switching Locomotives at On-Dock Rail Facility

Photo courtesy of PANYNJ

Figure 4.17: Example Switching Locomotive

Photo courtesy of PANYNJ

Figure 4.18: 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 prior years. 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 no identified Port Authority marine terminal related CMV activities or emissions occur 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).

After an executive summary, the remainder of this section consists of the following subsections:

- 5.1 - CMV Emission Estimates
- 5.2 - CMV Emission Comparisons
- 5.3 - CMV Emission Calculation Methodology
- 5.4 - Description of Marine Vessels and Vessel Activity

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.[25]

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_2e
New York and New Jersey	567,237	342,762	121,476	1,089,351	2,946,572	133,010	230,279,664
NYNJLINA	272,796	79,551	36,399	316,874	1,335,320	37,497	127,000,943
OGVs	2,624	150	123	160	284	542	148,619
Harbor Craft	376	12	12	14	63	0.3	22,236
Total Commercial Marine Vessels	3,000	162	135	174	347	542	170,854
% of NYNJLINA Emissions	**1.0%**	**0.2%**	**0.3%**	**0.1%**	**0.02%**	**1.4%**	**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.

[25] 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

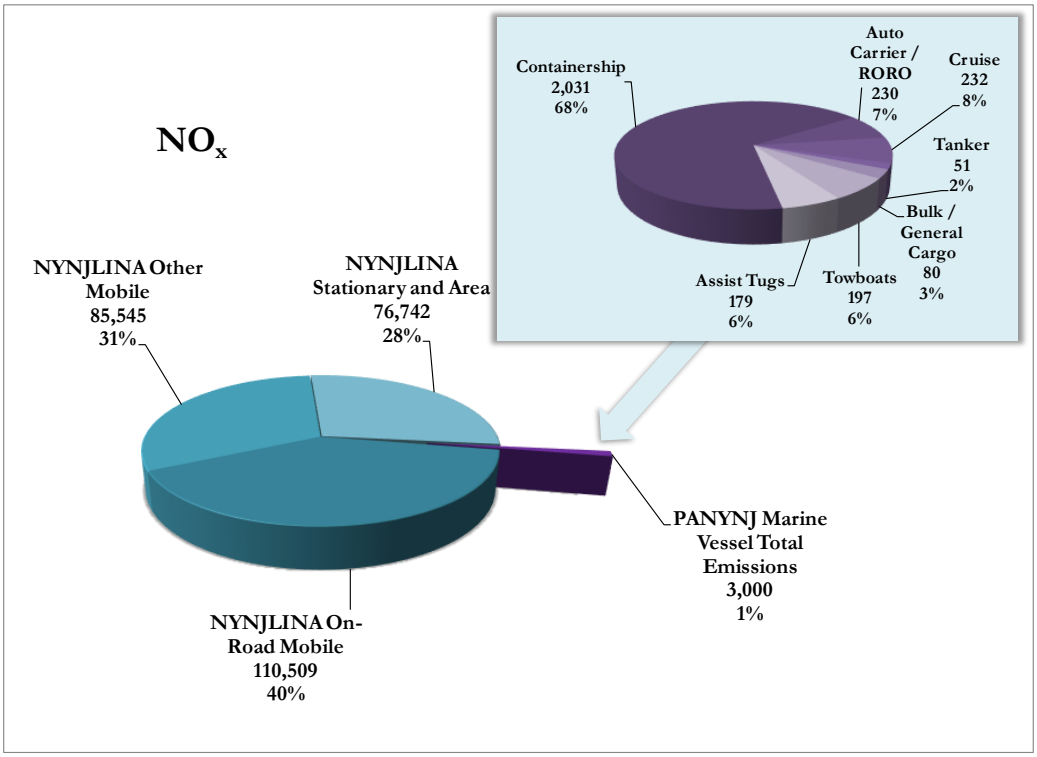


Figure ES5.2: Distribution and Comparison of PM_{10} from CMVs, tpy and percent

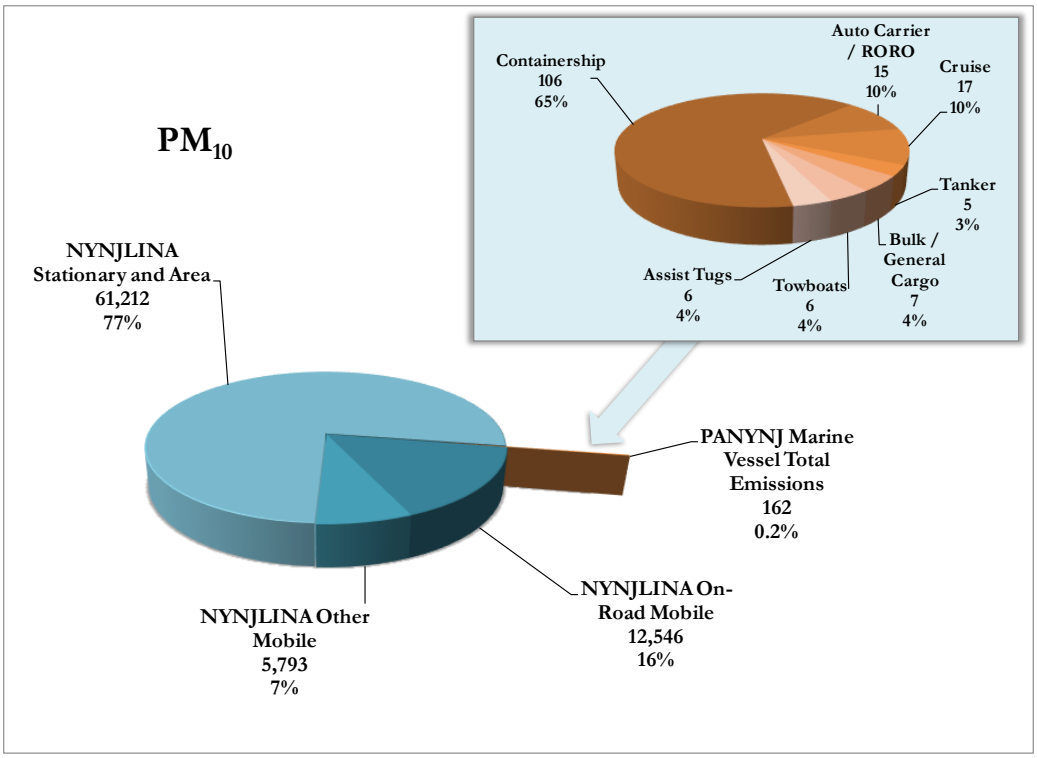


Figure ES5.3: Distribution and Comparison of $PM_{2.5}$ from CMVs, tpy and percent

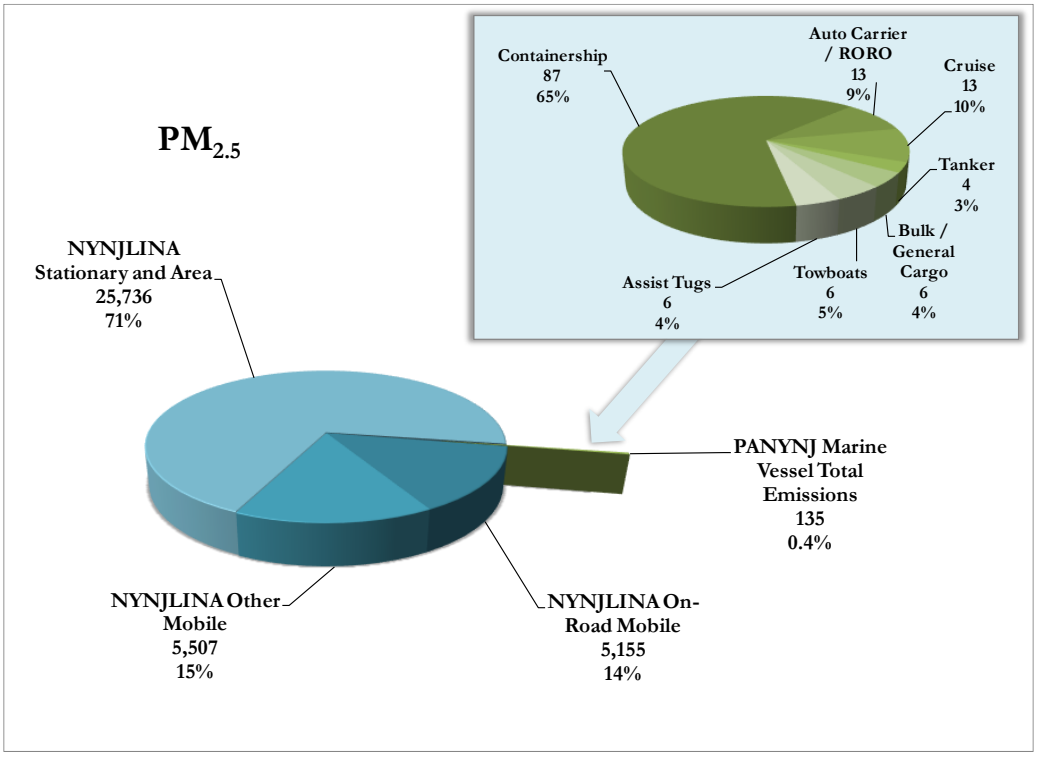


Figure ES5.4: Distribution and Comparison of VOC from CMVs, tpy and percent

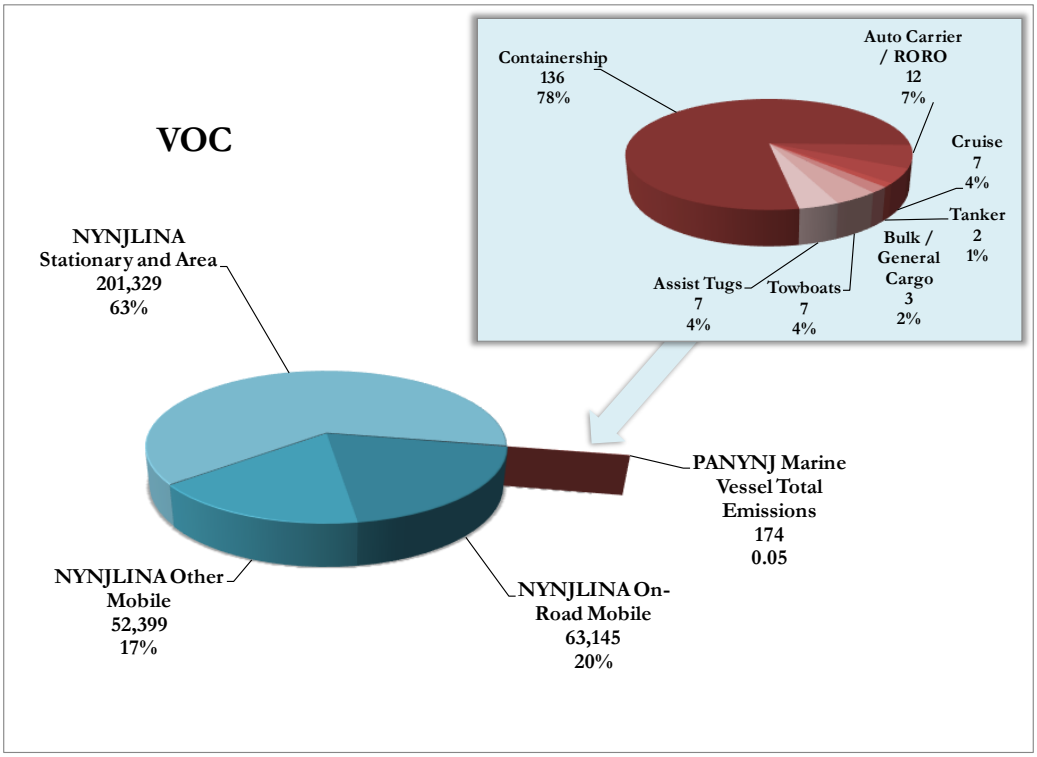


Figure ES5.5: Distribution and Comparison of CO from CMVs, tpy and percent

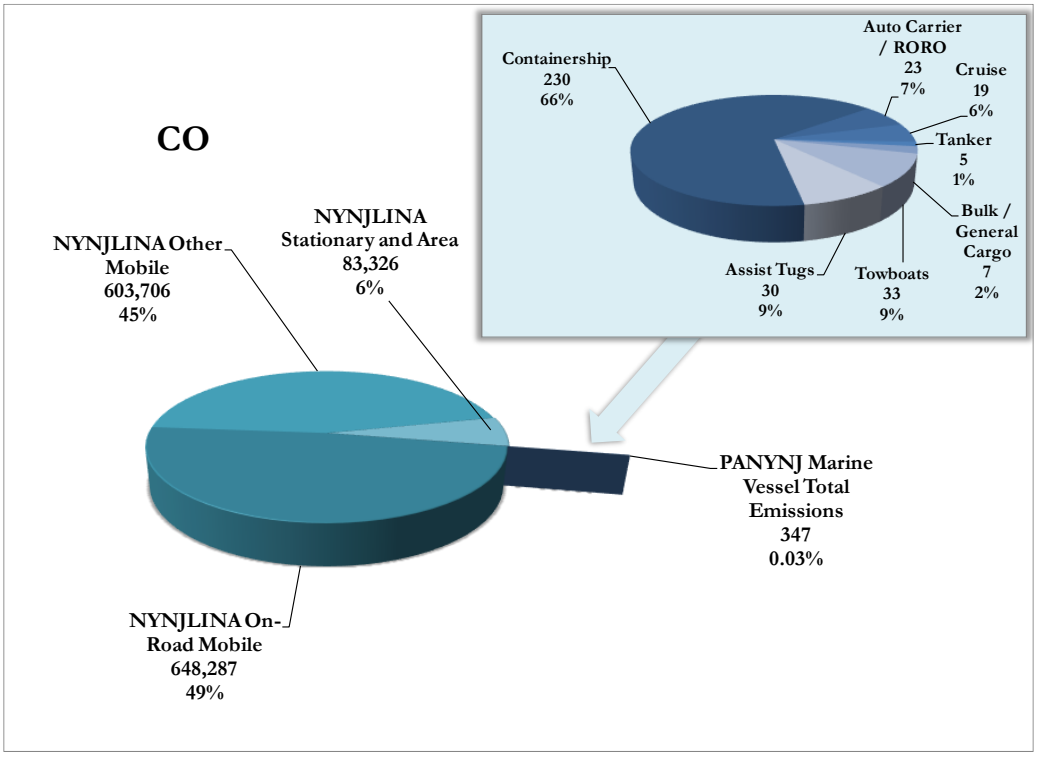


Figure ES5.6: Distribution and Comparison of SO_2 from CMVs, tpy and percent

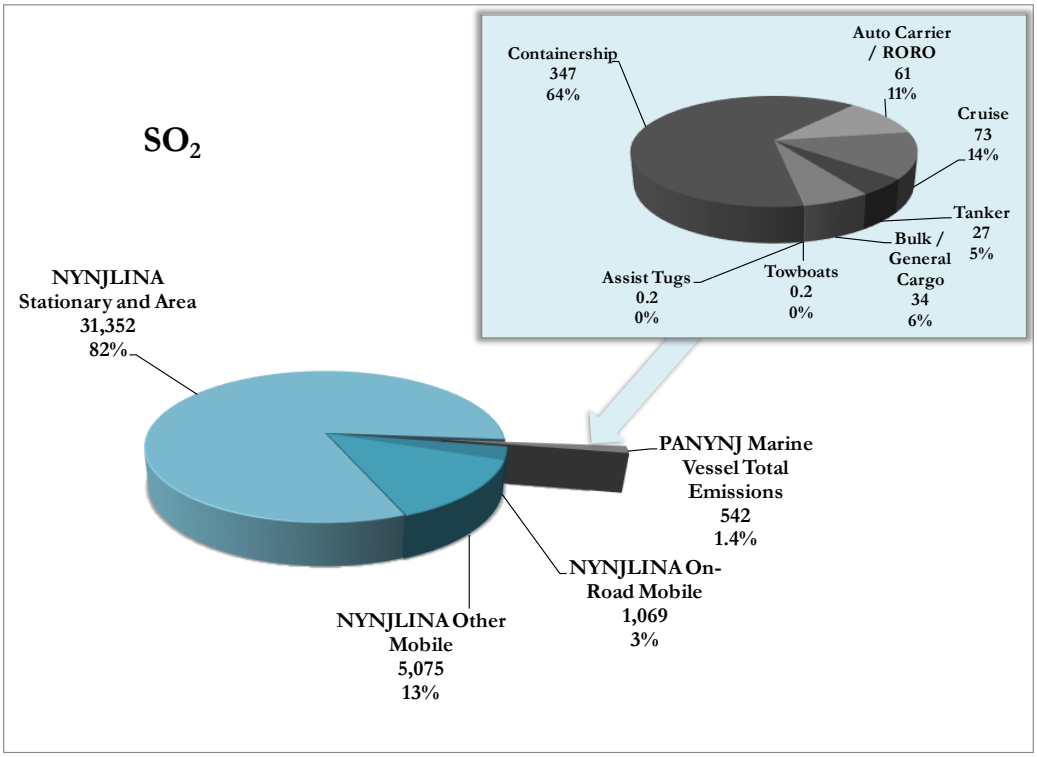
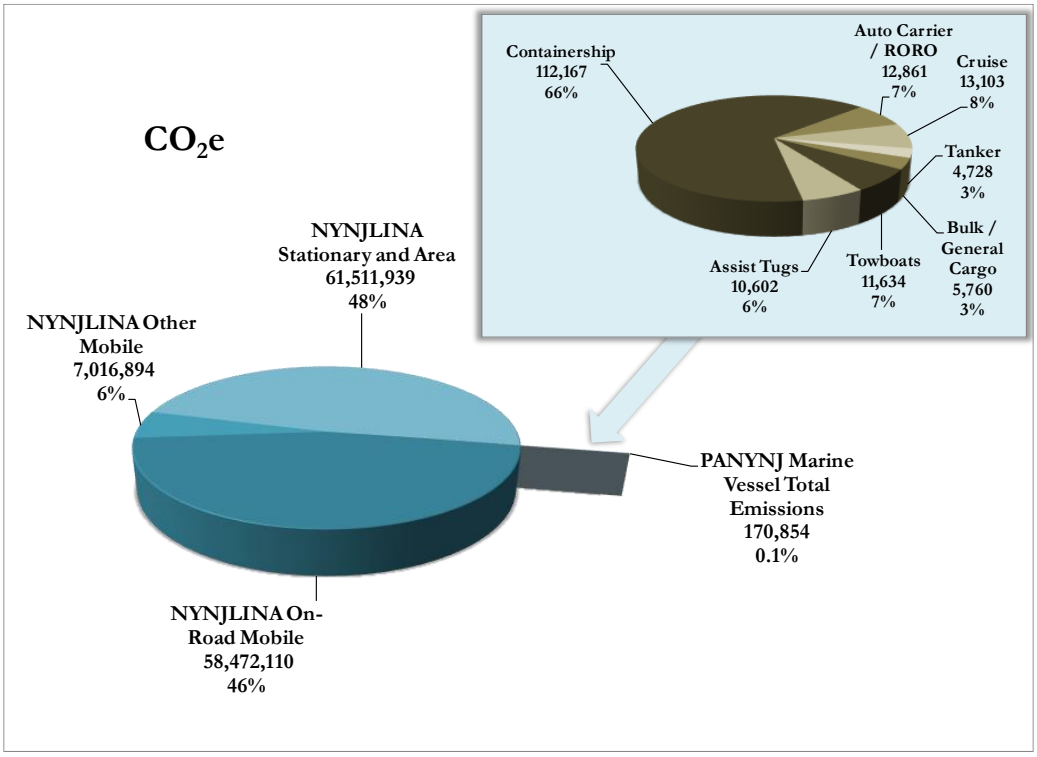


Figure ES5.7: Distribution and Comparison of CO_2e from CMVs, tpy and percent

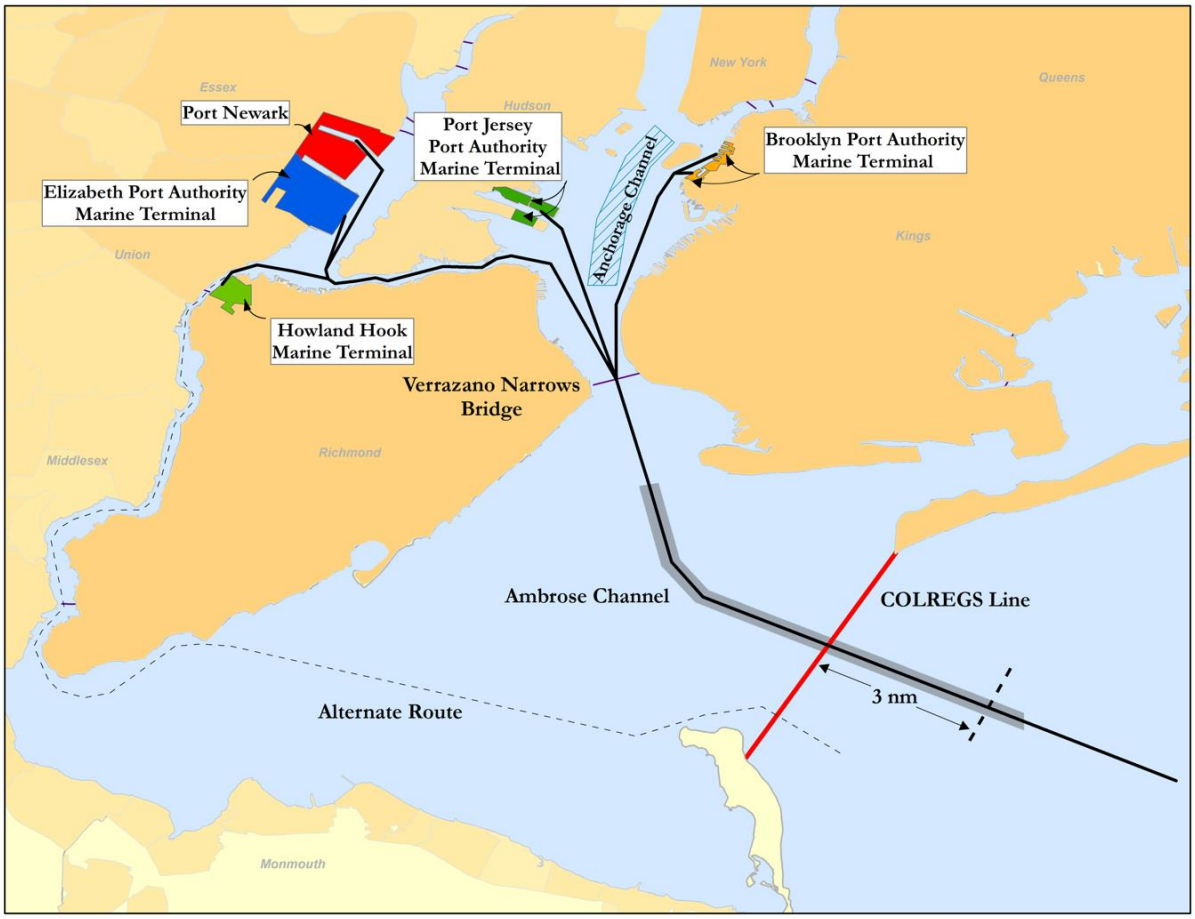


5.1 CMV Emission Estimates

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. Table 5.1 lists the estimated criteria pollutant and greenhouse gas emissions from OGVs by vessel type, Table 5.2 presents the OGV emissions by engine type, Table 5.3 differentiate emissions according to transiting and dwelling activity, and Table 5.4 presents 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 by Vessel Type

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Containership	2,031	106	87	136	230	347	112,167
Cruise	232	17	13	7	19	73	13,103
Auto Carrier	181	12	10	9	18	46	10,420
Tanker	51	5	4	2	5	27	4,728
RoRo	49	4	3	2	5	15	2,441
Bulk	48	5	4	2	5	22	3,726
General Cargo	25	2	2	1	2	9	1,532
Miscellaneous	8	1	0	0	1	3	502
Total	**2,624**	**150**	**123**	**160**	**284**	**542**	**148,619**

Table 5.2: OGV Emissions by Emission Source Type

Emission Source Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Main Engines	1,129	55	46	111	154	104	28,100
Auxiliary Engines	1,408	76	62	44	122	294	79,115
Boilers	87	18	15	4	9	144	41,403
Total	**2,624**	**150**	**123**	**160**	**284**	**542**	**148,619**

Table 5.3: OGV Emissions by Operating Mode

Operating Mode	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Transit	1,499	76	63	123	186	193	53,248
Dwelling	1,126	73	60	37	98	348	95,370
Total	**2,624**	**150**	**123**	**160**	**284**	**542**	**148,619**

Table 5.4: Assist Tug/Towboat (Harbor Craft) Emissions

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2e
Towboats/Pushbo	197	6	6	7	33	0	11,634
Assist Tugs	179	6	6	7	30	0	10,602
Totals	**376**	**12**	**12**	**14**	**63**	**0**	**22,236**

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 2014 emission estimates with the earlier year inventories developed for previous years. First, Port Authority marine terminal related OGV and tug/tow boat (harbor craft) 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.[26] These emission comparisons are segregated into ocean-going and harbor craft categories and are presented in sections 5.2.1 and 5.2.2 respectively. Section 5.2.3 presents 2014 OGV and harbor craft emission estimates in comparison with previous year emission estimates to illustrate the changes in emissions over time.

[26] 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 5.5 summarizes estimated criteria pollutant emissions from OGVs at the county level. The subsequent tables, 5.6 through 5.12, 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 5.5: Summary of OGV Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	0	0	0	0	0	0	0
Essex	NJ	665	42	34	42	73	161	40,470
Hudson	NJ	478	28	23	22	47	109	27,313
Middlesex	NJ	0	0	0	0	0	0	0
Monmouth	NJ	87	4	3	4	9	15	3,697
Union	NJ	898	51	42	66	104	169	53,256
New Jersey subtotal		**2,127**	**125**	**103**	**134**	**233**	**454**	**124,736**
Bronx	NY	0	0	0	0	0	0	0
Kings	NY	157	8	7	7	15	33	7,620
Nassau	NY	0	0	0	0	0	0	0
New York	NY	42	2	2	1	4	9	2,424
Orange	NY	0	0	0	0	0	0	0
Queens	NY	0	0	0	0	0	0	0
Richmond	NY	298	14	12	18	32	47	13,839
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		**497**	**25**	**20**	**26**	**51**	**88**	**23,883**
TOTAL		**2,624**	**150**	**123**	**160**	**284**	**542**	**148,619**

Table 5.6: 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 County	NJ	15,763	0	0.0%
Essex County	NJ	14,172	665	4.7%
Hudson County	NJ	10,059	478	4.8%
Middlesex County	NJ	15,574	0	0.0%
Monmouth County	NJ	10,795	87	0.8%
Union County	NJ	13,636	898	6.6%
New Jersey subtotal		**79,999**	**2,127**	**2.7%**
Bronx County	NY	9,912	0	0.0%
Kings County	NY	19,011	157	0.8%
Nassau County	NY	23,967	0	0.0%
New York County	NY	33,400	42	0.1%
Orange County	NY	8,857	0	0.0%
Queens County	NY	29,220	0	0.0%
Richmond County	NY	7,531	298	4.0%
Rockland County	NY	5,494	0	0.0%
Suffolk County	NY	39,142	0	0.0%
Westchester County	NY	16,263	0	0.0%
New York Subtotal		**192,797**	**497**	**0.3%**
TOTAL		**272,796**	**2,624**	**1.0%**

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

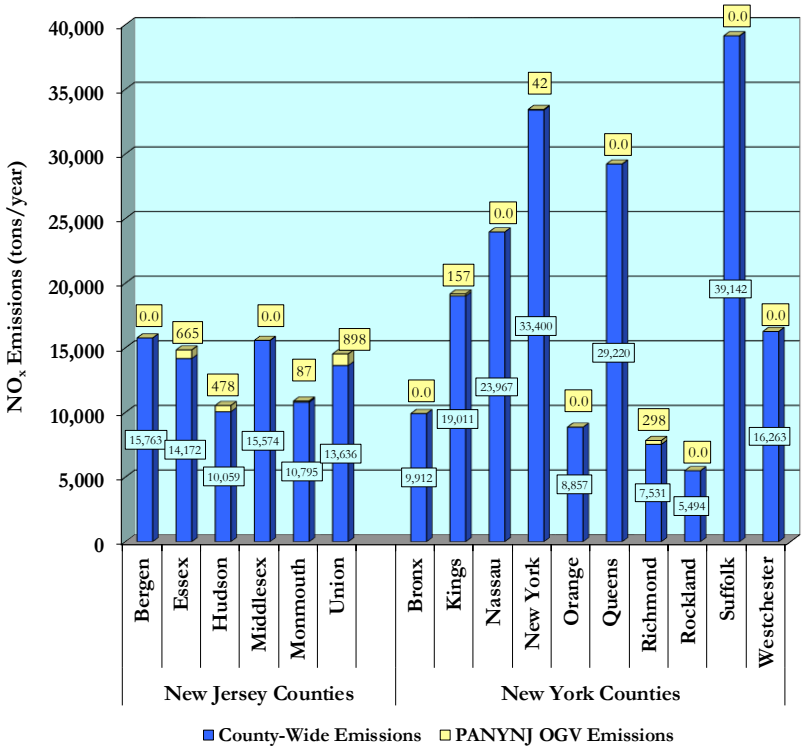


Table 5.7: Comparison of Ocean Going Vessel PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen County	NJ	3,896	0	0.0%
Essex County	NJ	2,631	42	1.6%
Hudson County	NJ	1,641	28	1.7%
Middlesex County	NJ	4,486	0	0.0%
Monmouth County	NJ	3,406	4	0.1%
Union County	NJ	2,761	51	1.8%
New Jersey subtotal		**18,821**	**125**	**0.7%**
Bronx County	NY	2,713	0	0.0%
Kings County	NY	4,984	8	0.2%
Nassau County	NY	6,975	0	0.0%
New York County	NY	7,049	2	0.0%
Orange County	NY	7,645	0	0.0%
Queens County	NY	5,881	0	0.0%
Richmond County	NY	1,972	14	0.7%
Rockland County	NY	2,149	0	0.0%
Suffolk County	NY	14,340	0	0.0%
Westchester County	NY	7,023	0	0.0%
New York Subtotal		**60,730**	**25**	**0.0%**
TOTAL		**79,551**	**150**	**0.2%**

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

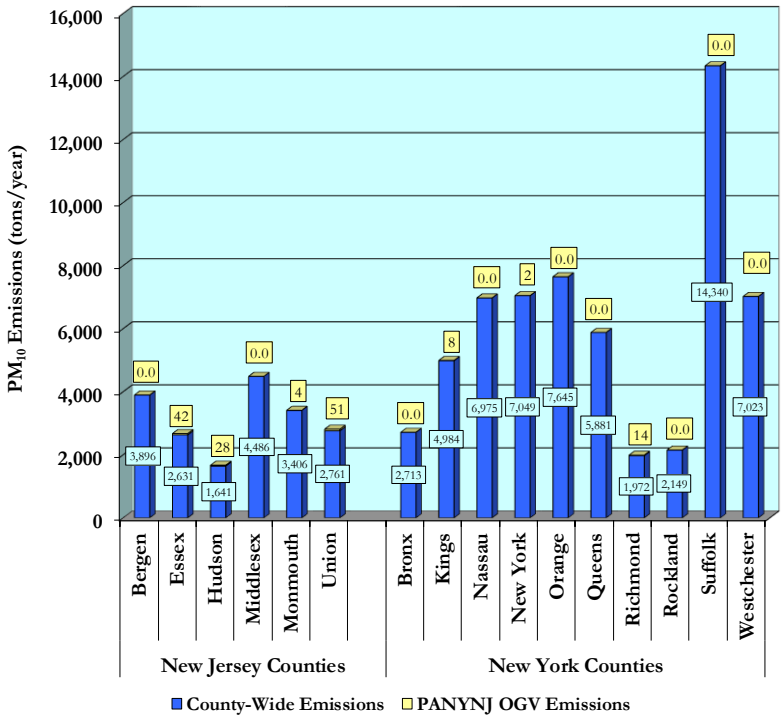


Table 5.8: Comparison of Ocean Going Vessel PM2.5 Emissions with Overall PM2.5 Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen County	NJ	2,097	0	0.0%
Essex County	NJ	1,627	34	2.1%
Hudson County	NJ	1,105	23	2.1%
Middlesex County	NJ	2,309	0	0.0%
Monmouth County	NJ	1,635	3	0.2%
Union County	NJ	1,704	42	2.5%
New Jersey subtotal		**10,477**	**103**	**1.0%**
Bronx County	NY	1,407	0	0.0%
Kings County	NY	2,600	7	0.3%
Nassau County	NY	2,984	0	0.0%
New York County	NY	3,295	2	0.1%
Orange County	NY	2,395	0	0.0%
Queens County	NY	3,167	0	0.0%
Richmond County	NY	1,000	12	1.2%
Rockland County	NY	827	0	0.0%
Suffolk County	NY	5,705	0	0.0%
Westchester County	NY	2,540	0	0.0%
New York Subtotal		**25,922**	**20**	**0.1%**
TOTAL		**36,399**	**123**	**0.3%**

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

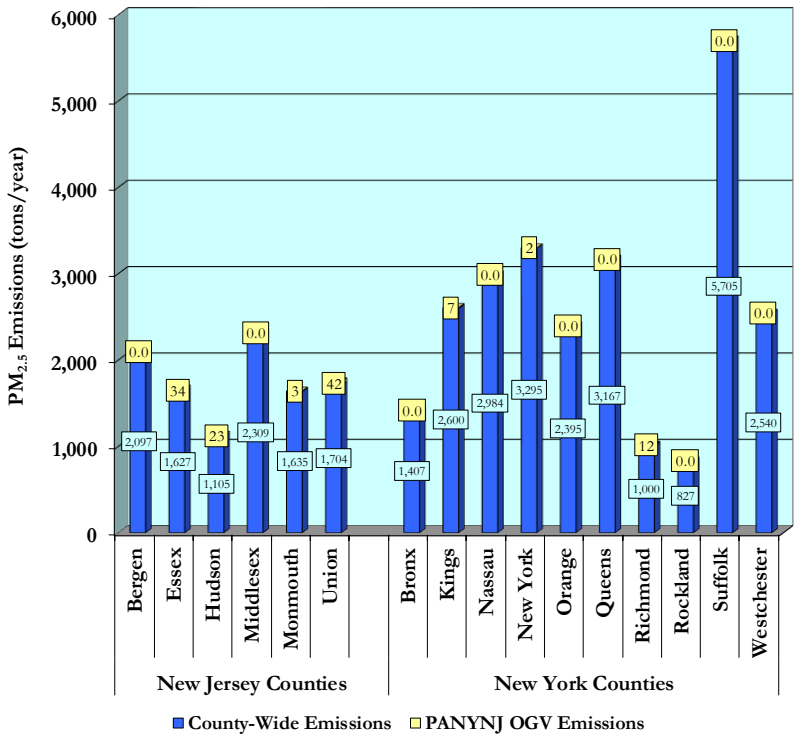


Table 5.9: Comparison of Ocean Going Vessel VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen County	NJ	18,980	0	0.00%
Essex County	NJ	14,151	42	0.30%
Hudson County	NJ	9,429	22	0.24%
Middlesex County	NJ	19,479	0	0.00%
Monmouth County	NJ	19,080	4	0.02%
Union County	NJ	12,608	66	0.52%
New Jersey subtotal		**93,727**	**134**	**0.14%**
Bronx County	NY	13,272	0	0.00%
Kings County	NY	24,871	7	0.03%
Nassau County	NY	27,629	0	0.00%
New York County	NY	20,469	1	0.01%
Orange County	NY	19,383	0	0.00%
Queens County	NY	27,772	0	0.00%
Richmond County	NY	7,600	18	0.23%
Rockland County	NY	8,861	0	0.00%
Suffolk County	NY	49,647	0	0.00%
Westchester County	NY	23,643	0	0.00%
New York Subtotal		**223,147**	**26**	**0.01%**
TOTAL		**316,874**	**160**	**0.05%**

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

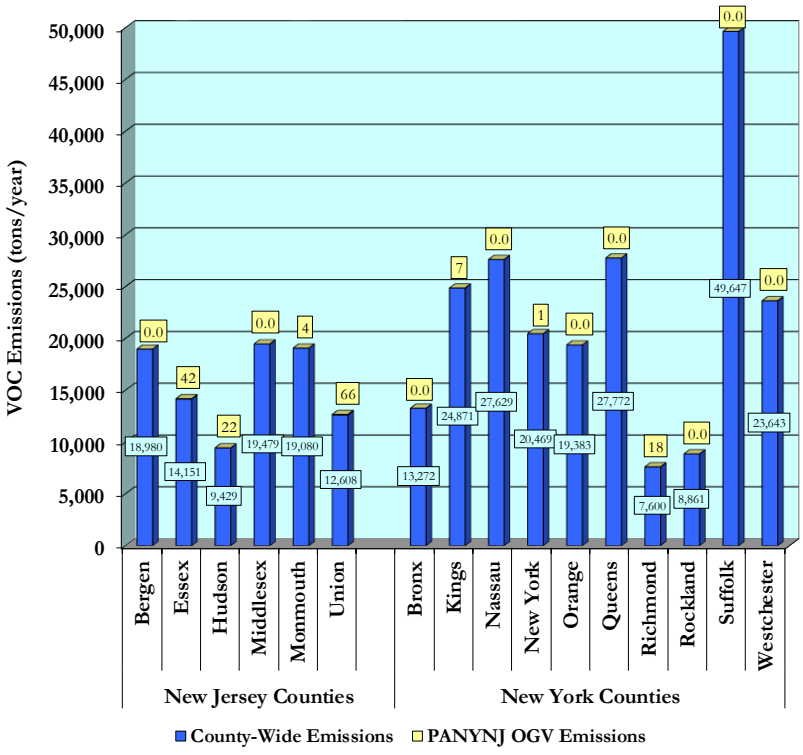


Table 5.10: Comparison of Ocean Going Vessel CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen County	NJ	111,914	0	0.00%
Essex County	NJ	64,014	73	0.11%
Hudson County	NJ	36,789	47	0.13%
Middlesex County	NJ	87,469	0	0.00%
Monmouth County	NJ	71,524	9	0.01%
Union County	NJ	53,352	104	0.20%
New Jersey subtotal		**425,060**	**233**	**0.05%**
Bronx County	NY	36,134	0	0.00%
Kings County	NY	78,793	15	0.02%
Nassau County	NY	143,985	0	0.00%
New York County	NY	109,627	4	0.00%
Orange County	NY	45,498	0	0.00%
Queens County	NY	111,129	0	0.00%
Richmond County	NY	32,985	32	0.10%
Rockland County	NY	33,695	0	0.00%
Suffolk County	NY	212,558	0	0.00%
Westchester County	NY	105,856	0	0.00%
New York Subtotal		**910,259**	**51**	**0.01%**
TOTAL		**1,335,320**	**284**	**0.02%**

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

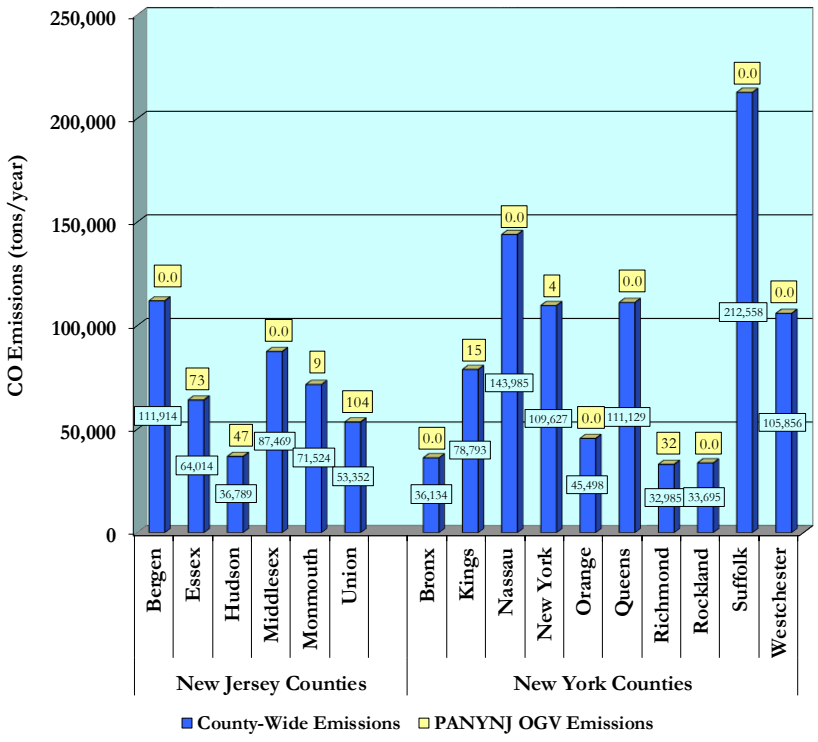


Table 5.11: Comparison of Ocean Going Vessel SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen County	NJ	685	0	0.0%
Essex County	NJ	1,226	161	13.1%
Hudson County	NJ	1,840	109	5.9%
Middlesex County	NJ	785	0	0.0%
Monmouth County	NJ	687	15	2.2%
Union County	NJ	1,583	169	10.7%
New Jersey subtotal		**6,806**	**454**	**6.7%**
Bronx County	NY	1,547	0	0.0%
Kings County	NY	1,525	33	2.1%
Nassau County	NY	2,563	0	0.0%
New York County	NY	5,574	9	0.2%
Orange County	NY	6,251	0	0.0%
Queens County	NY	2,513	0	0.0%
Richmond County	NY	409	47	11.4%
Rockland County	NY	297	0	0.0%
Suffolk County	NY	7,875	0	0.0%
Westchester County	NY	2,137	0	0.0%
New York Subtotal		**30,691**	**88**	**0.3%**
TOTAL		**37,497**	**542**	**1.4%**

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

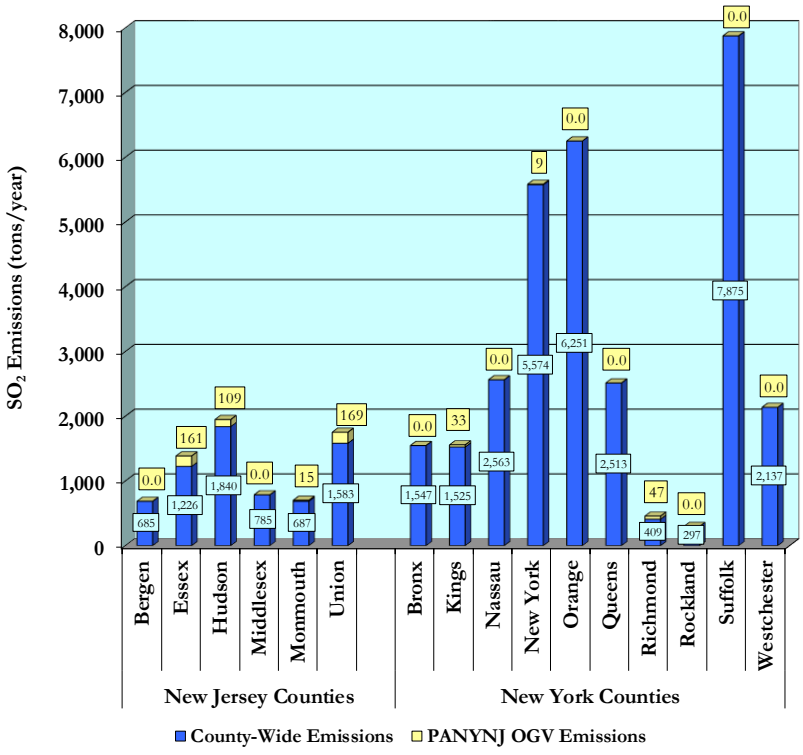
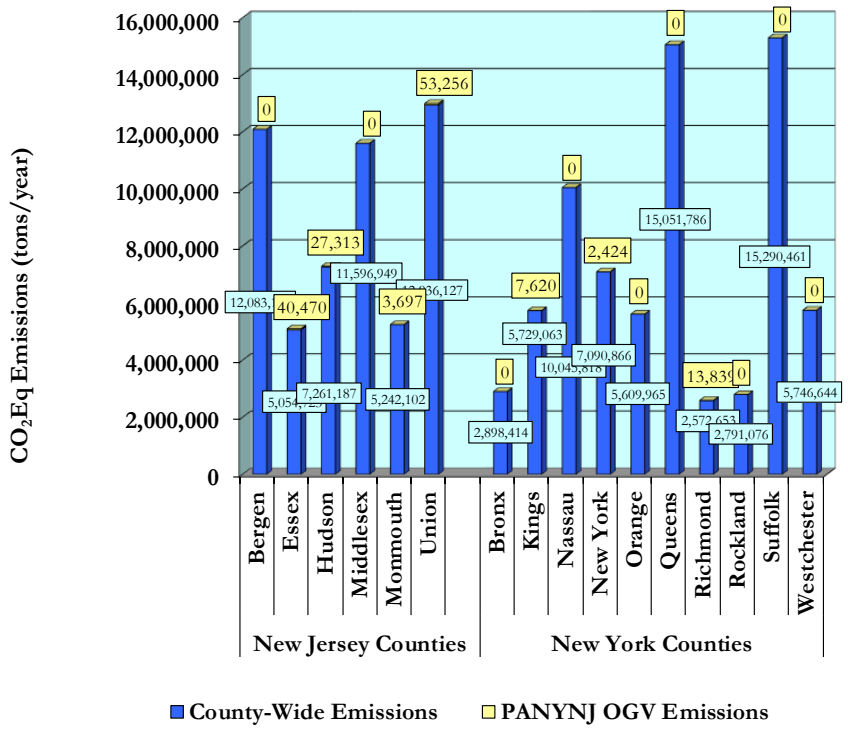


Table 5.12: Comparison of Ocean Going Vessel CO_2e. Emissions with Overall CO_2e Emissions by County, tpy

County	State	County-Wide Emissions	OGV Emissions in Inventory	Percent of Total
Bergen County	NJ	12,083,110	0	0.0%
Essex County	NJ	5,054,723	40,470	0.8%
Hudson County	NJ	7,261,187	27,313	0.4%
Middlesex County	NJ	11,596,949	0	0.0%
Monmouth County	NJ	5,242,102	3,697	0.1%
Union County	NJ	12,936,127	53,256	0.4%
New Jersey subtotal		**54,174,197**	**124,736**	**0.2%**
Bronx County	NY	2,898,414	0	0.0%
Kings County	NY	5,729,063	7,620	0.1%
Nassau County	NY	10,045,818	0	0.0%
New York County	NY	7,090,866	2,424	0.0%
Orange County	NY	5,609,965	0	0.0%
Queens County	NY	15,051,786	0	0.0%
Richmond County	NY	2,572,653	13,839	0.5%
Rockland County	NY	2,791,076	0	0.0%
Suffolk County	NY	15,290,461	0	0.0%
Westchester County	NY	5,746,644	0	0.0%
New York Subtotal		**72,826,745**	**23,883**	**0.0%**
TOTAL		**127,000,943**	**148,619**	**0.1%**

Figure 5.8: Comparison of Ocean Going Vessel CO_2e Emissions with Overall CO_2e 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 5.13 summarizes estimated criteria pollutant emissions from these vessels at the county level. The subsequent tables, 5.14 through 5.20, 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 5.13: Summary of Harbor Craft Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	1.90	0.06	0.06	0.07	0.32	0.00	112
Essex	NJ	72.66	2.38	2.32	2.66	12.15	0.06	4,308
Hudson	NJ	63.64	2.09	2.03	2.34	10.61	0.05	3,764
Middlesex	NJ	13.40	0.44	0.43	0.49	2.23	0.01	791
Monmouth	NJ	9.88	0.32	0.32	0.36	1.64	0.01	583
Union	NJ	95.55	3.13	3.05	3.50	15.98	0.08	5,665
New Jersey subtotal		**257.0**	**8.4**	**8.2**	**9.4**	**42.9**	**0.2**	**15,224**
Bronx	NY	0.35	0.01	0.01	0.01	0.06	0.00	21
Kings (Brookl	NY	12.43	0.41	0.40	0.46	2.07	0.01	735
Nassau	NY	2.54	0.08	0.08	0.09	0.42	0.00	150
New York	NY	3.44	0.11	0.11	0.13	0.57	0.00	203
Orange	NY	2.19	0.07	0.07	0.08	0.36	0.00	129
Queens	NY	3.88	0.13	0.12	0.14	0.65	0.00	229
Richmond (St	NY	79.15	2.59	2.53	2.91	13.19	0.07	4,677
Rockland	NY	2.68	0.09	0.09	0.10	0.45	0.00	158
Suffolk	NY	8.68	0.28	0.28	0.32	1.44	0.01	512
Westchester	NY	3.32	0.11	0.11	0.12	0.55	0.00	196
New York subtotal		**118.7**	**3.9**	**3.8**	**4.4**	**19.8**	**0.10**	**7,011**
TOTAL		**376**	**12**	**12**	**14**	**63**	**0.3**	**22,236**

Table 5.14: 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	15,763	2	0.01%
Essex	NJ	14,172	73	0.51%
Hudson	NJ	10,059	64	0.63%
Middlesex	NJ	15,574	13	0.09%
Monmouth	NJ	10,795	10	0.09%
Union	NJ	13,636	96	0.70%
New Jersey Subtotal		**79,999**	**257**	**0.32%**
Bronx	NY	9,912	0	0.00%
Kings (Brooklyn)	NY	19,011	12	0.07%
Nassau	NY	23,967	3	0.01%
New York	NY	33,400	3	0.01%
Orange	NY	8,857	2	0.02%
Queens	NY	29,220	4	0.01%
Richmond (Staten Isld)	NY	7,531	79	1.05%
Rockland	NY	5,494	3	0.05%
Suffolk	NY	39,142	9	0.02%
Westchester	NY	16,263	3	0.02%
New York Subtotal		**192,797**	**119**	**0.06%**
TOTAL		**272,796**	**376**	**0.14%**

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

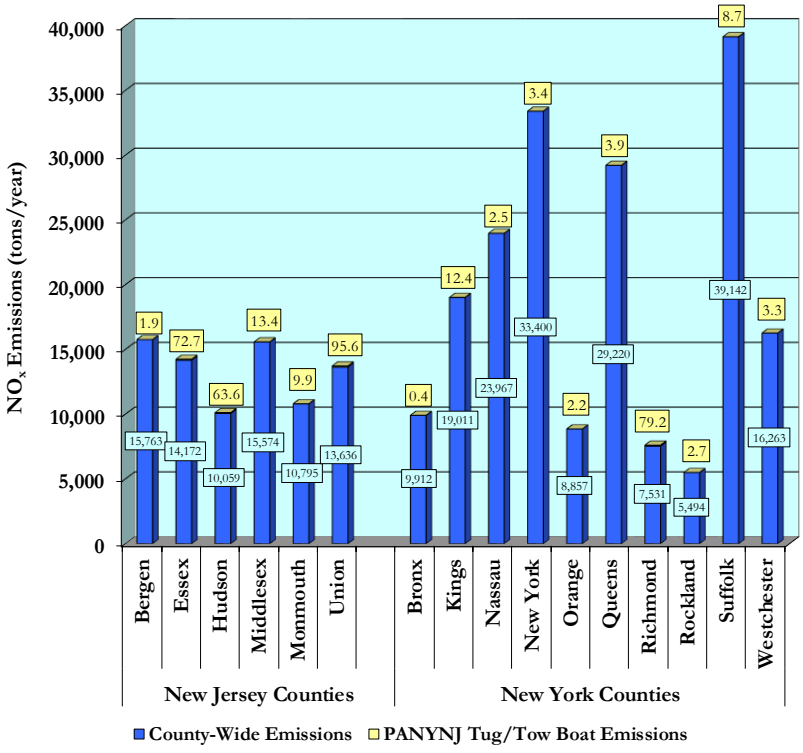


Table 5.15: Comparison of Harbor Craft PM_{10} Emissions with Overall PM_{10} Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	3,896	0	0.00%
Essex	NJ	2,631	2	0.09%
Hudson	NJ	1,641	2	0.13%
Middlesex	NJ	4,486	0	0.01%
Monmouth	NJ	3,406	0	0.01%
Union	NJ	2,761	3	0.11%
New Jersey Subtotal		**18,821**	**8**	**0.04%**
Bronx	NY	2,713	0	0.00%
Kings (Brooklyn)	NY	4,984	0	0.01%
Nassau	NY	6,975	0	0.00%
New York	NY	7,049	0	0.00%
Orange	NY	7,645	0	0.00%
Queens	NY	5,881	0	0.00%
Richmond (Staten Isld)	NY	1,972	3	0.13%
Rockland	NY	2,149	0	0.00%
Suffolk	NY	14,340	0	0.00%
Westchester	NY	7,023	0	0.00%
New York Subtotal		**60,730**	**4**	**0.01%**
TOTAL		**79,551**	**12**	**0.02%**

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

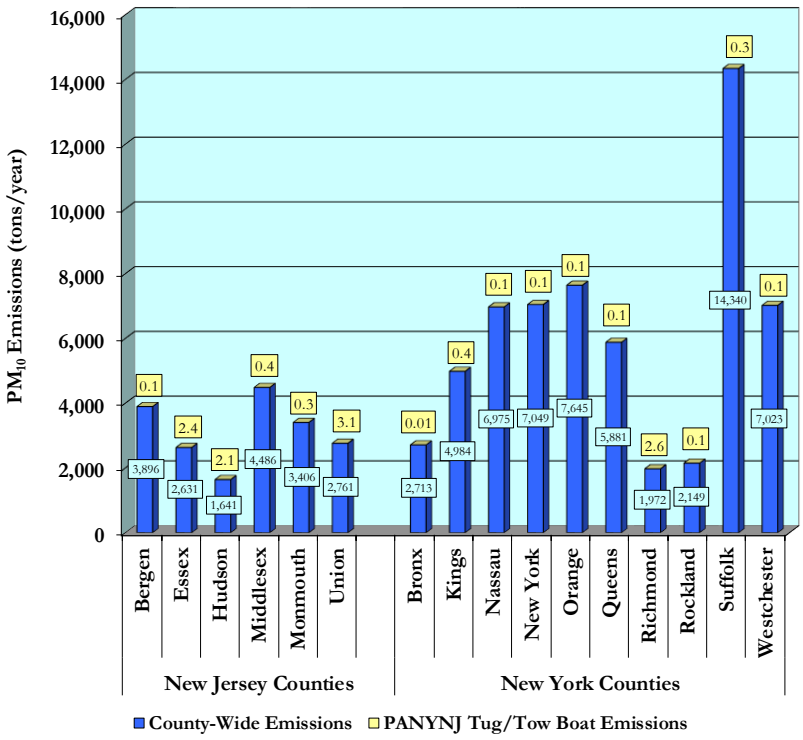


Table 5.16: Comparison of Harbor Craft $PM_{2.5}$ Emissions with Overall $PM_{2.5}$ Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	2,097	0	0.00%
Essex	NJ	1,627	2	0.14%
Hudson	NJ	1,105	2	0.18%
Middlesex	NJ	2,309	0	0.02%
Monmouth	NJ	1,635	0	0.02%
Union	NJ	1,704	3	0.18%
New Jersey Subtotal		**10,477**	**8**	**0.08%**
Bronx	NY	1,407	0	0.00%
Kings (Brooklyn)	NY	2,600	0	0.02%
Nassau	NY	2,984	0	0.00%
New York	NY	3,295	0	0.00%
Orange	NY	2,395	0	0.00%
Queens	NY	3,167	0	0.00%
Richmond (Staten Isld)	NY	1,000	3	0.25%
Rockland	NY	827	0	0.01%
Suffolk	NY	5,705	0	0.00%
Westchester	NY	2,540	0	0.00%
New York Subtotal		**25,922**	**4**	**0.01%**
TOTAL		**36,399**	**12**	**0.03%**

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

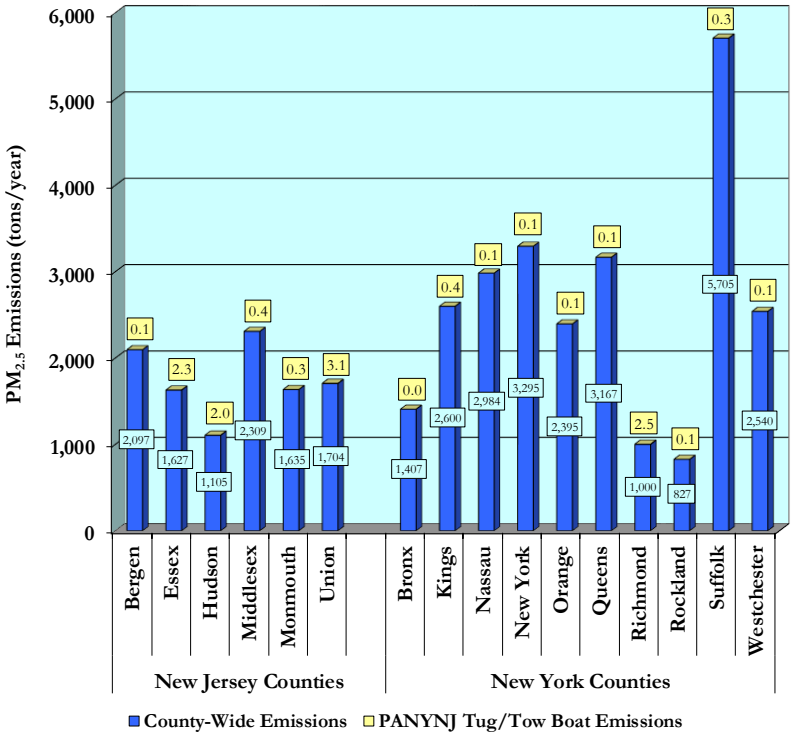


Table 5.17: Comparison of Harbor Craft VOC Emissions with Overall VOC Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	18,980	0	0.000%
Essex	NJ	14,151	3	0.019%
Hudson	NJ	9,429	2	0.025%
Middlesex	NJ	19,479	0	0.003%
Monmouth	NJ	19,080	0	0.002%
Union	NJ	12,608	4	0.028%
New Jersey Subtotal		**93,727**	**9**	**0.010%**
Bronx	NY	13,272	0	0.000%
Kings (Brooklyn)	NY	24,871	0	0.002%
Nassau	NY	27,629	0	0.000%
New York	NY	20,469	0	0.001%
Orange	NY	19,383	0	0.000%
Queens	NY	27,772	0	0.001%
Richmond (Staten Isld)	NY	7,600	3	0.038%
Rockland	NY	8,861	0	0.001%
Suffolk	NY	49,647	0	0.001%
Westchester	NY	23,643	0	0.001%
New York Subtotal		**223,147**	**4**	**0.002%**
TOTAL		**316,874**	**14**	**0.004%**

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

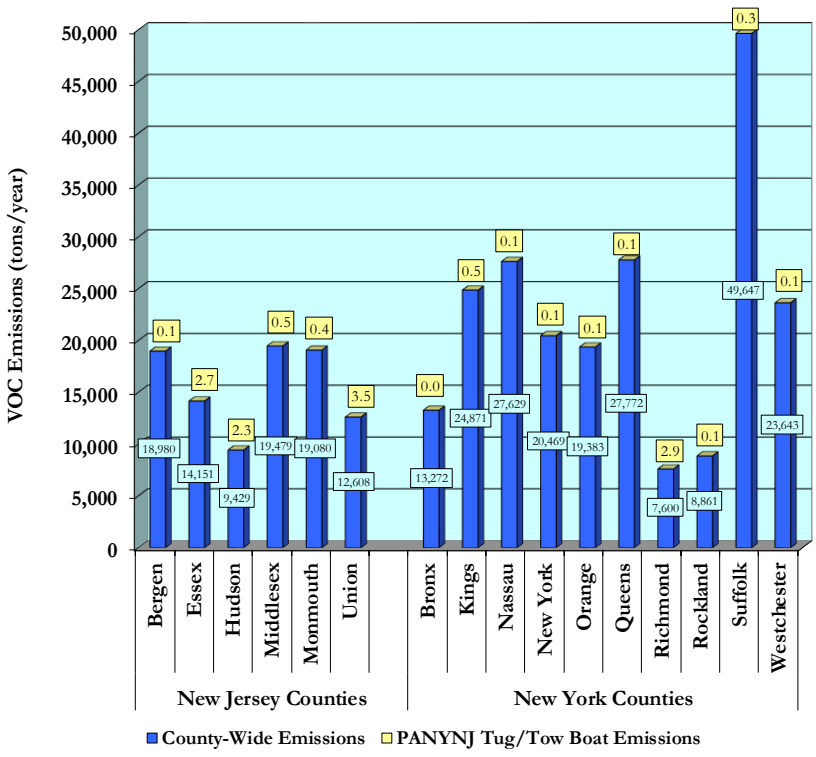


Table 5.18: Comparison of Harbor Craft CO Emissions with Overall CO Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	111,914	0	0.000%
Essex	NJ	64,014	12	0.019%
Hudson	NJ	36,789	11	0.029%
Middlesex	NJ	87,469	2	0.003%
Monmouth	NJ	71,524	2	0.002%
Union	NJ	53,352	16	0.030%
New Jersey Subtotal		**425,060**	**43**	**0.010%**
Bronx	NY	36,134	0	0.000%
Kings (Brooklyn)	NY	78,793	2	0.003%
Nassau	NY	143,985	0	0.000%
New York	NY	109,627	1	0.001%
Orange	NY	45,498	0	0.001%
Queens	NY	111,129	1	0.001%
Richmond (Staten Isld)	NY	32,985	13	0.040%
Rockland	NY	33,695	0	0.001%
Suffolk	NY	212,558	1	0.001%
Westchester	NY	105,856	1	0.001%
New York Subtotal		**910,259**	**20**	**0.002%**
TOTAL		**1,335,320**	**63**	**0.005%**

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

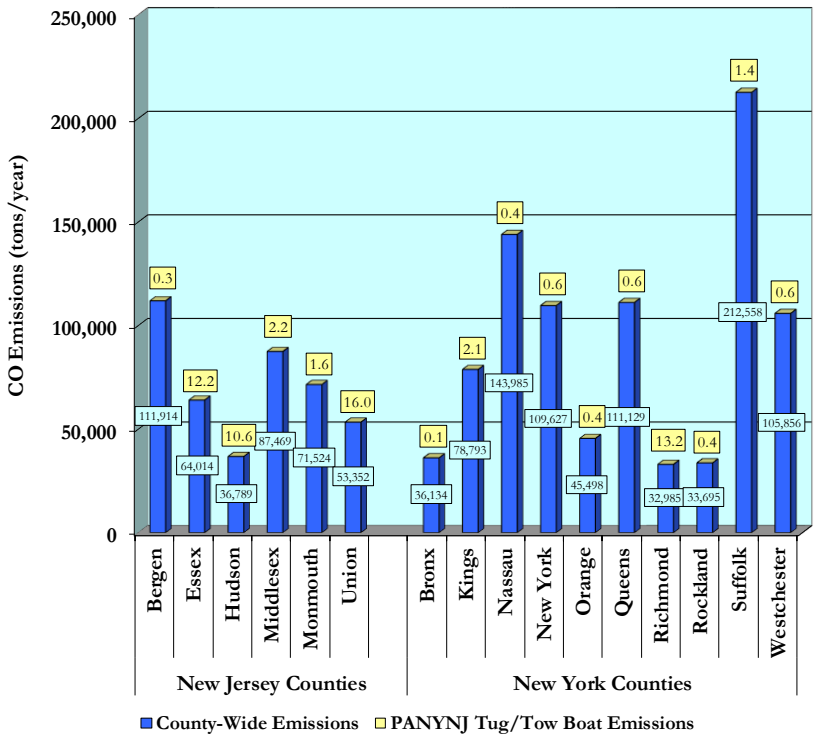


Table 5.19: Comparison of Harbor Craft SO_2 Emissions with Overall SO_2 Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	685	0.0	0.00%
Essex	NJ	1,226	0.1	0.01%
Hudson	NJ	1,840	0.1	0.00%
Middlesex	NJ	785	0.0	0.00%
Monmouth	NJ	687	0.0	0.00%
Union	NJ	1,583	0.1	0.01%
New Jersey Subtotal		**6,806**	**0.2**	**0.00%**
Bronx	NY	1,547	0.0	0.000%
Kings (Brooklyn)	NY	1,525	0.0	0.001%
Nassau	NY	2,563	0.0	0.000%
New York	NY	5,574	0.0	0.000%
Orange	NY	6,251	0.0	0.000%
Queens	NY	2,513	0.0	0.000%
Richmond (Staten Isld)	NY	409	0.1	0.016%
Rockland	NY	297	0.0	0.001%
Suffolk	NY	7,875	0.0	0.000%
Westchester	NY	2,137	0.0	0.000%
New York Subtotal		**30,691**	**0.1**	**0.000%**
TOTAL		**37,497**	**0.3**	**0.001%**

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

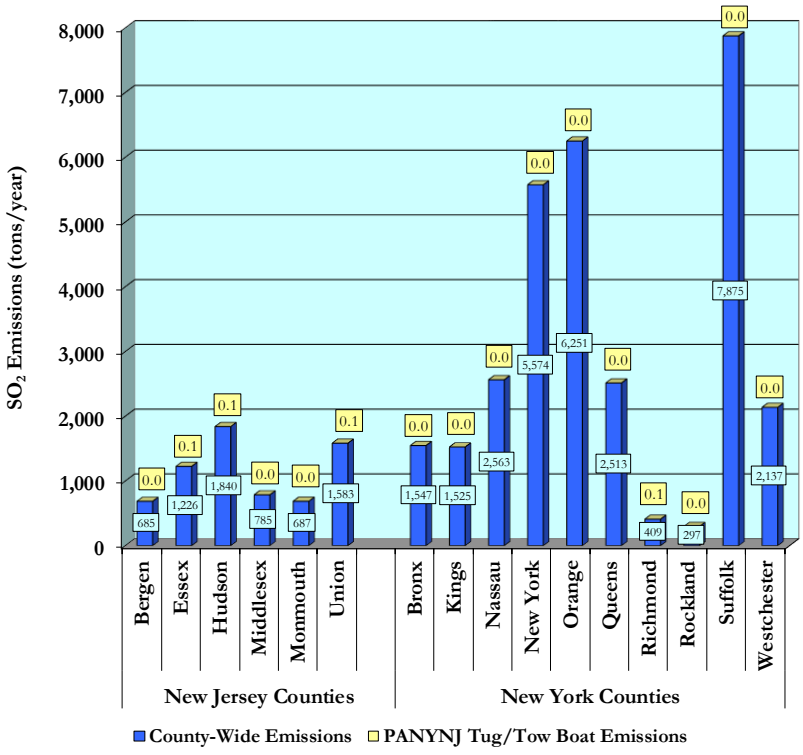
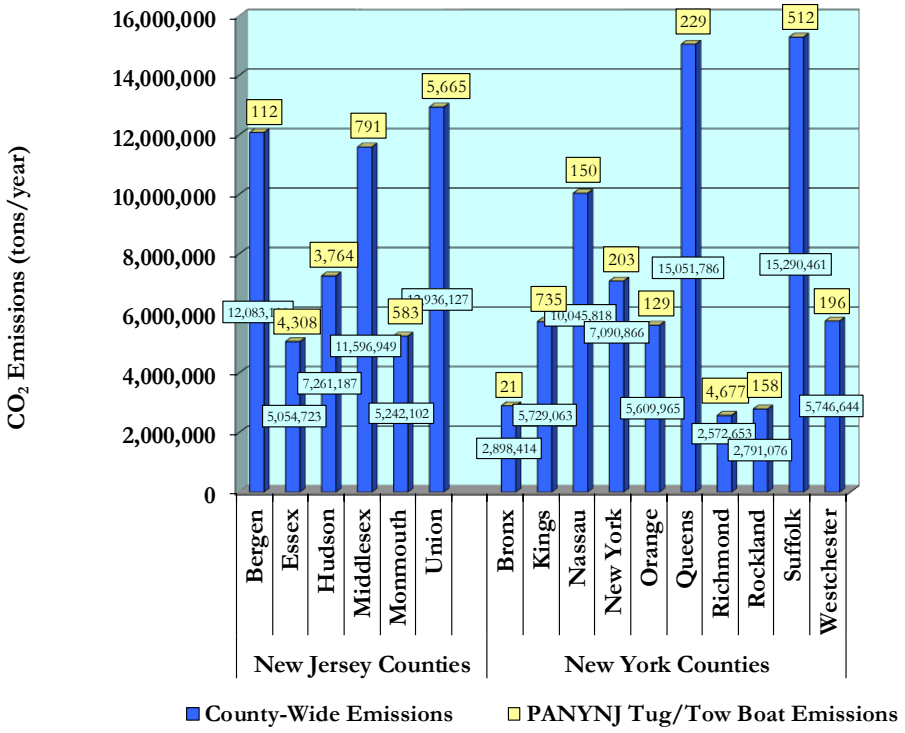


Table 5.20: Comparison of Harbor Craft CO_2e. Emissions with Overall CO_2e Emissions by County, tpy

County	State	County-Wide Emissions	Tug/Tow Boat Emissions in Inventory	Percent of Total
Bergen	NJ	12,083,110	112	0.00%
Essex	NJ	5,054,723	4,308	0.09%
Hudson	NJ	7,261,187	3,764	0.05%
Middlesex	NJ	11,596,949	791	0.01%
Monmouth	NJ	5,242,102	583	0.01%
Union	NJ	12,936,127	5,665	0.04%
New Jersey Subtotal		**54,174,197**	**15,224**	**0.03%**
Bronx	NY	2,898,414	21	0.00%
Kings (Brooklyn)	NY	5,729,063	735	0.01%
Nassau	NY	10,045,818	150	0.00%
New York	NY	7,090,866	203	0.00%
Orange	NY	5,609,965	129	0.00%
Queens	NY	15,051,786	229	0.00%
Richmond (Staten Isld)	NY	2,572,653	4,677	0.18%
Rockland	NY	2,791,076	158	0.01%
Suffolk	NY	15,290,461	512	0.00%
Westchester	NY	5,746,644	196	0.00%
New York Subtotal		**72,826,745**	**7,011**	**0.01%**
TOTAL		**127,000,943**	**22,236**	**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

Changes in OGV emissions between 2014 and prior years' emissions are due to many factors. Contributing factors may include changing levels of cargo of different types, higher proportion of calls by newer ships, programs implemented by the Port Authority to lower emissions, such as the Clean Vessel Incentive Program, and the 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 have been no methodology changes in the quantification of OGV emissions between 2014 and earlier years. Below are programs that had an impact on emissions for 2014 calendar year:

- The North American Emission Control Area (ECA) continued to be in effect for the full year in 2014. 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 continued to be in effect in 2014. During the year, 1,217 calls were made to the Port Authority marine terminals by vessels enrolled in the program, with 251 individual vessels making a total of 617 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 5.21 presents a comparison of 2014 OGV emissions with emissions in earlier inventory years, and Table 5.22 presents 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 2014 estimates, emissions in tons per million TEUs, and the percentage differences in tons per million TEUs between the prior years and 2014. The OGV emissions presented in Table 5.21 estimates emissions to the three nautical mile boundary.

Emissions of PM and SO_2 were lower in 2014 than in the previous 2 years, as shown in Table 5.21. Compared to 2006, all emissions were reduced by lower sulfur fuel and the CVI program, despite the 13% increase in throughput.

Table 5.21: Comparison of 2014 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_2e	Million TEUs
Tons per year, with adjustments								
2014	2,624	150	123	160	284	542	148,619	5.772
2013	2,495	158	127	149	262	652.4	139,772	5.467
2012	2,513	250	197	144	256	1,728.4	143,780	5.530
2010	2,797	294	235	170	289	2,445.1	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 2014 - tons per year								
2013 - 2014	5%	-5%	-3%	7%	8%	-17%	6%	6%
2012 - 2014	4%	-40%	-38%	11%	11%	-69%	3%	4%
2010 - 2014	-6%	-49%	-48%	-6%	-2%	-78%	4%	9%
2008 - 2014	-21%	-54%	-53%	25%	-2%	-84%	-25%	10%
2006 - 2014	-36%	-61%	-60%	-13%	-20%	-85%	-32%	13%
Tons per million TEU								
2014	455	26	21	28	49	94	25,748	
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 2014 - tons per million TEU								
2013 - 2014	0%	-10%	-9%	4%	2%	-21%	1%	
2012 - 2014	0%	-42%	-42%	8%	7%	-70%	-1%	
2010 - 2014	-14%	-54%	-52%	-13%	-11%	-80%	-5%	
2008 - 2014	-28%	-58%	-58%	17%	-11%	-85%	-32%	
2006 - 2014	-44%	-66%	-66%	-22%	-30%	-87%	-40%	

The following figures graphically illustrate the changes in emissions, in tons per year, between the 2006 baseline emissions inventory and the 2014 update. The 2006 emissions are shown in each figure as a dashed line horizontal with the x axis, and the overall percent change between 2006 and 2014 is shown to the right of each chart, with an arrow indicating the direction of change in emissions. The units on the y-axis are tons per year. Inventories were developed for even numbered years between 2006 and 2012, so for the intervening odd-numbered years the charts have been prepared by interpolating between even numbered years. The inventories became annual starting with the 2012 update.

Figure 5.16: NO_x Emissions Trend for OGV

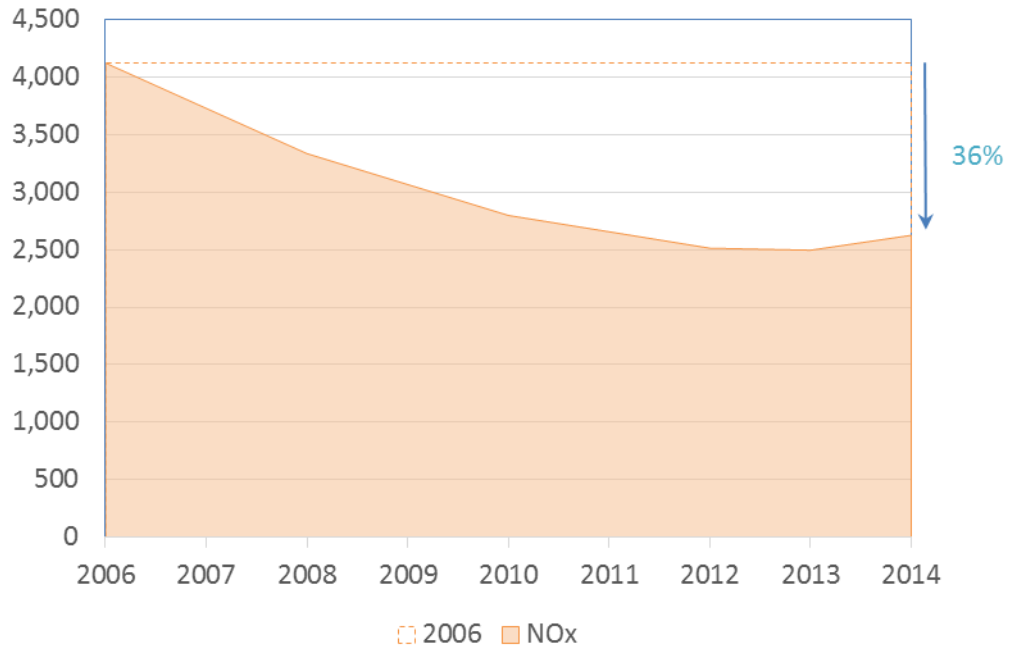


Figure 5.17: PM_{10} Emissions Trend for OGV

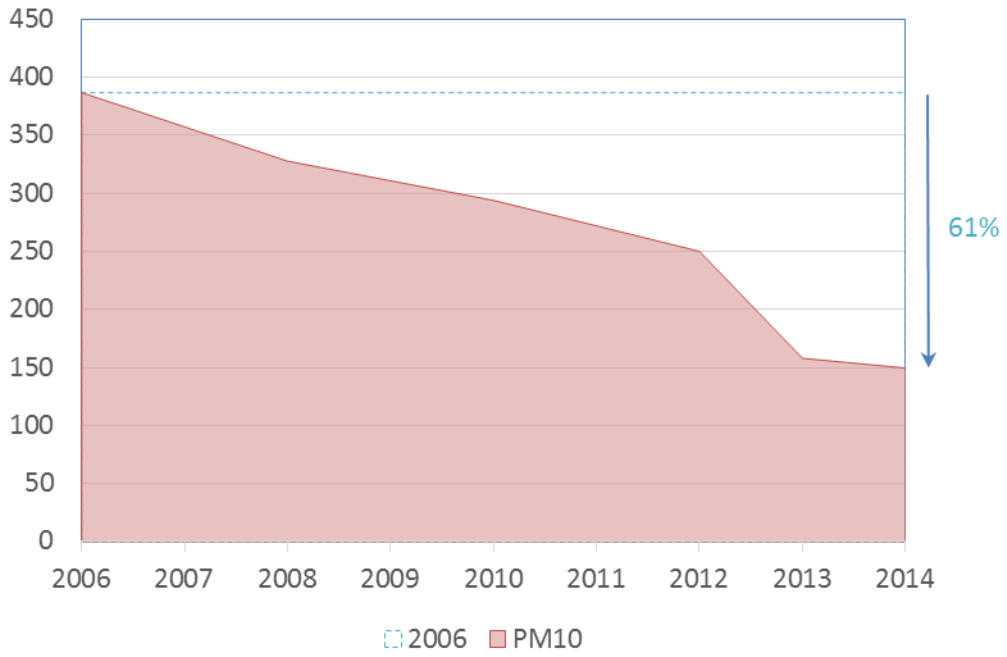


Figure 5.18: $PM_{2.5}$ Emissions Trend for OGV

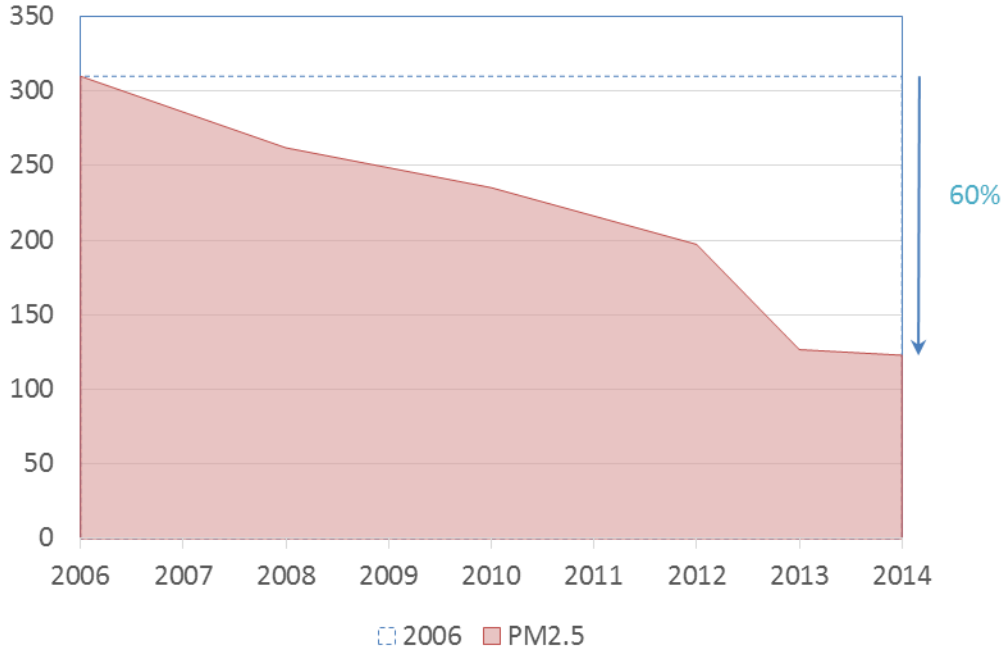


Figure 5.19: VOC Emissions Trend for OGV

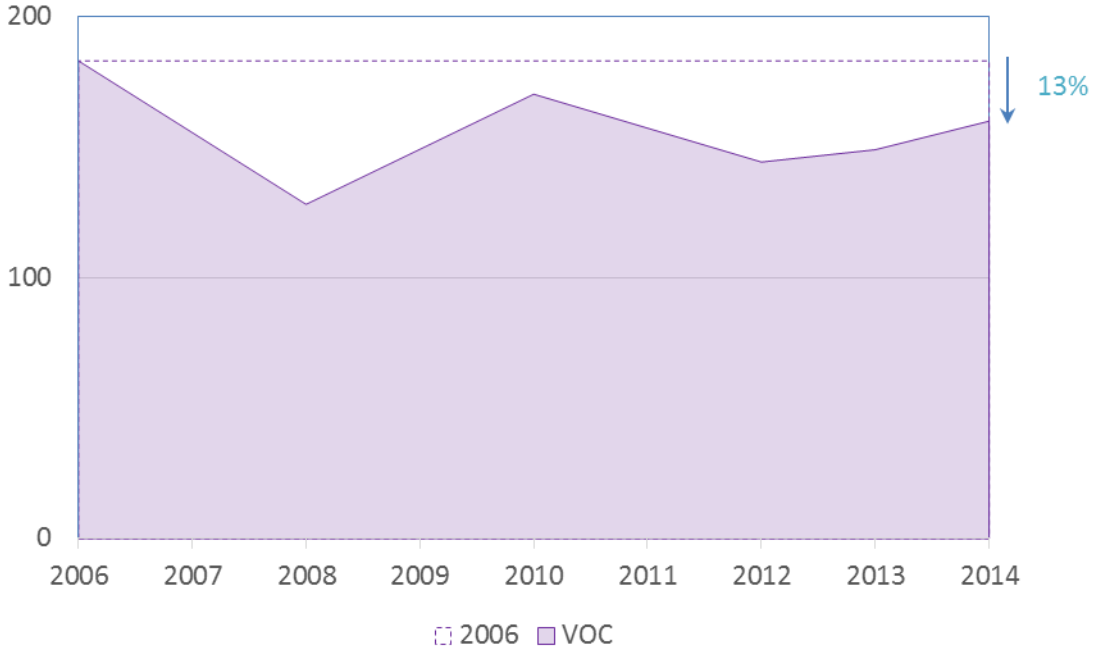


Figure 5.20: CO Emissions Trend for OGV

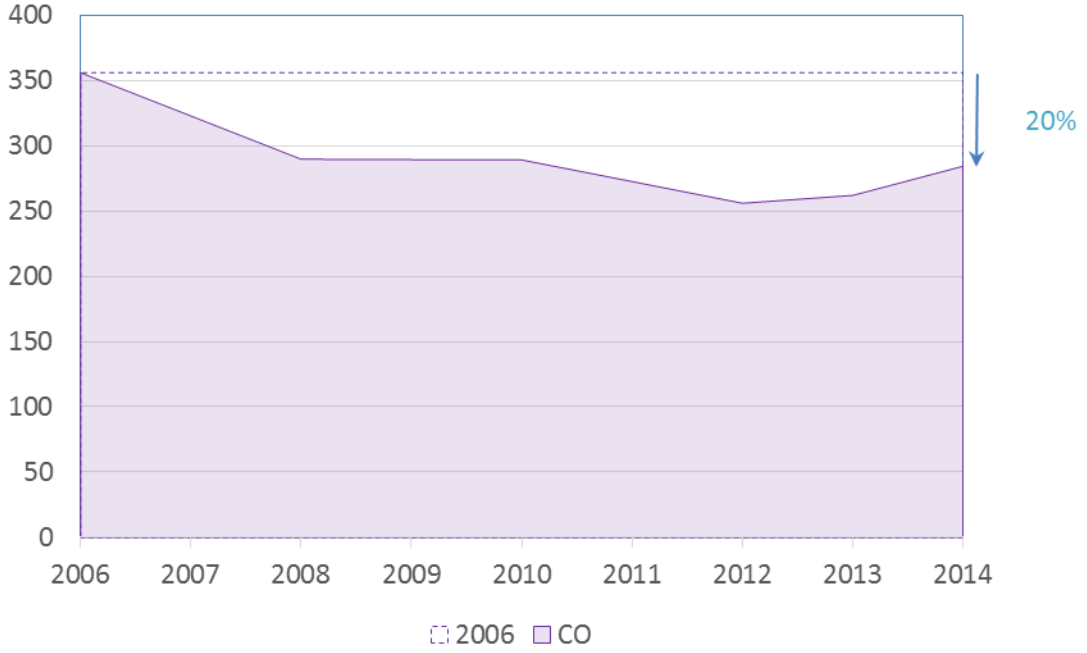


Figure 5.21: SO_2 Emissions Trend for OGV

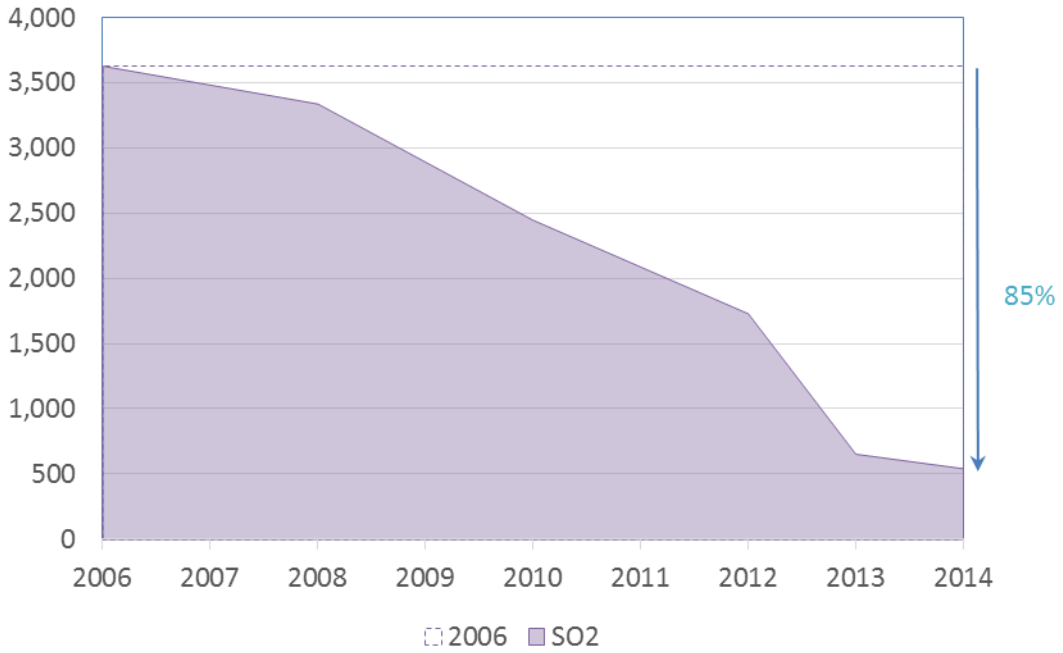


Figure 5.22: CO_2 Emissions Trend for OGV

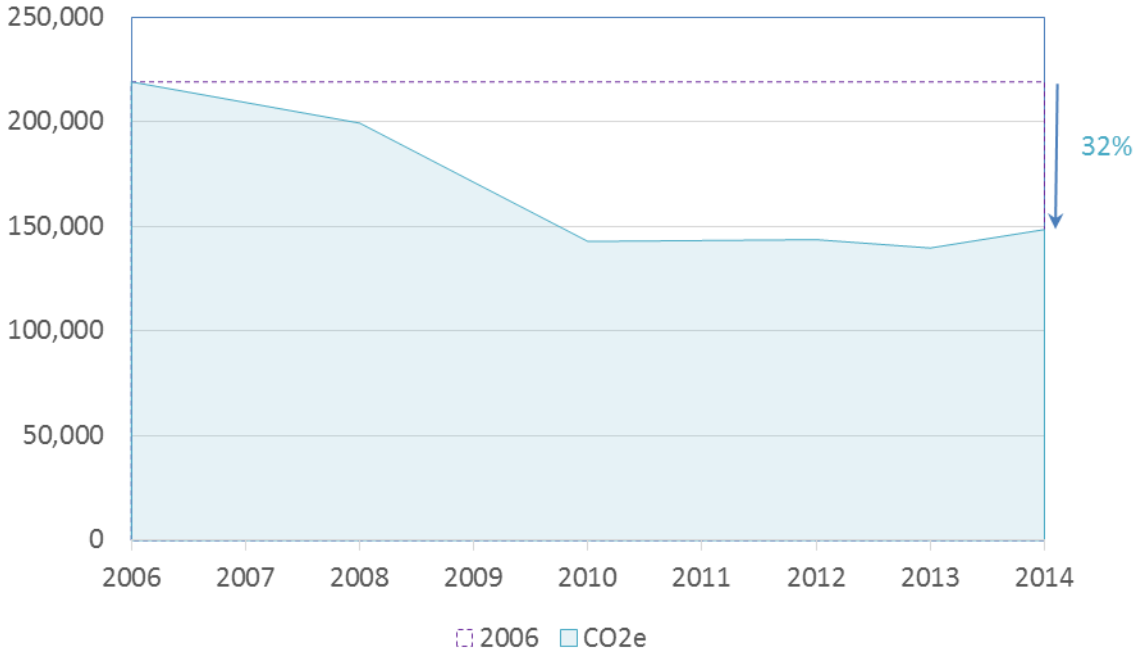


Table 5.22 presents the harbor craft emissions comparison to prior years' emissions, followed by trend charts graphically illustrating the changes in emissions, in tons per year, between the 2006 baseline emissions inventory and the 2014 update, as for the preceding OGV trend charts.

Table 5.22: Comparison of 2014 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_2e	Million TEUs
Tons per year, with adjustments								
2014	376	12	12	14	63	0.3	22,236	5.772
2013	384	19	18	15	50	0.5	22,468	5.467
2012	403	22	21	16	45	1.7	22,796	5.530
2010	369	20	19	14	41	7.8	20,871	5.292
2008	443	24	23	17	50	9.4	25,100	5.265
2006	505	27	25	19	43	52.0	27,712	5.093
Percent change relative to 2014 - tons per year								
2013 - 2014	-2%	-34%	-33%	-10%	25%	-35%	-1%	6%
2012 - 2014	-7%	-44%	-44%	-12%	40%	-82%	-2%	4%
2010 - 2014	2%	-38%	-38%	-3%	53%	-96%	7%	9%
2008 - 2014	-15%	-49%	-49%	-20%	26%	-97%	-11%	10%
2006 - 2014	-26%	-55%	-52%	-27%	46%	-99%	-20%	13%
Tons per million TEU								
2014	65	2.1	2.1	2.4	10.9	0.1	3,852	
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 2014 - tons per million TEU								
2013 - 2014	-7%	-38%	-36%	-14%	18%	0%	-6%	
2012 - 2014	-11%	-48%	-45%	-14%	35%	-67%	-7%	
2010 - 2014	-7%	-45%	-43%	-11%	42%	-93%	-2%	
2008 - 2014	-23%	-54%	-52%	-27%	16%	-94%	-19%	
2006 - 2014	-34%	-61%	-57%	-35%	28%	-99%	-29%	

Figure 5.23: NO_x Emissions Trend for Harbor Craft

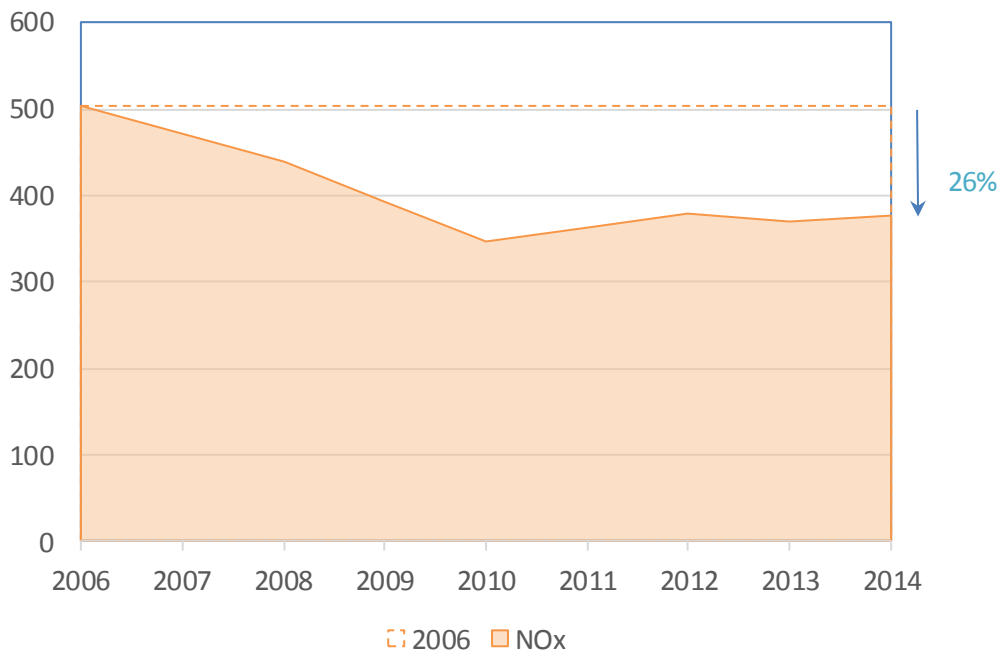


Figure 5.24: PM_{10} Emissions Trend for Harbor Craft

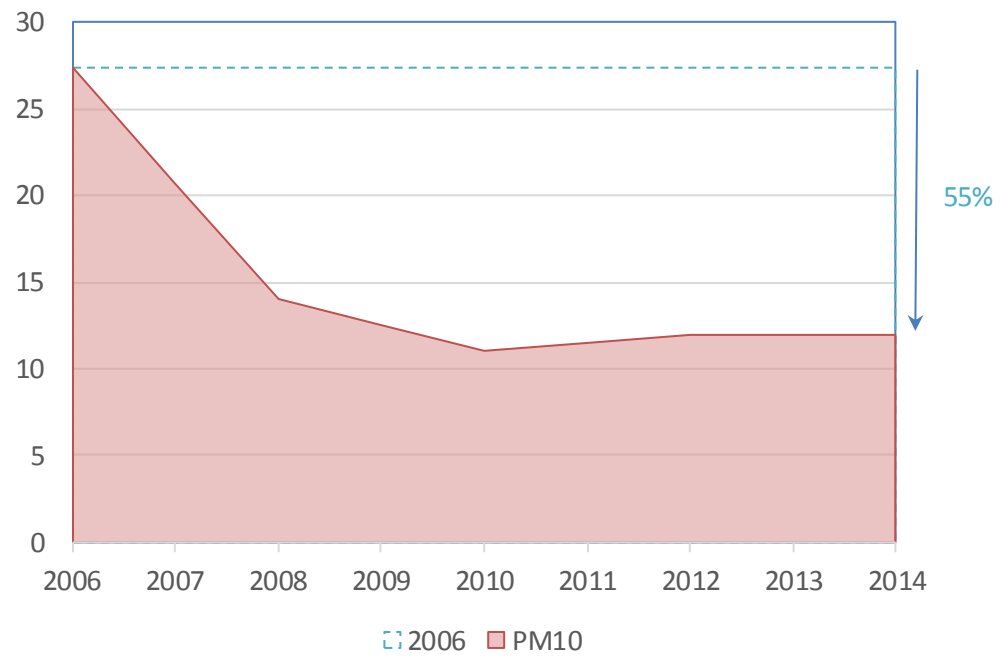


Figure 5.25: $PM_{2.5}$ Emissions Trend for Harbor Craft

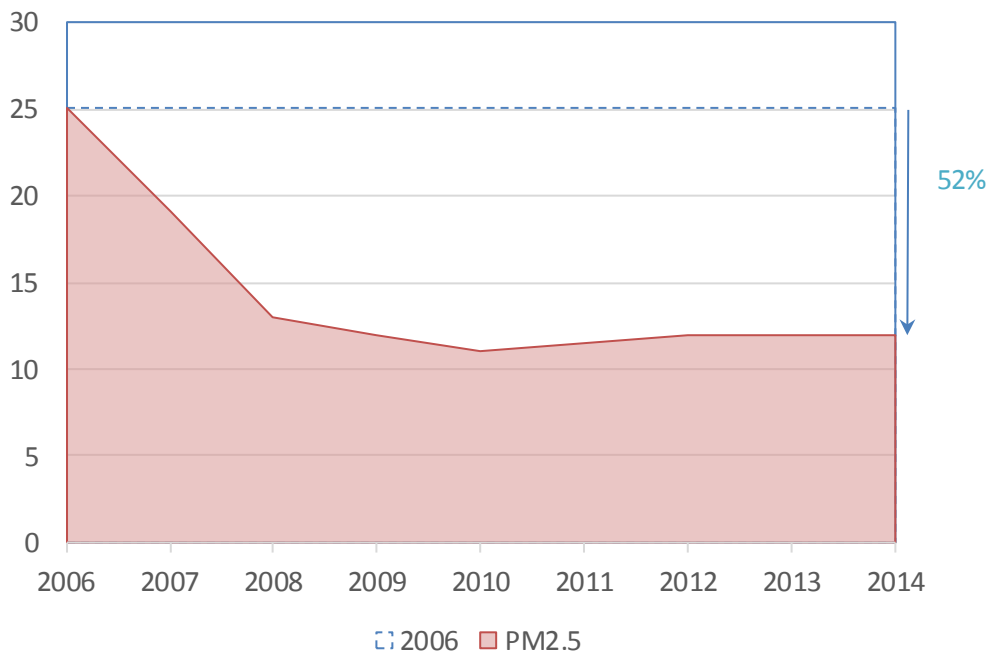


Figure 5.26: VOC Emissions Trend for Harbor Craft

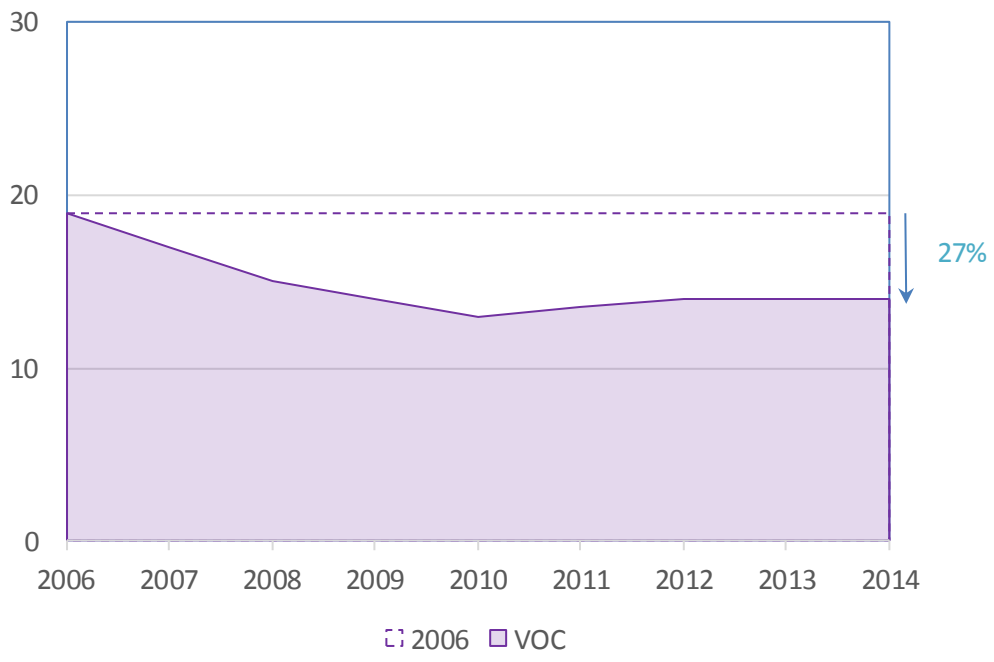


Figure 5.27: CO Emissions Trend for Harbor Craft

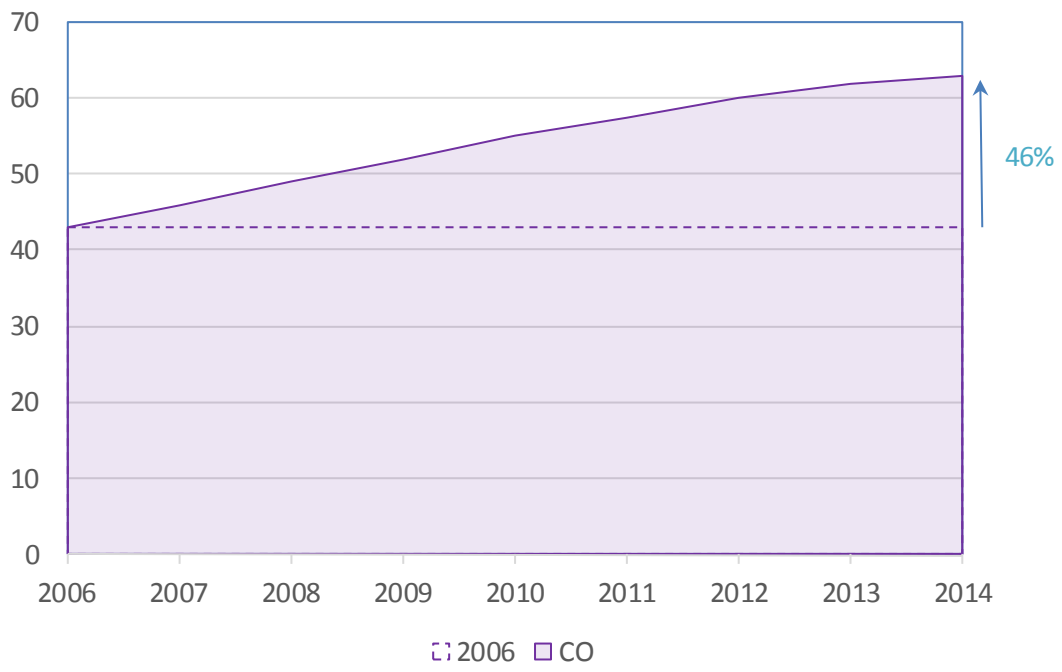


Figure 5.28: SO_2 Emissions Trend for Harbor Craft

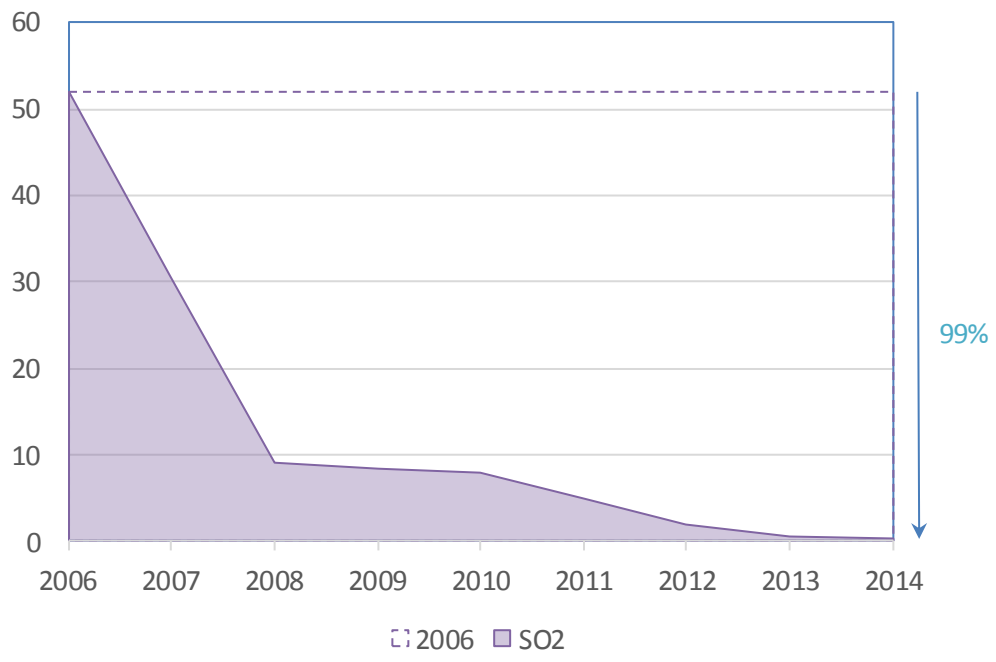
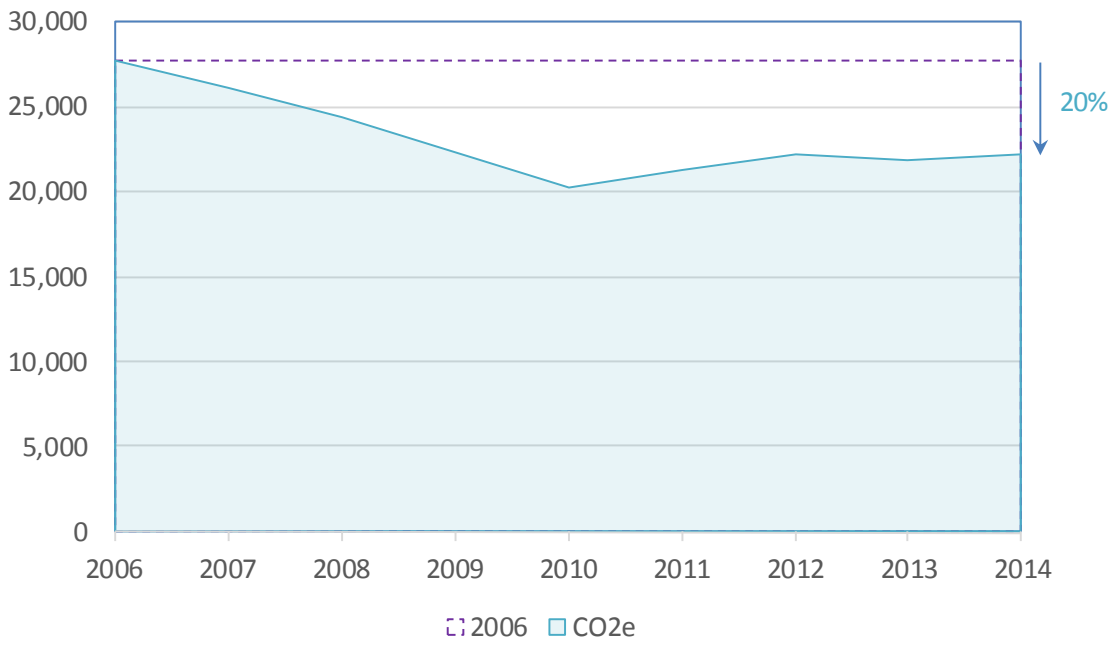


Figure 5.29: CO_2e Emissions Trend for Harbor Craft



In the preceding figures it can be seen that the CO emission trend runs counter to the general trend of lower emissions over time that is seen with the other pollutants. This is due to the emission standards for CO emissions from newer marine engines being generally more relaxed than for older engines. The standards are relaxed somewhat for CO to allow engine manufacturers to meet the more stringent limits established for other pollutants, such as NOx and PM, that are of greater concern to ambient air conditions.

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 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 2014, 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 (main) 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 5.23. While previous years have included calls by refrigerated cargo vessels (commonly known as reefers), the AIS data did not include calls by refers in 2014.

Table 5.23: Vessel Movements for the Port Authority Marine Terminals

Vessel Type	Arrivals/ Calls	Departures	Shifts	Total
Auto Carrier	328	328	63	719
Bulk Carrier	94	94	21	209
Containership	2,199	2,199	74	4472
Cruise Ship	94	94	0	188
General Cargo	32	32	8	72
Miscellaneous	3	3	0	6
RoRo	96	95	52	243
Tanker	79	79	38	196
Total	**2,925**	**2,924**	**256**	**6,105**

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 5.24 lists the minimum, maximum, and average dwell times for the different vessel types and sizes that called at Port Authority terminals.

Table 5.24: Average Dwell Times, hours

Vessel Type	Min	Max	Average
Auto Carrier	3	197	17
Bulk	7	505	111
Bulk - Heavy Load	18	209	123
Containership 1000	2	518	22
Containership 2000	7	40	16
Containership 3000	9	62	24
Containership 4000	4	86	21
Containership 5000	3	108	29
Containership 6000	11	62	24
Containership 7000	15	58	38
Containership 8000	21	227	53
Containership 9000	23	85	45
Cruise	1	58	10
General Cargo	11	393	53
Miscellaneous	6	677	301
Ro-Ro	4	457	18
Tanker - Chemical	9	73	30
Tanker - Handysize	12	19	15
Tanker - Panamax	12	32	22

5.3.1.2 Assist Tugs (Harbor Craft)

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 5.25 lists the number of vessel assists and the average number of assist tugs per arrival or departure for the various vessel types.

Table 5.25: Assist Tug Operating Data and Assumptions

Vessel Type	Inbound trips	Outbound trips	Shifts	Total trips	Average Assists per Movement	Total Assists
Auto Carrier	328	328	63	719	2	1,438
Bulk Carrier	94	94	21	209	2	418
Containership	2,199	2,199	74	4,472	2	8,944
Cruise Ship	94	94	0	188	1	188
General Cargo	32	32	8	72	2	144
Miscellaneous	3	3	0	6	2	12
RoRo	96	95	52	243	2	486
Tanker	79	79	38	196	2	392
Total	**2,925**	**2,924**	**256**	**6,105**		**12,022**

5.3.1.3 Towboats/Pushboats (Harbor Craft)

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 and for vessels with ESI bunker data.

5.3.2.1 OGV Main Engines

Main engine emissions are only estimated for transiting mode 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:

$$E_i = Energy_i \times EF \times FCF \times CF$$

Where:

E_i = Emissions
$Energy_i$ = Energy demand, calculated using the equation below as the energy output of the engine(s) or boiler(s) over the period of time, kW-hr
EF = emission factor, expressed in terms of g/kW-hr
FCF = fuel correction factor, dimensionless (discussed below in subsection 5.3.2.4)
CF = control factor(s) for emission reduction technologies, dimensionless

Energy is calculated using the following equation:

$$Energy_i = Load \times Act$$

Where:

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

Most of the emission factors used to estimate emissions were reported in a 2002 Entec study,[27] updated based on newer information.[28] The PM_{10} and SO_2 emission factors have been based on the following equations[29] for HFO fuel with 2.7% sulfur content:

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

Where:

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

[27] 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.
[28] 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)
[29] Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report, April 2009

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

Where:

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

The 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 5.26 (criteria pollutants) and 5.27 (greenhouse gases).

Table 5.26: 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	18.10	1.42	1.14	0.60	1.40	10.29
Slow Speed Main (Tier 1)	2000 to 2011	17.00	1.42	1.14	0.60	1.40	10.29
Slow Speed Main (Tier 2)	2011 to 2016	15.30	1.42	1.14	0.60	1.40	10.29
Medium Speed Main (Tier 0)	1999 and older	14.00	1.43	1.14	0.50	1.10	11.35
Medium Speed Main (Tier 1)	2000 to 2011	13.00	1.43	1.14	0.50	1.10	11.35
Medium Speed Main (Tier2)	2011 to 2016	11.20	1.43	1.14	0.50	1.10	11.35
Steam Main and Boiler	All	2.10	0.93	0.74	0.10	0.20	16.10
Medium Auxiliary (Tier 0)	1999 and older	14.70	1.44	1.15	0.40	1.10	11.98
Medium Auxiliary (Tier 1)	2000 to 2011	13.00	1.44	1.15	0.40	1.10	11.98
Medium Auxiliary (Tier 2)	2011 to 2016	11.20	1.44	1.15	0.40	1.10	11.98

Table 5.27: 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	0.080	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 5.28 lists the low load adjustment factors (unitless) used in estimating slow speed emissions. Currently, greenhouse gas emission factors are not adjusted for low load operation.

Table 5.28: 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 Load Defaults

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 a 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.[30] Table 5.29 lists the OGV auxiliary load factor assumptions used in this inventory.

Table 5.29: 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
Container - 1000	545	1,058	429
Container - 2000	981	2,180	1,035
Container - 3000	602	2,063	516
Container - 4000	1,434	2,526	1,161
Container - 5000	1,725	3,367	900
Container - 6000	1,453	2,197	990
Container - 7000	1,444	3,357	1,372
Container - 8000	1,494	2,753	902
Container - 9000	1,501	2,942	1,037
Cruise	7,058	9,718	5,353
General Cargo	516	1,439	722
Miscellaneous	793	2,100	467
RoRo	132	396	229
Tanker - Chemical	658	890	816
Tanker - Handysize	537	601	820
Tanker - Panamax	561	763	623

[30] Port of Los Angeles Inventory of Air Emissions, 2014; and Port of Long Beach 2014 Emissions Inventory.

For diesel electric cruise ships, house load defaults are listed in Table 5.30. Most cruise ships that called the cruise terminal were diesel-electric.

Table 5.30: Diesel-Electric Cruise Ship Auxiliary Engine Load, kW

Passenger Range	Sea	Maneuvering	Berth Hotelling
<1,500	3,500	3,500	3,000
1,500 < 2,000	7,000	7,000	6,500
2,000 < 2,500	10,500	10,500	9,500
2,500 < 3,000	11,000	11,000	10,000
3,000 < 3,500	11,500	11,500	10,500
3,500 < 4,000	12,000	12,000	11,000
4,000+	13,000	13,000	12,000

5.3.2.3 OGV Auxiliary Boilers

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

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

Where:

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

As with auxiliary engines, the primary source of load data is from the VBP, and direct values for vessels boarded are used on an individual basis for vessels boarded and their sister ships. There is no load data from the Lloyds database by mode. For vessels not boarded nor have any sister vessels boarded through the VBP, average loads are developed by class from the data available from the VBP program.

Ocean-going tugboats do not have boilers, so their boiler energy default is zero. Auxiliary boilers are not typically used when the main engine load is greater than 20% due to heat recovery systems that are used to produce speed while the ship is underway. If the main engine load is less than or equal to 20%, the maneuvering boiler load defaults shown in the table are used. Auxiliary boiler energy defaults in kilowatts used for each vessel type are presented in Table 5.31.

Table 5.31: Auxiliary Boiler Load Defaults, kW

Vessel Type	Transit	Maneuvering	Berth Dwelling	Anchorage Hotelling
Auto Carrier	253	351	351	351
Bulk	132	132	132	132
Bulk - Heavy Load	132	132	132	132
Container - 1000	241	241	241	241
Container - 2000	325	325	325	325
Container - 3000	474	474	474	474
Container - 4000	492	492	492	492
Container - 5000	545	547	547	547
Container - 6000	577	573	573	573
Container - 7000	538	551	551	551
Container - 8000	650	531	531	531
Container - 9000	475	475	475	475
Cruise	1,482	1,482	1,482	1,482
General Cargo	137	137	137	137
Miscellaneous	137	137	137	137
RoRo	243	243	243	243
Tanker - Chemical	371	371	821	371
Tanker - Handysize	371	371	2,586	371
Tanker - Panamax	371	371	3,293	371

5.3.2.4 OGV Fuel Correction Factors

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 5.32 shows the FCF[31] 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 5.32: Fuel Correction Factors (unitless)

Actual Fuel Used	Sulfur Content by weight %	Fuel Correction Factors							
		NO_x	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	0.154	1.000	1.000	0.007	0.950	0.940	1.000
MDO/MGO	0.01%	0.940	0.152	1.000	1.000	0.004	0.950	0.940	1.000

[31] Port of Los Angeles Inventory of Air Emissions, 2014.

5.3.2.5 Assist Tugs, Towboats, Pushboats (Harbor Craft)

The emission estimating methodology for assist tugs and towboats/pushboats (harbor Craft) 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.

$$\boldsymbol{E = kW \times Act \times LF \times EF \times FCF}$$

Where:

E = emission, g/year
kW = rated horsepower of the engine converted to kilowatts
Act = activity, hours/year
LF = load factor
EF = emission factor, g/kW-hr
FCF = fuel correction factor

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,[32] and which has been used widely since that time. The 43% factor for auxiliary engines is based on the EPA NONROAD model guidance[33] 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[34] 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.

[32] 2001 POLA Baseline Emissions Inventory
[33] EPA, *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling*, December 2002, EPA 420-P-02-014.
[34] California Air Resources Board, *Statewide Commercial Harbor Craft Survey*, Final Report, March 2004.

The fleet composite emission factors used for assist tug, towboat, and pushboat main and auxiliary engines are listed in Table 5.33.

Table 5.33: Harbor Craft 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	11.9	0.39	0.38	0.44	1.97	0.01	690	0.031	0.01
Auxiliary Engines	9.50	0.31	0.30	0.26	2.05	0.01	690	0.03	0.01

The base emission factors[35] are based on marine engine standards (i.e., Tier 1, Tier 2, and Tier 3) and the EPA engine category (1 or 2). 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 2014 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 11 vessels that had main engines with newer engines due vessel repower, new vessels in the fleet, or had engine remanufacture kits installed. Five of the vessels had engines that fell into Tier 1 (IMO regulation for NO_x starting in the year 2000) and six of the vessels had engines that were Tier 2 (EPA regulation that affects engines with model year 2005 and newer). For auxiliary engines, there were 3 vessels with engines that fell into Tier 1, five vessels with engines that fell into Tier 2, and 1 vessel with engines that fell into Tier 3.

In order to account for 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 15 ppm in 2014. The average 15 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.[36]

[35] *Appendix 1 of [73 FR 37243, June 30, 2008, as amended at 75 FR 23012, Apr. 30, 2010.*
[36] *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 5.30: 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 5.31: 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 5.32: 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 5.33: 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 5.34: 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 transport 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 5.35: Tugboat