The Port Authority of New York and New Jersey
Port Department
2016 Multi-Facility Emissions Inventory

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

January 2018

Prepared by:
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THE PORT AUTHORITY OF NY & NJ

PORT DEPARTMENT

2016 MULTI-FACILITY EMISSIONS INVENTORY

JANUARY 2018

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

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List of Acronyms

A	activity
Act	activity, hours
AIS	automatic identification system
BSFC	brake specific fuel consumption
CF	control factor
CHE	cargo handling equipment
CH_4	methane
CMV	commercial marine vessel
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
COLREG	Convention on the International Regulations for Preventing Collision at Sea
CSX	CSX Transportation, a US railroad
CVI	Clean Vessel Incentive Program
E	emissions
ECA	North American Emissions Control Area
EF	emission factor
EI	emissions inventory
EPA	United States Environmental Protection Agency
EPAMT	Elizabeth Port Authority Marine Terminal
ESI	Environmental Ship Index
FCF	fuel correction factor
GCT Bayonne	Global Container Terminal at the Port Jersey Port Authority Marine Terminal
GCT New York	Global Container Terminal at Howland Hook Marine Terminal on Staten Island
GHGs	greenhouse gases
g/hp-hr	grams per horsepower hour
g/mi	grams per mile
g/hr	grams per hour
g/MMGTM	grams of emissions per million gross ton-miles
GTM	gross ton-miles
GVWR	gross vehicle weight rating
GWP	global warming potential
HDDV	heavy-duty diesel vehicle
HFO	heavy fuel oil
hp	horsepower
hp-hr	horsepower hour
IMO	International Maritime Organization
kW	kilowatt
LF	load factor
LPG	liquefied petroleum gas
MDO	marine diesel oil
MOBILE6.2	EPA's prior on-road vehicle emission estimating model
MOVES2014a	EPA's new-generation motor vehicle emission estimating model
NO_x	oxides of nitrogen
N_2O	nitrous oxide
NEI	National Emissions Inventory
NJCCC	New Jersey Clean Cities Coalition
NJDEP	New Jersey Department of Environmental Protection
nm	nautical miles
NONROAD	EPA MOVES modeling option

LIST OF ACRONYMS, CONT

NYCDOT	New York City Department of Transportation
NYNJHS	New York/New Jersey Harbor System
NYNJLINA	New York/New Jersey Long Island Non-Attainment Area
OGV	ocean-going vessel
PANYNJ	Port Authority of New York and New Jersey
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
R-1	US Surface Transportation Board annual report
RAT	Regional Air Team
RFID	radio frequency identification
SCC	source classification code
SFC	specific fuel consumption
SO_2	sulfur dioxide
TEUs	twenty-foot equivalent units
tonnes	metric tons
tons	short tons
tpy	tons per year
ULSD	ultra-low sulfur diesel
VBP	Vessel Boarding Program
VOCs	volatile organic compounds
VMT	vehicle miles traveled

EXECUTIVE SUMMARY

The purpose of this emissions inventory (EI) report is to present and explain the estimates of air emissions generated in 2016 by mobile emission sources associated with the marine terminal activities linked to facilities maintained by the Port Authority of New York and New Jersey (Port Authority or PANYNJ) and leased to private terminal operators. These mobile emission sources include land-based mobile sources (cargo handling equipment, heavy-duty diesel vehicles, and locomotives) and marine mobile sources or commercial marine vessels (ocean-going vessels and harbor craft). This 2016 EI report is an update of the 2015 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 2016 calendar year emissions inventory and report is to provide an update to the emission estimates presented in the previous 2015 inventory report, the report also discusses additional findings. The report includes emissions estimated for the previous years' inventories back to 2006, adjusted to account for emissions modeling changes from year to year. The following figure and table show the year-to-year emission changes, based on the emission estimates that have been adjusted to account for methodology changes.

Figure ES.1 graphically illustrates the changes in port-wide emissions of NO_x, PM_{10}, SO_2 and CO_2 between the 2006 baseline emissions inventory and the 2016 update, with emission trend lines superimposed over the annual TEU throughput (in millions). The figure shows that although TEU has increased, emissions have decreased overall since 2006.

Figure ES.1: Port Related Emissions Relative to TEU Throughput

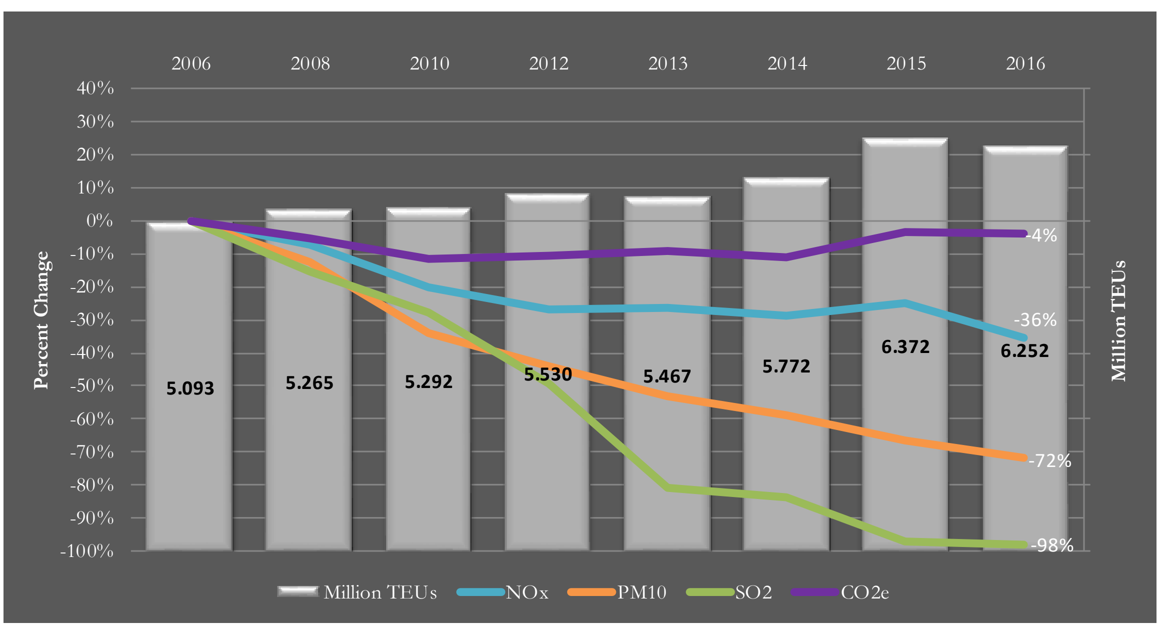


Table ES.1 summarizes the emissions in each year for which an inventory was developed and the percent change relative to 2016. The emissions listed for prior years have been adjusted to account for methodology changes that have occurred as inventory methods or data sources have improved, so they are not the same as the emissions originally reported for these years in the relevant emissions inventory reports. Methodology changes are discussed in each emission source category section. In this table, a negative percent change reflects a reduction in emissions while a positive percent change is an increase in emissions.

Table ES.1: Trends in Emissions over Inventory Years, tpy and %

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e	Million TEUs
Tons per year, with adjustments								
2016	5,707	219	204	326	1,251	77	659,439	6.252
2015	6,663	261	244	403	1,403	103	661,531	6.372
2014	6,337	319	286	377	1,305	640	611,382	5.772
2013	6,515	364	329	392	1,410	771	623,472	5.467
2012	6,511	437	385	387	1,391	2,036	612,208	5.530
2010	7,068	516	448	377	1,334	2,886	606,992	5.292
2008	8,220	685	591	420	1,615	3,396	648,408	5.265
2006	8,868	781	667	482	1,708	4,000	685,221	5.093
Percent change relative to 2016 - tons per year								
2015 - 2016	-14%	-16%	-16%	-19%	-11%	-25%	0%	-2%
2014 - 2016	-10%	-31%	-28%	-14%	-4%	-88%	8%	8%
2013 - 2016	-12%	-40%	-38%	-17%	-11%	-90%	6%	14%
2012 - 2016	-12%	-50%	-47%	-16%	-10%	-96%	8%	13%
2010 - 2016	-19%	-58%	-54%	-14%	-6%	-97%	9%	18%
2008 - 2016	-31%	-68%	-65%	-22%	-23%	-98%	2%	19%
2006 - 2016	-36%	-72%	-69%	-32%	-27%	-98%	-4%	23%

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

- Port Authority maritime emissions of oxides of nitrogen (NO_x) related to the Port Authority marine terminals were 14% lower in tons between 2016 and 2015, and 36% lower than in 2006. On an emissions-per-TEU basis, emissions in 2016 were 13% lower than the 2015 estimates and 48% 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 16% lower in tons in 2016 than in 2015 and 72% lower than in 2006. On an emissions-per-TEU basis, emissions in 2016 were 15% lower than the 2015 estimates and 77% 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 16% lower in tons in 2016 than in 2015 and 69% lower than in 2006. On an emissions-per-TEU basis, emissions in 2016 were 13% lower than the 2015 estimates and 75% lower than the 2006 estimates.
- Port Authority maritime emissions of volatile organic compounds (VOCs) related to the Port Authority marine terminals were 19% lower in tons in 2016 than in 2015 and 32% lower than in 2006. On an emissions-per-TEU basis, emissions in 2016 were 17% lower than the 2015 estimates and 45% lower than the 2006 estimates.
- Port Authority maritime emissions of carbon monoxide (CO) related to the Port Authority marine terminals were 11% lower in tons in 2016 than in 2015 and 27% lower than in 2006. On an emissions-per-TEU basis, emissions in 2016 were 9% lower than the 2015 estimates and 40% lower than the 2006 estimates.
- Port Authority maritime emissions of sulfur dioxide (SO_2) related to the Port Authority marine terminals were 25% lower in tons in 2016 than in 2015 and 98% lower than in 2006. On an emissions-per-TEU basis, emissions in 2016 were 25% lower than the 2015 estimates and 98% 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 essentially the same in 2016 as in 2015 and 4% lower than in 2006. On an emissions-per-TEU basis, emissions in 2016 were 2% higher than the 2015 estimates and 22% 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).

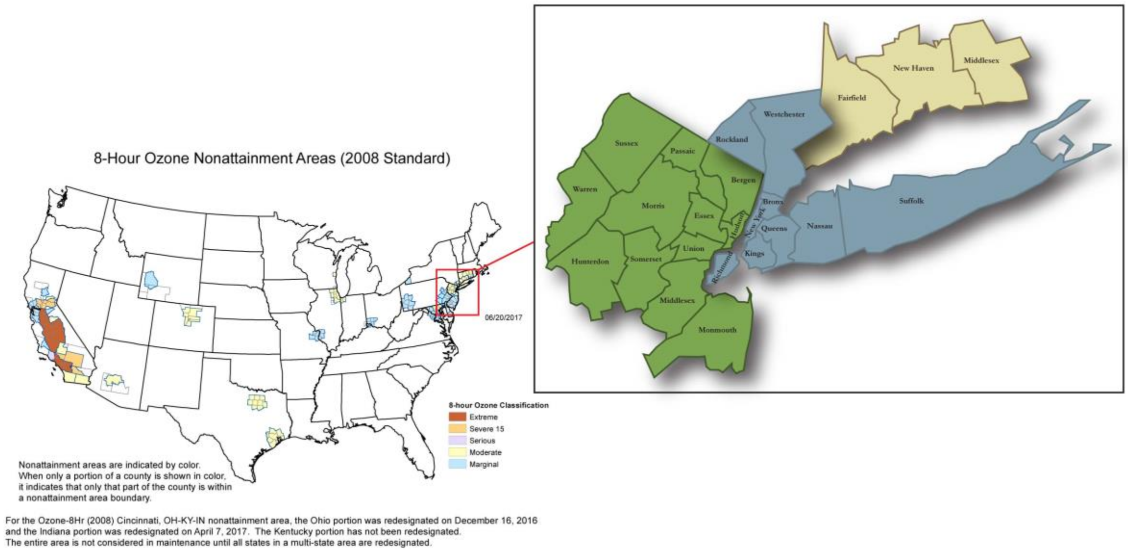
Despite the 23% increase in TEU throughput since 2006, the overall emissions were lower in 2016 as compared to 2006. Key reasons for the emission reductions are listed below and include both regulatory items and measures from the PANYNJ Clean Air Strategy that have been implemented to date. In 2016, the North American Emissions Control Area (ECA) was in effect, as it was in 2015.

- The North American Emissions Control Area, in place since mid-2012 to the end of 2014 requiring 1% sulfur content in fuel oils, was lowered to 0.1% starting in January 2015. The regulation is for fuel used by OGV while transiting within 200 nm of the North American coast and impacts SO_2, NO_x and PM emissions.
- In 2016, cruise vessels at one of the cruise terminals were able to use shore power for the first time, which reduced all emissions.
- The PANYNJ Low-Sulfur Fuel Incentive Program and Clean Vessel Incentive (CVI) Program both provide financial incentives to OGV operators to voluntarily reduce emissions. The impact is mainly reductions in SO_2, NO_x and PM emissions.
- Use of ultra-low sulfur diesel fuel (ULSD) by all land-based emission sources impacts SO_2, NO_x and PM emissions.
- The PANYNJ cargo handling equipment (CHE) modernization program and fleet turnover, plus using electric-powered equipment when possible.
- PANYNJ Truck Replacement Program provided incentives to replace old drayage trucks with cleaner, newer alternatives.
- Adopted truck appointment system reduced vehicle turn times and queuing.
- Tier 4i switchers are being operated for rail-to-barge cross-harbor service.
- The rail-to-barge cross-harbor service took truck trips off the roads.
- Assist tug fleet turnover and repowers accomplished under the New York City Department of Transportation (NYCDOT) and New Jersey Clean Cities Coalition (NJCCC) repower programs.

ES.2 Emission Estimates and Comparison to Regional Emissions

The Port Authority marine terminals included in this report are in a moderate 8-hr ozone nonattainment area for designated counties in New York, northern New Jersey, and Connecticut[2]. Figure ES.2 illustrates the counties that are within the nonattainment area for the 2008 8-hr ozone standard.

Figure ES.2: Map of 8-Hour Ozone Nonattainment Areas for New York, Northern New Jersey, Long Island, and Connecticut

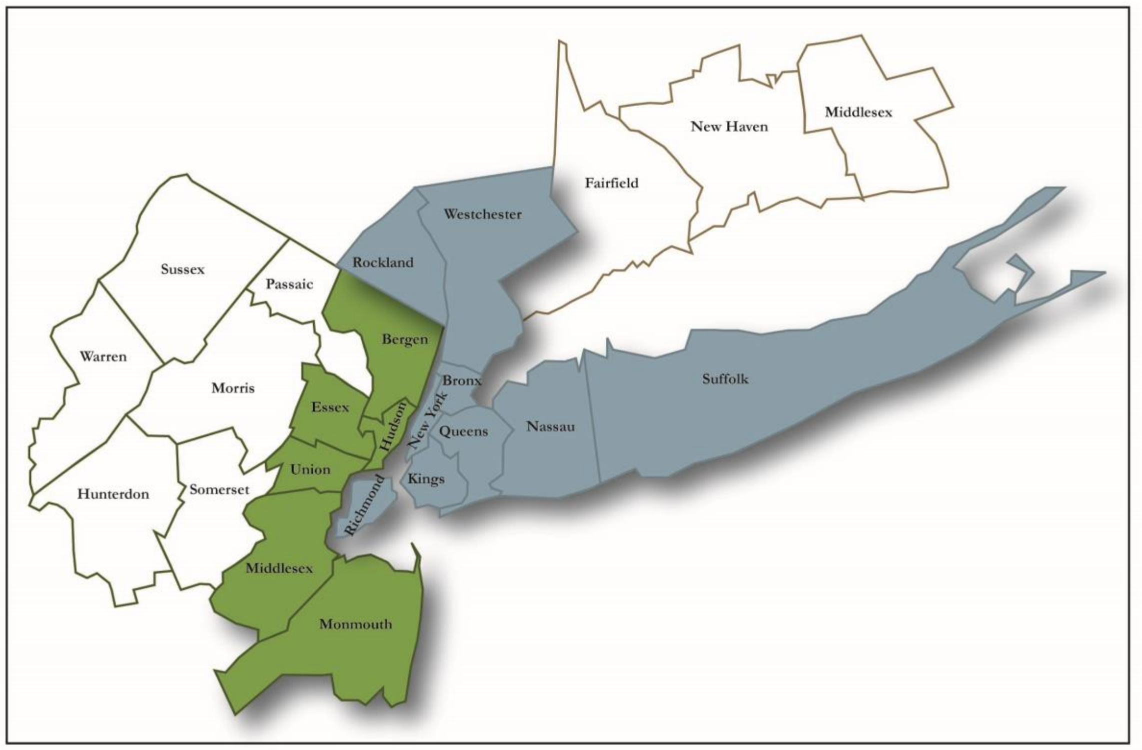


The marine terminals are located in several of the counties in the states of New Jersey and New York that are within an area that has been called the New York/New Jersey/Long Island Non-Attainment Area (NYNJLINA) in the series of maritime emissions inventories developed by the Port Authority. The NYNJLINA counties that have been included in the emissions inventories do not include all counties in the current non-attainment area but were recognized by the multi-agency Regional Air Team (RAT), of which the Port Authority is a member, as an appropriate boundary within which to conduct a series of marine-industry related emissions inventories that initially looked at the year 2000 commercial marine vessel fleet. Subsequent inventories have been focused on these counties as a means of maintaining consistency with prior reporting and because they remain relevant areas within which to estimate and track emissions related to the Port Authority marine terminals.

[2] For example, see: *https://www.epa.gov/airquality/greenbook/hbca.html#Ozone_8-hr.2008.New_York*

Figure ES.3 shows the counties in the NYNJLINA with shading that highlights the counties included in this emissions inventory for emissions comparison to regional emissions.

Figure ES.3: Map of NYNJLINA Counties Included in Regional Comparison



The following counties are included in the emissions inventory and are included in the emissions comparisons:

New Jersey Counties
Bergen
Essex
Hudson
Middlesex
Monmouth
Union

New York Counties
Bronx
Kings
Nassau
New York
Orange
Richmond
Rockland
Suffolk
Westchester

Including only these selected New Jersey and New York counties for the comparison of PANYNJ maritime emissions against regional emissions is not only consistent with past studies, but is also more realistic in emphasizing the local contribution of emissions to the immediate port community counties. Comparing against all counties in the non-attainment area would dilute the relative contribution of marine terminal related emissions and would include counties where marine terminal related emissions do not occur to any significant degree, such as the Connecticut counties. Orange County is included in the emissions inventory and the regional emissions, but is the only county that is not within the current nonattainment area.

The 2016 PANYNJ emission estimates 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[3] in tons per year, and the percentage that the PANYNJ emissions made up of the total NYNJLINA emissions in 2016. Comparing 2016 PANYNJ emissions to the latest 2014 v1 NEI is not a complete "apples to apples" comparison since they are different inventory years which represent different activity levels, and due to the different sulfur content for ECA compliance between 2014 and 2016. However, the comparison serves to generally illustrate the relative contribution of the emission sources covered by his inventory to total emissions in the area.

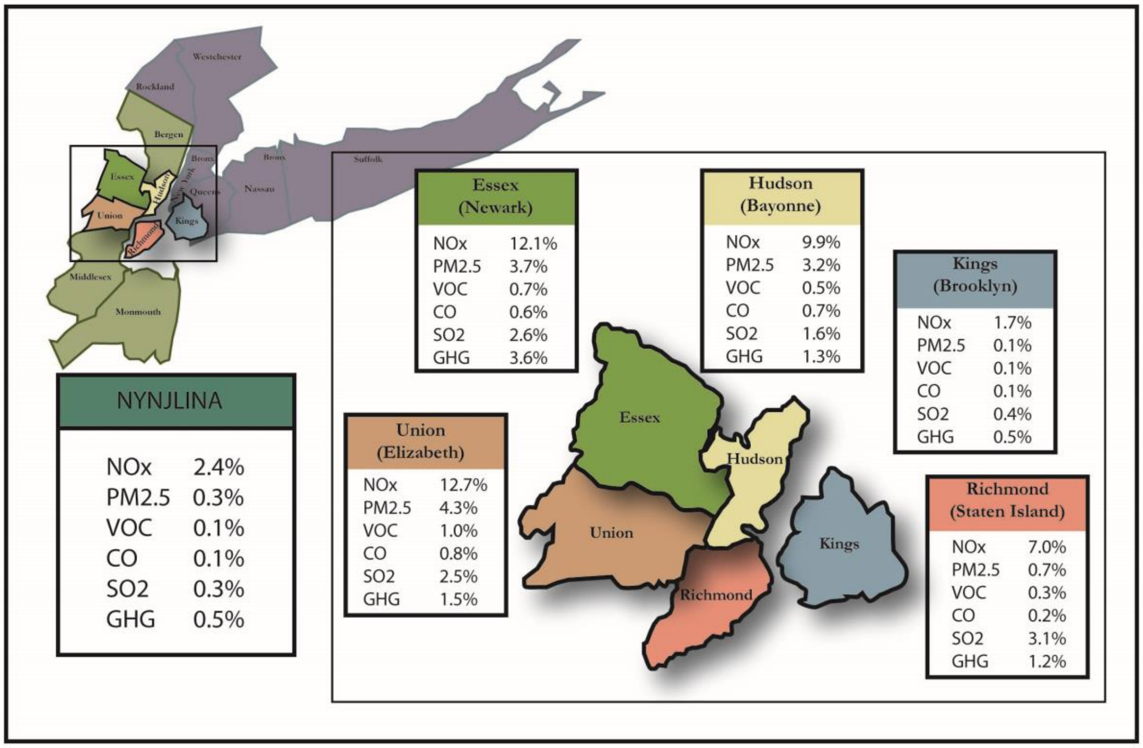
Table ES.2: Emission Summary by Source Category, tons per year

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Cargo Handling Equipment	509	33	32	68	263	0.7	113,001
Heavy-Duty Diesel Vehicles	2,237	119	109	149	626	3	311,734
Railroad Locomotives	289	10	10	22	59	0	22,406
Ocean-Going Vessels	2,280	46	42	72	222	73	188,102
Harbor Craft	392	12	12	15	80	0.3	24,197
Total PANYNJ Emissions	**5,707**	**219**	**204**	**326**	**1,251**	**77.4**	**659,441**
NYNJLINA Emissions	**241,605**	**130,600**	**67,408**	**254,018**	**1,311,532**	**22,641**	**127,000,943**
PANYNJ Percentage	**2.4%**	**0.2%**	**0.3%**	**0.1%**	**0.1%**	**0.3%**	**0.5%**

[3]Criteria pollutant emissions are primarily from the 2014 Ver 1.0 National Emissions Inventory, April 2017. *www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data*
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 or 2014 Inventory.
www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data
www.epa.gov/air-emissions-inventories/2008-national-emissions-inventory-nei-data

The following figure illustrates the PANYNJ percentage of emissions in the context of the NYNJLINA emissions (table on the left of the figure) and the percentage that PANYNJ emissions make up of all emissions in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure ES.4: PANYNJ contribution to NYNJLINA and Local Air Emissions



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 or PANYNJ).

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 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 a maintenance area for particulate matter 2.5 microns or less in diameter ($PM_{2.5}$).[4]

The purpose of this 2016 emissions inventory is to update the emission estimates presented in the 2015 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 2016, which allows for a comparison with the earlier emission estimates for those source categories. The goals of this emissions inventory include:

- Estimate the contribution to overall emissions in the NYNJLINA attributable to CHE, HDDV, 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.

[4] 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 emissions inventories. The report compares emissions related to terminal operations, including visiting vessels, cargo handling equipment, trucks and locomotives within the NYNJLINA emissions and regional emissions by local counties. 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 Port Authority marine terminals, and compares the change in emission levels since the previous inventory year and over time since the baseline emissions inventory year of 2006.

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 2016, and are reported in tons per year. Emissions of the following criteria pollutants are included:

- Oxides of nitrogen (NO_X), an ozone precursor,
- 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,
- Carbon monoxide (CO), 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)

GHG emissions are presented in terms of CO_2 equivalents (CO_2e), a measure that weights each gas by its global warming potential (GWP) value relative to CO_2. The CO_2e emissions include CO_2, methane (CH_4) and nitrous oxide (N_2O); the CO_2e value is calculated by multiplying each GHG's total emissions by its corresponding GWP value from EPA's latest report "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014"5. The sum of the three GHGs is reported as one CO_2e value using the following GWP values.

- CO_2 – 1 N_2O – 298 CH_4 – 25

[5] See: *www.epa.gov/ghgemissions/us-greenhouse-gas-inventory-report-1990-2014*

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.

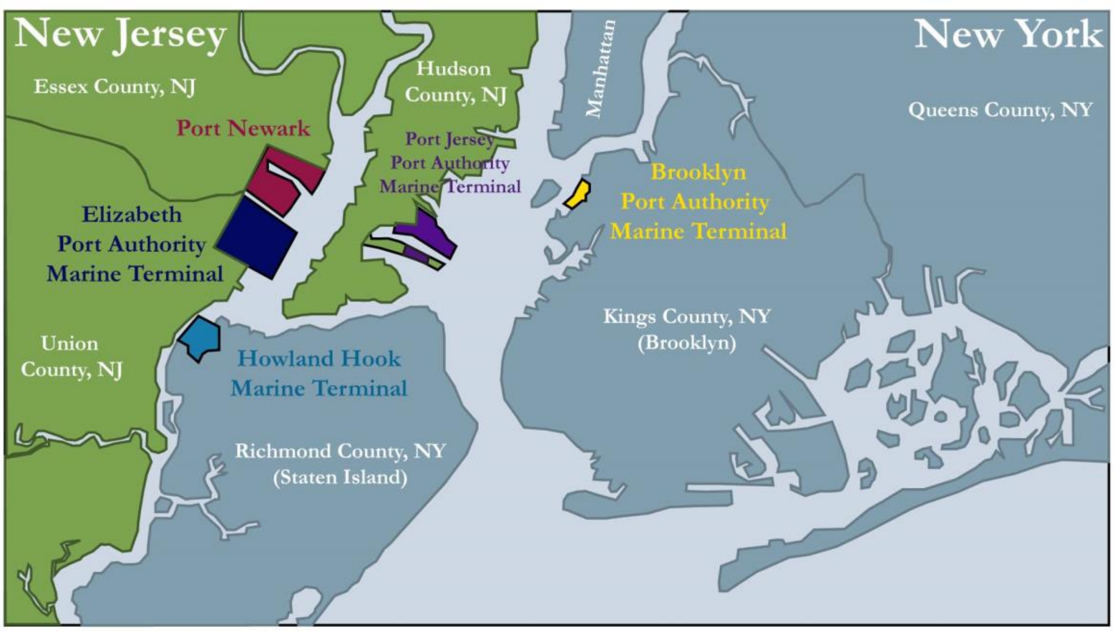
The Port Authority's New Jersey marine terminals are:

- Port Newark (which includes container, auto, bulk, 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 2016

There were no major changes to Port Authority facilities in 2016. Minor changes were made to the calculation methodology for OGVs. These changes are discussed in the report section detailing OGV emissions. Prior year emission estimates have been adjusted to account for these changes so the emission trends over time can be evaluated.

1.2 Report Organization by Section

The sections that follow are organized by emission source category and summarize 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

Table 1.1 presents the criteria pollutant and CO_2e emissions by source category and compares the PANYNJ total to the total emissions in the NYNJLINA[6] in tons per year (tpy). Comparing 2016 PANYNJ emissions to the latest 2014 NEI is not a complete "apples to apples" comparison since they are different inventory years which represent different activity levels. The sulfur content for ECA compliance is also different between 2014 and 2016. However, the comparison serves to generally illustrate the relative contribution of the emission sources covered by this inventory to total emissions in the area. Table 1.2 illustrates the percentage contribution of each source category to the total PANYNJ emissions of each pollutant.

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	509	33	32	68	263	0.7	113,001
Heavy-Duty Diesel Vehicles	2,237	119	109	149	626	3	311,734
Railroad Locomotives	289	10	10	22	59	0	22,406
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PANYNJ Percentage	**2.4%**	**0.2%**	**0.3%**	**0.1%**	**0.1%**	**0.3%**	**0.5%**

[6] Criteria pollutant emissions are from the 2014 National Emissions Inventory: *http://www.epa.gov/ttn/chief/net/2014inventory.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 or 2014 Inventory.
http://www.epa.gov/ttn/chief/net/2008inventory.html

Table 1.2: Emission Summary by Source Category, %

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Cargo Handling Equipment	9%	15%	16%	21%	21%	1%	17%
Heavy-Duty Diesel Vehicles	39%	54%	53%	46%	50%	3%	47%
Railroad Locomotives	5%	5%	5%	7%	5%	0%	3%
Ocean-Going Vessels	40%	21%	21%	22%	18%	95%	29%
Harbor Craft	7%	5%	6%	5%	6%	0%	4%
Totals	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

1.4 Overall Comparison of PANYNJ Emissions

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. [7]

[7] 2011 National Emission Inventory Database, US EPA.

The following figure illustrates the PANYNJ percentage of emissions in the context of the NYNJLINA emissions (table on the left of the figure) and the percentage that PANYNJ emissions make up of all emissions in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 1.2: PANYNJ contribution to NYNJLINA and Local Air Emissions

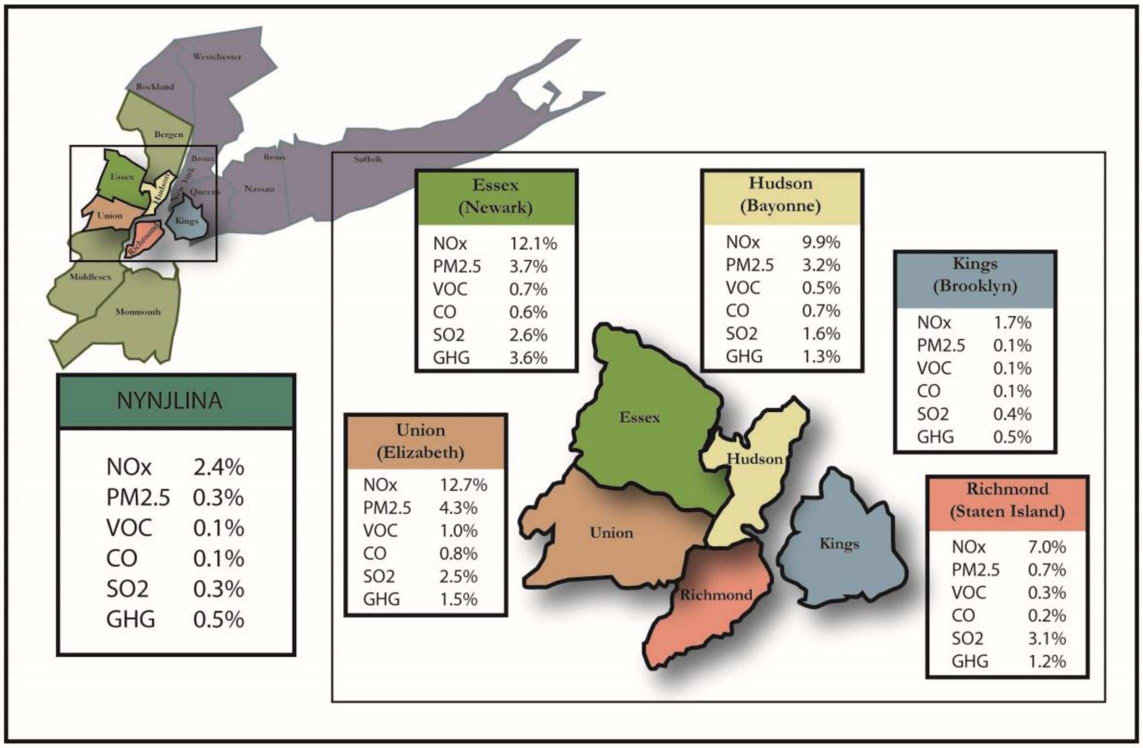


Table 1.3 summarizes by county the estimated emissions from the Port Authority marine terminal related activities covered by this report, and Table 1.4 lists total emissions of each criteria pollutant by county and state, as reported in the most recent National Emissions Inventory database, which is updated by EPA as reports come in from the states and represents the best source of area-wide emissions data. Criteria pollutant emissions are primarily from the 2014 National Emissions Inventory[8] while greenhouse gas emissions are from the 2011 and 2008 National Emissions Inventories.[9] Stationary and area source GHG emissions have been obtained from the 2008 Inventory because they are not provided by the 2011 or 2014 inventories.

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	156	7	6	8	40	0	20,370
Essex	NJ	1,516	55	51	82	297	24	180,503
Hudson	NJ	873	31	28	46	201	14	96,155
Middlesex	NJ	433	21	19	24	115	1	59,838
Monmouth	NJ	118	3	2	4	16	2	8,312
Union	NJ	1,541	67	63	113	375	24	194,242
New Jersey subtotal		**4,637**	**184**	**171**	**277**	**1,044**	**65**	**559,420**
Bronx	NY	35	2	2	2	9	0	4,961
Kings	NY	296	10	9	13	60	4	26,997
Nassau	NY	66	3	3	4	17	0	9,098
New York	NY	56	2	2	2	9	1	4,726
Orange	NY	42	2	2	2	11	0	5,788
Queens	NY	32	1	1	2	8	0	4,235
Richmond	NY	424	11	11	18	63	7	31,177
Rockland	NY	52	1	1	2	12	0	4,591
Suffolk	NY	29	1	1	1	7	0	3,333
Westchester	NY	38	2	2	2	10	0	5,115
New York subtotal		**1,070**	**35**	**33**	**49**	**207**	**13**	**100,021**
PANYNJ Total		**5,707**	**219**	**204**	**326**	**1,251**	**77**	**659,441**

[8] *https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data*
[9] *https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data*
https://www.epa.gov/air-emissions-inventories/2008-national-emissions-inventory-nei-data

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	13,438	3,636	1,957	17,278	96,315	526	12,083,110
Essex	NJ	12,541	2,415	1,395	12,451	54,065	927	5,054,723
Hudson	NJ	8,821	1,443	894	8,502	30,763	889	7,261,187
Middlesex	NJ	16,170	4,566	2,296	18,750	81,628	561	11,596,949
Monmouth	NJ	12,364	4,022	2,110	17,978	71,598	653	5,242,102
Union	NJ	12,142	2,558	1,470	11,204	46,370	965	12,936,127
New Jersey subtotal		**75,475**	**18,640**	**10,121**	**86,162**	**380,740**	**4,521**	**54,174,197**
Bronx	NY	8,717	4,518	3,150	8,473	43,041	860	2,898,414
Kings (Brooklyn)	NY	17,270	9,993	7,597	15,869	86,900	1,034	5,729,063
Nassau	NY	21,734	17,451	7,456	20,776	139,510	1,780	10,045,818
New York	NY	24,522	20,863	10,917	16,720	121,789	2,726	7,090,866
Orange	NY	7,500	9,898	3,060	17,052	43,713	1,703	5,609,965
Queens	NY	27,863	15,193	8,123	17,877	111,622	2,132	15,051,786
Richmond (Staten Island)	NY	6,030	2,387	1,447	5,544	30,071	234	2,572,653
Rockland	NY	5,947	3,256	1,740	7,386	34,091	375	2,791,076
Suffolk	NY	31,306	18,429	8,346	38,985	205,074	5,632	15,290,461
Westchester	NY	15,240	9,972	5,453	19,173	114,982	1,645	5,746,644
New York subtotal		**166,129**	**111,960**	**57,287**	**167,855**	**930,793**	**18,120**	**72,826,745**
NYNJLINA Total		**241,605**	**130,600**	**67,408**	**254,018**	**1,311,532**	**22,641**	**127,000,943**

1.5 Comparison of 2016 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, the emissions estimated for 2016 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). Adjustments have been made to earlier emission estimates to make them compatible with the latest estimates to account for changes in emission estimating methodology. The latest such changes have been to the OGV emission estimating methodology and are described in that section of this report. Because these adjustments have been made to allow comparison between inventory years, the emission estimates published in prior year emissions inventories may not match the emissions presented in this report, which should be considered the most up-to-date estimates of those prior year emissions.

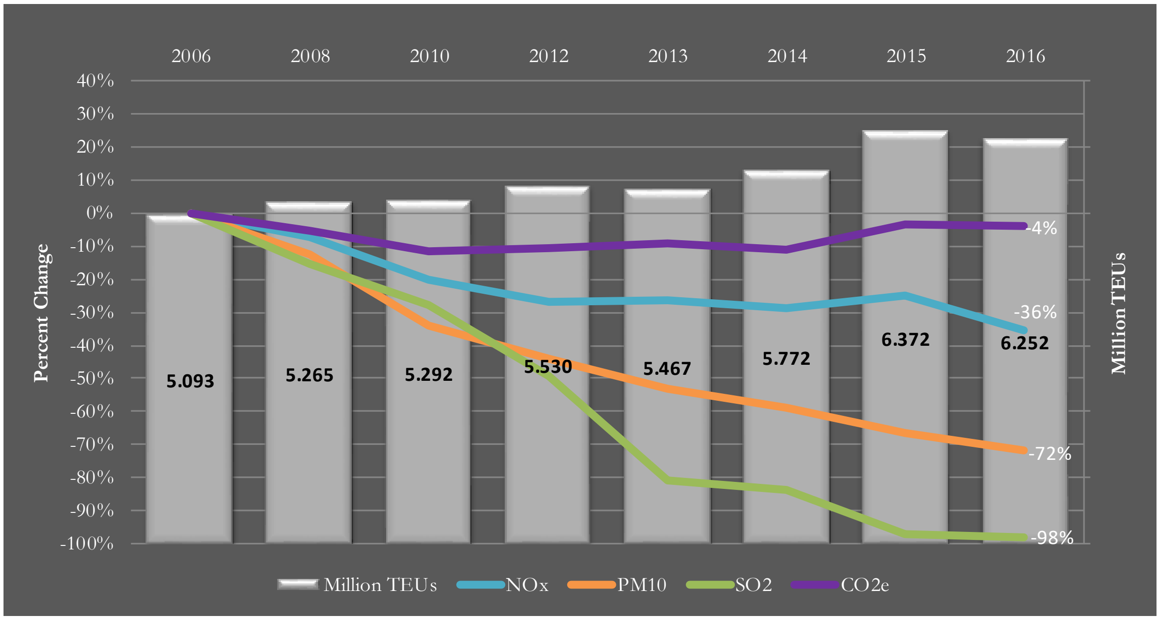
Table 1.5 presents the annual emissions from 2006, 2008, 2010, and 2012-2015 as adjusted to be compatible with the latest estimates for 2016. The emissions are expressed as tons per year and as the percentage increases or decreases between each prior inventory year and 2016. This table shows that there has been a general downward trend in emissions in tons per year between 2006 and 2016. 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, as do the emission numbers.

Table 1.5: Trends in Emissions over Inventory Years, tpy and %

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e	Million TEUs
Tons per year, with adjustments								
2016	5,707	219	204	326	1,251	77	659,439	6.252
2015	6,663	261	244	403	1,403	103	661,531	6.372
2014	6,337	319	286	377	1,305	640	611,382	5.772
2013	6,515	364	329	392	1,410	771	623,472	5.467
2012	6,511	437	385	387	1,391	2,036	612,208	5.530
2010	7,068	516	448	377	1,334	2,886	606,992	5.292
2008	8,220	685	591	420	1,615	3,396	648,408	5.265
2006	8,868	781	667	482	1,708	4,000	685,221	5.093
Percent change relative to 2016 - tons per year								
2015 - 2016	-14%	-16%	-16%	-19%	-11%	-25%	0%	-2%
2014 - 2016	-10%	-31%	-28%	-14%	-4%	-88%	8%	8%
2013 - 2016	-12%	-40%	-38%	-17%	-11%	-90%	6%	14%
2012 - 2016	-12%	-50%	-47%	-16%	-10%	-96%	8%	13%
2010 - 2016	-19%	-58%	-54%	-14%	-6%	-97%	9%	18%
2008 - 2016	-31%	-68%	-65%	-22%	-23%	-98%	2%	19%
2006 - 2016	-36%	-72%	-69%	-32%	-27%	-98%	-4%	23%

Figure 1.3 graphically illustrates the changes in port-wide emissions of NO_x, PM_{10}, SO_2 and CO_2 between the 2006 baseline emissions inventory and the 2016 update, with emission trend lines superimposed over the annual TEU throughput (in millions).

Figure 1.3: Port Related Emissions Relative to TEU throughput



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, at the Port Jersey Port Authority Marine Terminal; &
- Brooklyn Cruise Terminals, at the Brooklyn Port Authority Marine Terminal.

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

2.1 Emission Estimates

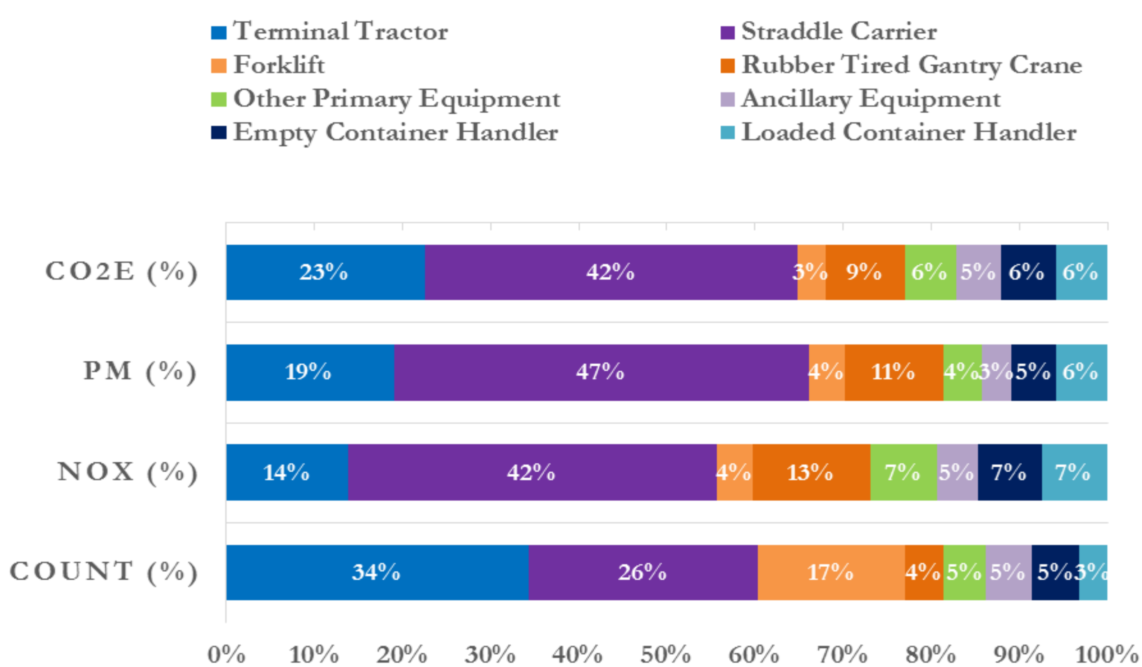
Table 2.1 presents emissions sorted by equipment type for all terminals combined. The equipment types are described later in this section.

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	71	6	6	11	31	0.14	25,459
Straddle Carrier	213	15	15	35	99	0.28	47,818
Forklift	21	1	1	4	68	0.02	3,574
Empty Container Handler	37	2	2	3	8	0.04	6,996
Loaded Container Handler	38	2	2	4	9	0.04	6,627
Rubber Tired Gantry Crane	68	4	4	7	33	0.07	10,213
Other Primary Equipment	38	1	1	2	10	0.04	6,523
Ancillary Equipment	24	1	1	2	5	0.03	5,792
Totals	**509**	**33**	**32**	**68**	**263**	**0.67**	**113,001**

Figure 2.1 shows the distribution of NO_x emissions among the various types of CHE. Straddle carriers make up most of the emissions from CHE equipment, although they make up only 26% of the equipment count.

Figure 2.1: Distribution of CHE Count and Emissions



2.2 Cargo Handling Equipment Emission Comparisons

This subsection presents Port Authority marine terminal CHE emissions in the context of countywide and non-attainment area-wide emissions. The section also presents a comparison of 2016 CHE emissions with the results of earlier emissions inventories.

2.2.1 Comparisons with County and Regional Emissions

Table 2.2 presents the estimated CHE 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. Table 2.3 summarizes the CHE emissions by county and state.

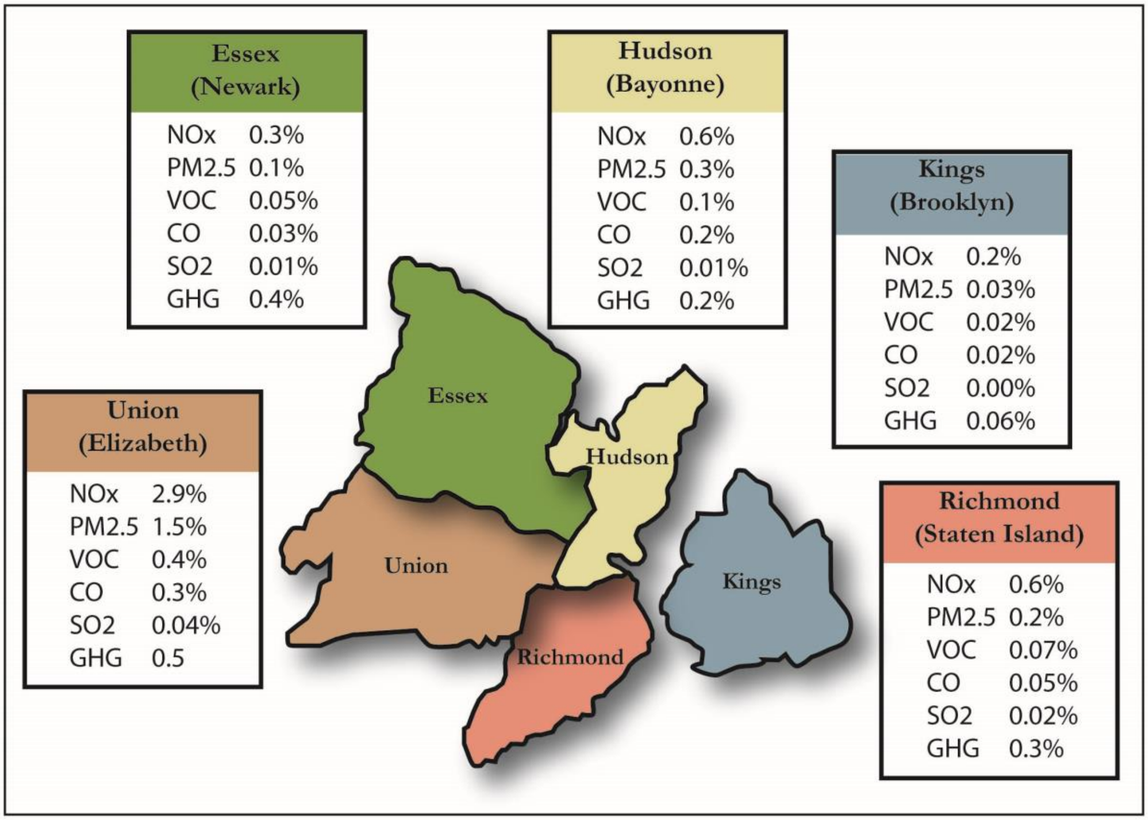
Table 2.2: Comparison of PANYNJ CHE Emissions with State and NYNJLINA, tpy

Geographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
NY and NJ	506,572	482,907	175,942	966,642	2,900,237	85,314	230,279,664
NYNJLINA	241,605	130,600	67,408	254,018	1,311,532	22,641	127,000,943
CHE	509	33	32	68	263	0.7	113,001
% of NYNJLINA Emissions	0.21%	0.03%	0.05%	0.03%	0.02%	0.003%	0.09%

Table 2.3: Summary of CHE Criteria Pollutant 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	0.00	0
Essex	NJ	35	2	2	6	15	0.09	17,903
Hudson	NJ	56	3	3	7	53	0.08	15,544
Middlesex	NJ	0	0	0	0	0	0.00	0
Monmouth	NJ	0	0	0	0	0	0.00	0
Union	NJ	357	23	23	49	162	0.42	68,834
New Jersey subtotal		**448**	**28**	**27**	**62**	**230**	**0.60**	**102,281**
Bronx	NY	0	0	0	0	0	0.00	0
Kings	NY	27	2	2	3	18	0.02	3,712
Nassau	NY	0	0	0	0	0	0.00	0
New York	NY	0	0	0	0	0	0.00	0
Orange	NY	0	0	0	0	0	0.00	0
Queens	NY	0	0	0	0	0	0.00	0
Richmond	NY	34	3	3	4	15	0.04	7,009
Rockland	NY	0	0	0	0	0	0.00	0
Suffolk	NY	0	0	0	0	0	0.00	0
Westchester	NY	0	0	0	0	0	0.00	0
New York subtotal		**61**	**5**	**5**	**6**	**33**	**0.07**	**10,720**
Total		**509**	**33**	**32**	**68**	**263**	**0.7**	**113,001**

Figure 2.2: CHE Percent Contribution to Local Air Emissions



2.2.2 Comparisons with Prior Year Emission Estimates

Table 2.4 presents the annual cargo handling equipment emissions for each year and the percentage difference between each prior inventory's adjusted emissions and the 2016 estimates.

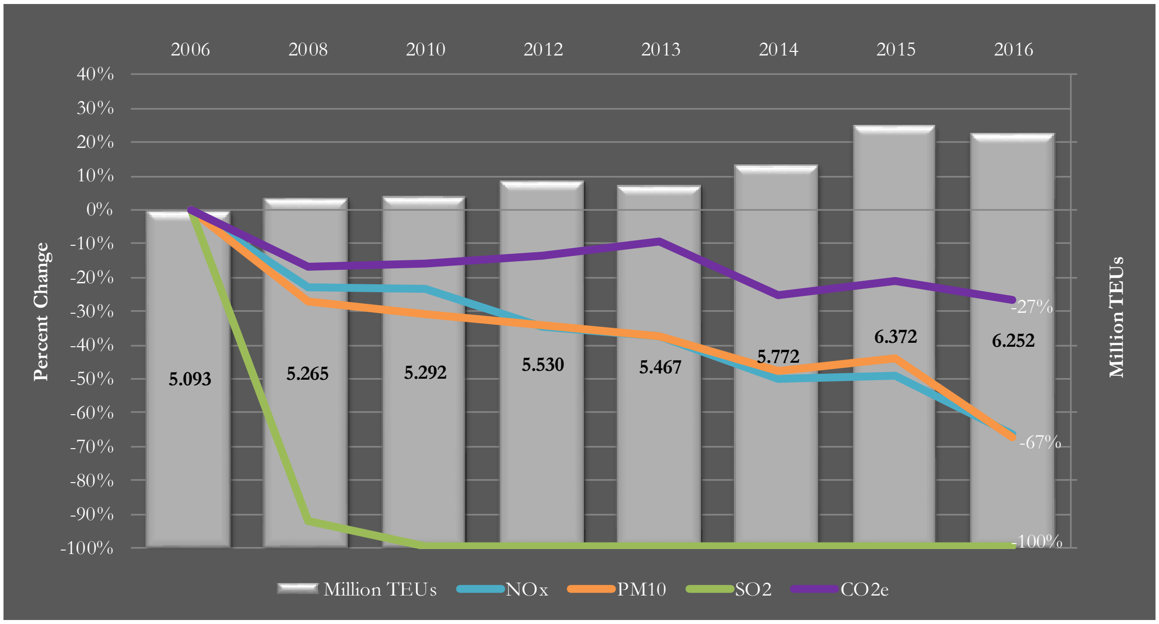
Table 2.4: CHE Trends in Emissions over Inventory Years, tpy and %

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e	Million TEUs
Tons per year, with adjustments								
2016	509	33	32	68	263	0.7	113,001	6.252
2015	768	56	54	85	326	0.8	121,486	6.372
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	19.0	128,121	5.265
2006	1,503	100	92	132	495	233.0	154,184	5.093
Percent change relative to 2016 - tons per year								
2015 - 2016	-34%	-42%	-42%	-20%	-19%	-13%	-7%	-2%
2014 - 2016	-32%	-37%	-37%	-19%	-17%	-34%	-2%	8%
2013 - 2016	-46%	-48%	-48%	-23%	-29%	-45%	-19%	14%
2012 - 2016	-48%	-50%	-50%	-24%	-31%	-45%	-15%	13%
2010 - 2016	-56%	-53%	-53%	-31%	-33%	-45%	-13%	18%
2008 - 2016	-56%	-55%	-55%	-31%	-33%	-96%	-12%	19%
2006 - 2016	-66%	-67%	-66%	-48%	-47%	-100%	-27%	23%

Overall, emissions from cargo handling equipment decreased between 2006 and 2016, while throughput increased 23%. During the years between 2006 and 2016, emission changes can be attributed to factors such as fleet turnover to newer equipment and increased utilization of equipment in response to higher terminal throughput. Compared to the previous year (2015), TEU throughput in 2016 decreased by 2% and the overall CHE emissions decreased for all pollutants.

The following figure graphically illustrates the changes in CHE emissions of NO_x, PM_{10}, SO_2 and CO_2 between the 2006 baseline emissions inventory and the 2016 update, with emission trend lines superimposed over the annual TEU throughput (in millions).

Figure 2.3: CHE Emissions Relative to TEU Throughput



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 2016, most of the terminal operators provided actual annual equipment hours.

2.3.2 Emission Estimating Model

Emissions were estimated using EPA's MOVES2014a emission estimating model.[10] 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.

[10] 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 2.5, which presents equipment types by Source Classification Code (SCC), load factor, and MOVES2014 category common name.

Table 2.5: 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 Propane Forklift	2270003020 2267003020	0.59 0.30	Forklift 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 2.6 lists the population of equipment identified at port facilities, listed by common name. The table does not include electric equipment count.

Table 2.6: MOVES/NONROAD Equipment Category Population List

NONROAD Category	Source Category Code	2006 Count	2015 Count	2016 Count
Aerial lift	2270003010	11	12	14
Crane	2270002045	13	2	2
Diesel forklift	2270003020	0	121	111
Propane forklift	2267003020	87	89	93
Front end loader	2270002060	13	0	0
Other industrial equipment	2270003040	130	166	165
Other material handling equipment	2270003050	260	349	368
Offroad truck	2270002051	9	21	22
Signal board / light plant	2270002027	12	12	12
Skid-steer Loader	2270002072	0	2	2
Sweeper / scrubber	2270003030	2	9	9
Terminal tractor	2270003070	350	408	418
Totals		**887**	**1,191**	**1,216**

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

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

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, which is the 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 the piece of equipment's model year, horsepower rating, annual hours of operation, and equipment-specific load factor assumptions. Summaries of these estimates are presented in the next subsection.

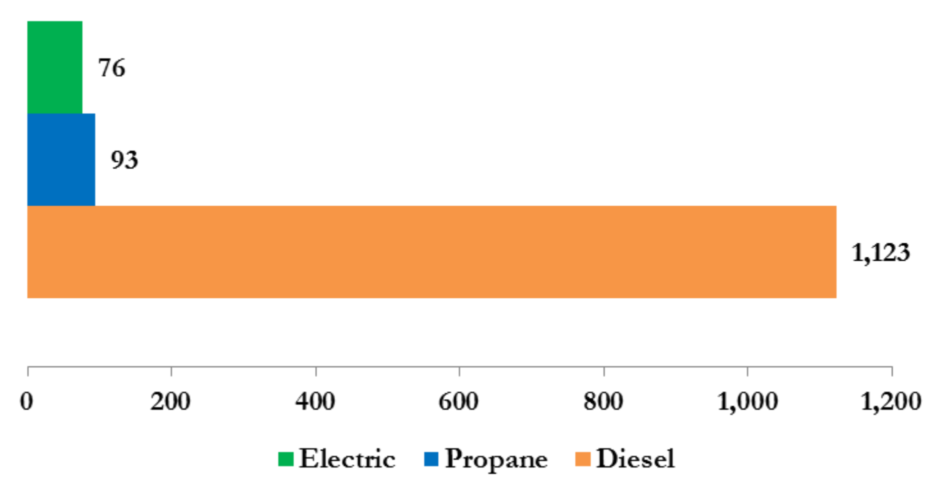
The MOVES2014a model contains a load factor and default conditions for each source category. The default sulfur content used in the model is 20 ppm[11]. Since ULSD fuel with a sulfur content of 15 ppm was used for CHE operated at the PANYNJ terminals, the emission factors for PM_{10}, $PM_{2.5}$, DPM 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.

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 2.4. The inventory also includes 93 propane powered forklifts and 76 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. The use of electric equipment has gone up by 2% since the previous inventory.

Figure 2.4: Equipment Count by Fuel Type



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

Table 2.7 summarizes the 2016 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 2.7: Cargo Handling Equipment Characteristics

Equipment Type	Count	Percent of Population	Average Model Year	Average hp	Average hrs/year
Primary Equipment					
Terminal Tractor	418	34.4%	2010	180	1,473
Straddle Carrier	315	25.9%	2009	237	2,823
Forklift	204	16.8%	2006	107	633
Empty Container Handler	65	5.3%	2008	199	2,126
Rubber Tired Gantry Crane	53	4.4%	2005	522	2,519
Loaded Container Handler	39	3.2%	2006	299	2,243
Subtotal "Primary Equipment"	1,094	90.0%	2008	205	1,822
Other Primary Equipment					
Reach Stacker	14	1.2%	2006	324	1,846
Stacker	23	1.9%	2004	239	1,014
Top Loader	19	1.6%	2008	362	1,531
Chassis Flipper	3	0.2%	2003	155	1,000
Subtotal "Other Primary Equipment"	59	4.9%	2006	295	1,377
Ancillary Equipment					
Portable Light Set	12	1.0%	2001	50	350
Sweeper	9	0.7%	2001	90	200
Aerial Platform	12	1.0%	2007	47	400
Crane	2	0.2%	1983	925	485
Diesel Fuel Truck	5	0.4%	2005	242	600
Truck	17	1.4%	2013	na	3,352
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"	63	5.2%	2005	90	1,144
Total	**1,216**				
Electric Equipment Count	**76**				
Total	**1,292**				

Figure 2.5 illustrates the total population distribution of the CHE by equipment type. Other primary and ancillary equipment were grouped together for the figure.

Figure 2.5: Population Distribution of CHE, by Number and Percent

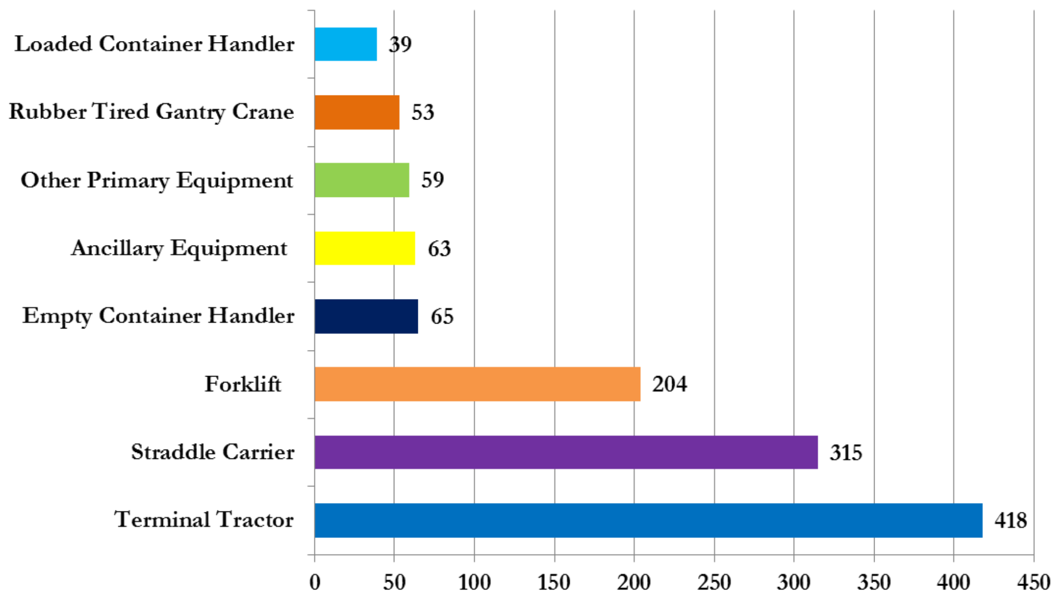


Table 2.8 presents summary data on the diesel engines in the 2016 inventory. In 2016, 34% of the diesel engines were Tier 0 to Tier 2 which contributed to 28% of the total work and almost 50% of NO_x, PM and VOC emissions. In addition, 42% of diesel engines were Tier 3 to Tier 4 which contributed to 49% of the total work and less than 40% of NO_x, PM and VOC emissions. The newer pieces of equipment are being used more and produce lower emissions. The engines characterized as "unknown" are due to model year not available at time of data collection, and therefore a default value was provided to estimate the emissions. Please note that the table includes diesel engine count and does not match the overall equipment count since some equipment included in this inventory have two engines.

Table 2.8: CHE Diesel Engine Tier Count

Equipment Type	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4i	Tier 4f	Onroad	Unknown	Total
Empty Container Handler	0	4	15	24	15	7	0	0	65
Forklift	10	22	20	6	48	1	0	4	111
Loaded Container Handler	3	1	14	12	1	8	0	0	39
Reach Stacker	0	1	3	10	0	0	0	0	14
Stacker	0	9	9	2	2	1	0	0	23
RTG Crane	0	0	35	13	3	2	0	0	53
Straddle Carrier	0	56	131	161	30	88	0	0	466
Terminal Tractor	0	34	65	89	51	103	62	14	418
Other	7	20	11	15	26	2	4	0	85
Total	**20**	**147**	**303**	**332**	**176**	**212**	**66**	**18**	**1,274**

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. 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
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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 MOVES2014a 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. Section 3.2 contains a more detailed description of the comparison of estimated 2016 emissions with 2015 and earlier year estimates. The totals of on-terminal and on-road emissions (for container, auto and warehouse facilities) are presented in Table 3.1.

Table 3.1: Total Marine Terminal Emission Estimates, tpy

Activity Component	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
On-Terminal Driving	101	7.1	6.6	8	36	0.12	16,028
On-Terminal Idling	198	17	16	32	69	0.16	20,623
On-Road Driving	1,939	94	87	109	521	2.41	275,083
Total	**2,237**	**119**	**109**	**149**	**626**	**2.68**	**311,734**

3.1.1 On-Terminal Emissions

Summaries of combined driving and idling emissions are presented in Table 3.2. Estimates of on-terminal driving emissions are presented in Table 3.3. Table 3.4 presents estimates of on-terminal idling emissions. As noted above, the estimates were prepared using the MOVES2014a model and are only comparable with prior-year estimates presented in the emissions inventory reports in the 2013 report and later.

Table 3.2: Summary of Total HDDV On-Terminal Emissions, tpy

Facility Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Auto Terminals	27	0.6	0.6	6	11	0.01	1,150
Container Terminals	258	22.3	20.6	32	89	0.25	33,834
Warehouses	14	1.3	1.2	2	5	0.01	1,668
Total	**298**	**24.3**	**22.3**	**40**	**105**	**0.28**	**36,652**

Table 3.3: Summary of HDDV On-Terminal Driving Emissions, tpy

Facility Type	VMT	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Auto Terminals	12,631	0	0.0	0.0	0.0	0	0.00	37
Container Terminals	5,334,107	99	7.0	6.4	8.3	35	0.12	15,689
Warehouses	102,658	2	0.1	0.1	0.2	1	0.00	302
Total	**5,449,396**	**101**	**7.1**	**6.6**	**8.5**	**36**	**0.12**	**16,028**

Table 3.4: Summary of HDDV On-Terminal Idling Emissions, tpy

Facility Type	Idling Hours	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Auto Terminals	107,795	27	0.6	0.6	6.2	11	0.01	1,112
Container Terminals	1,901,015	159	15.3	14.1	23.6	54	0.14	18,145
Warehouses	143,071	12	1.2	1.1	1.8	4	0.01	1,366
Total	**2,151,881**	**198**	**17.1**	**15.7**	**31.5**	**69**	**0.16**	**20,623**

3.1.2 On-Road Emissions

Table 3.5 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 and later emissions inventory reports.

Table 3.5: Summary of HDDV On-Road Emissions by State, tpy

State	VMT (thousands)	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
New Jersey	113,973	1,602	77.9	71.7	90.1	430.2	1.99	227,288
New York	23,967	337	16.4	15.1	18.9	90.5	0.42	47,795
Total	**137,939**	**1,939**	**94.3**	**86.8**	**109.0**	**520.7**	**2.41**	**275,083**

3.2 Heavy-Duty Diesel Vehicle Emission Comparisons

This section presents the heavy-duty truck emission estimates in the context of countywide and regional 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 (NEI) numbers.[12] The extent to which the NEI estimates of on-road emissions were prepared using either the MOVES2014s or MOVES2010 model or the previous-generation model, MOBILE6.2, is not known, nor is the magnitude of changes in the county-wide emissions over the years since the NEI was compiled, so the percentage comparisons should be considered as approximate.

This section also presents a comparison of 2016 heavy-duty truck emission estimates, prepared using the MOVES2014a model, with the results of earlier emissions inventories, prepared using earlier emission estimating models. The 2012 and earlier emissions have been adjusted to reflect the relative differences in outputs between the models to make them comparable to the MOVES2014a results. Differences between MOVES2014 and MOVES2014a are not significant for the vehicle types included in this inventory. With the "state-of-the-art" in emission estimating models occasionally being advanced as in these cases, adjustments are necessary at times 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 GCT Bayonne during those earlier years, as discussed in Section 1: Introduction.

[12] Criteria pollutant emissions are primarily from the 2014 National Emissions Inventory: *https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data*
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 or 2014 Inventory.
https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data
https://www.epa.gov/air-emissions-inventories/2008-national-emissions-inventory-nei-data

3.2.1 Comparisons with County and Regional Emissions

Table 3.6 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. This table includes emissions in tons per year and the percentage that PANYNJ HDDV emissions make up of overall NYNJLINA emissions. Table 3.7 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.

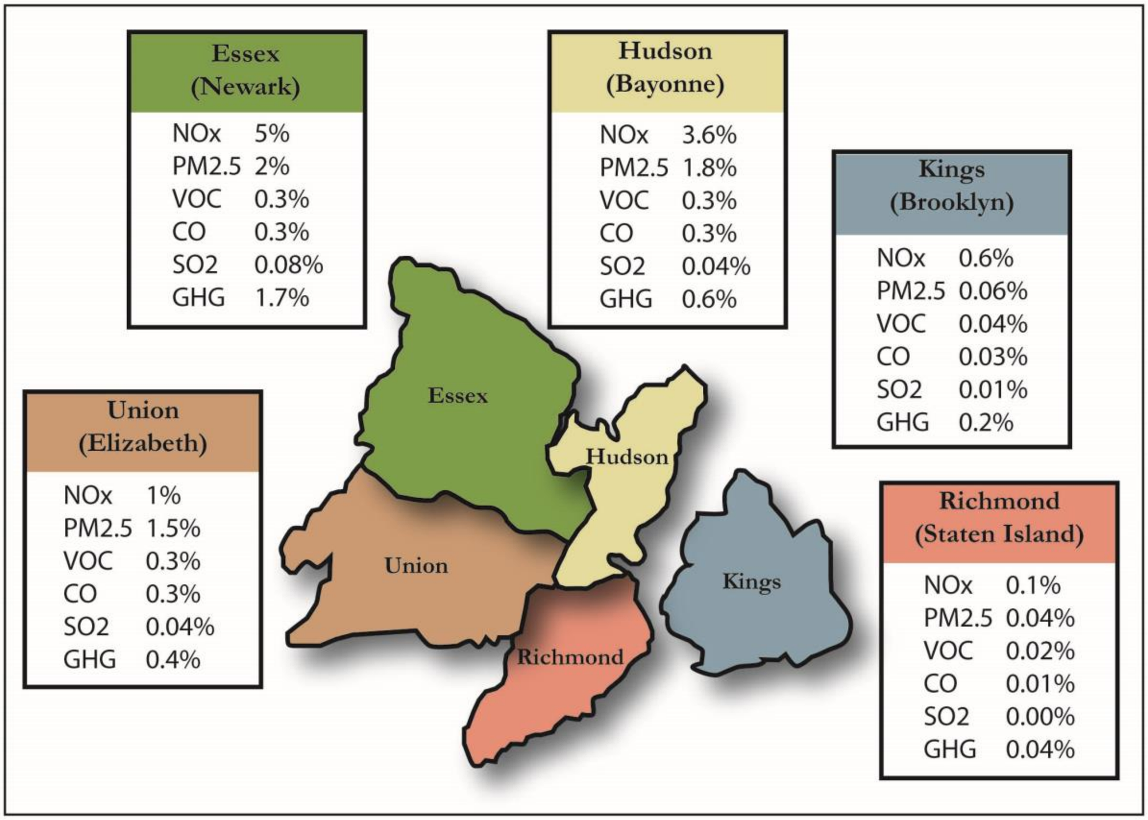
Table 3.6: Comparison of PANYNJ HDDV Emissions with State and NYNJLINA Emissions, tpy

Geographical Extent/ Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
New York and New Jersey	506,572	482,907	175,942	966,642	2,900,237	85,314	230,279,664
NYNJLINA	241,605	130,600	67,408	254,018	1,311,532	22,641	127,000,943
Heavy-Duty Diesel Vehicles	2,237	119	109	149	626	2.7	311,734
Percent of NYNJLINA Emissions	0.93%	0.09%	0.16%	0.06%	0.05%	0.01%	0.25%

Table 3.7: 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_2	CO_2e
Bergen	NJ	126	6	6	7	34	0.16	17,903
Essex	NJ	634	33	30	42	177	0.76	88,123
Hudson	NJ	320	17	16	22	90	0.38	44,411
Middlesex	NJ	412	20	18	23	111	0.51	58,396
Monmouth	NJ	26	1	1	1	7	0.03	3,741
Union	NJ	375	24	22	34	114	0.42	50,463
New Jersey subtotal		**1,893**	**101**	**93**	**129**	**533**	**2.26**	**263,036**
Bronx	NY	35	2	2	2	9	0.04	4,936
Kings	NY	95	5	4	6	26	0.12	13,418
Nassau	NY	63	3	3	4	17	0.08	8,921
New York	NY	17	1	1	1	5	0.02	2,426
Orange	NY	40	2	2	2	11	0.05	5,636
Queens	NY	28	1	1	2	8	0.03	3,966
Richmond	NY	9	1	1	1	3	0.01	1,108
Rockland	NY	5	0	0	0	1	0.01	670
Suffolk	NY	19	1	1	1	5	0.02	2,731
Westchester	NY	34	2	2	2	9	0.04	4,885
New York subtotal		**344**	**17**	**16**	**20**	**93**	**0.43**	**48,698**
Total		**2,237**	**119**	**109**	**149**	**626**	**2.68**	**311,734**

Figure 3.1: HDDV Percent Contribution to Local Air Emissions



3.2.2 Comparisons with Prior Year Emission Estimates

The HDDV emission estimates published in emissions inventories prior to the 2012 inventory were prepared using the MOBILE6.2 model, which was replaced as EPA's accepted emissions model by the MOVES series of models, with the current version being MOVES2014a. 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.

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 succeeding emissions inventories. Table 3.8 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 2016 estimates, emissions in tons per million TEUs, and the percentage differences in tons per million TEUs between the prior years and 2016.

The effects of the progressively newer fleet over the recent few years, discussed later in this section, shows up in the decreases of NO_x and PM compared with earlier inventories. In addition, the 2% decrease in the Port's TEU throughput between 2015 and 2016, with a corresponding decrease in HDDV activity, resulted in a decrease in emissions in 2016 over the previous year, and emissions per million TEU also declined over that period due to continued improvement in the truck fleet. 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 provides up-to-date model year distributions that will reflect the effectiveness of the program. Subsequent emissions inventories, which will be developed using versions of the MOVES2014 model, which has been used since the 2013 inventory, will provide a clearer picture of changes in emissions resulting from 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.

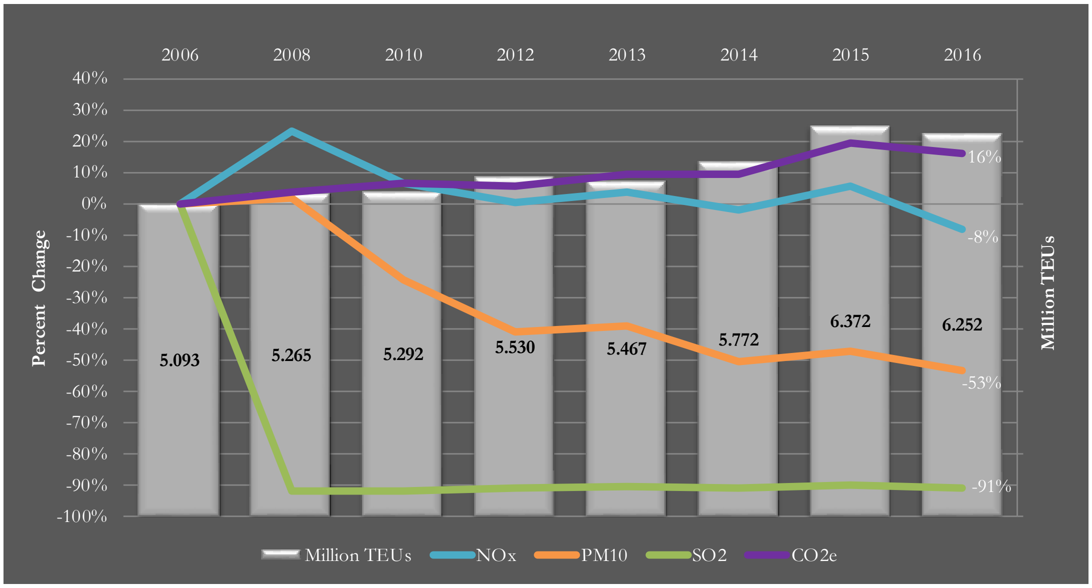
Table 3.8 presents the 2016 emission estimates and the prior year estimates that have been adjusted as needed for comparability with the 2016 estimates. The table also shows the percentage difference between each prior inventory's adjusted emissions and the 2016 estimates.

Table 3.8: HDDV Trends in Emissions Over Inventory Years, tpy and %

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e	Million TEUs
Tons per year, with adjustments								
2016	2,237	119	109	149	626	2.7	311,734	6.252
2015	2,569	135	124	171	730	2.9	319,728	6.372
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	29.0	268,189	5.093
Percent change relative to 2016 - tons per year								
2015 - 2016	-13%	-12%	-12%	-13%	-14%	-7%	-3%	-2%
2014 - 2016	-6%	-6%	-6%	-5%	-7%	1%	6%	8%
2013 - 2016	-11%	-23%	-26%	-16%	-16%	-1%	6%	14%
2012 - 2016	-8%	-21%	-23%	-13%	-13%	3%	10%	13%
2010 - 2016	-14%	-38%	-37%	8%	-2%	12%	9%	18%
2008 - 2016	-25%	-54%	-53%	-5%	-25%	17%	12%	19%
2006 - 2016	-8%	-53%	-52%	17%	-19%	-91%	16%	23%

The following figure graphically illustrates the changes in HDDV emissions of NO_x, PM_{10}, SO_2 and CO_2 between the 2006 baseline emissions inventory and the 2016 update, with emission trend lines superimposed over the annual TEU throughput (in millions).

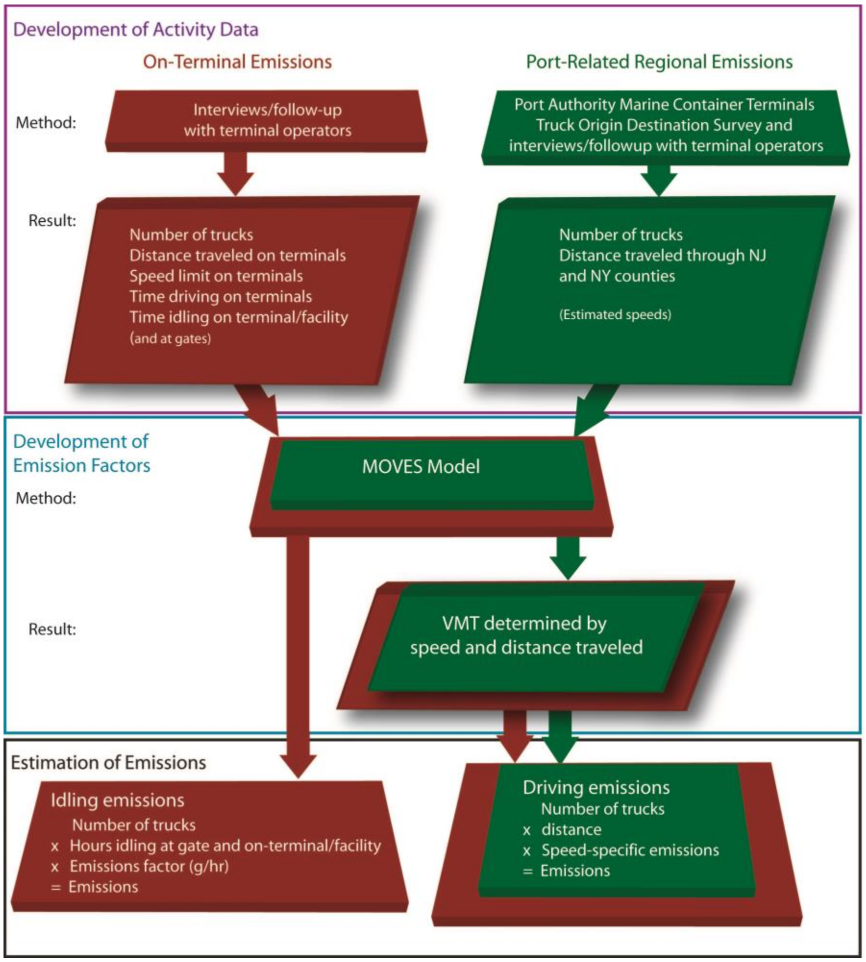
Figure 3.2: HDDV Emissions Relative to TEU Throughput



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 for HDDVs. Figure 3.3 illustrates this process in a flow diagram for on-terminal and off-terminal activity.

Figure 3.3: HDDV Emission Estimating Process



3.3.1 Data Acquisition

Activity data for the HDDV emission estimates came from the Port's PortTruckPass (PTP) system, from cargo throughput records, and from contacting facility operators to request an update of the information provided for previous inventories. Because the information is provided by operators on a voluntary basis, the operators have been reluctant to provide detailed information, based on uncertainty regarding how the Port will use their information. For this reason, many of the on-terminal operating parameters are unchanged from previous inventories. However, the activity data reflect reasonable operating characteristics and the actual changes in cargo throughput from year to year. Table 3.9 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 3.9: Summary of Reported On-Terminal Operating Characteristics

Maritime Operation	Annual Trips	Vehicle Miles Traveled	Average Speed (mph)	Average Idling Time (hours)
Auto-Handling Facilities	71,668	12,631	5	1.5
Container Terminals	4,253,276	5,334,107	15	0.4
Warehouses	211,240	102,658	15	0.7

The average idling times were based on information previously 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 during a previous drayage truck survey, 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. While a 5-minute idling limit rule is in place on and around the terminals, the aggregate of several 5-minute (or less) periods of idling during a truck's transit through a terminal (stop-and-go activity) can produce total idling times as shown in the table.

On-Road

As used in previous HDDV emissions inventories, Vollmer's draft origin/destination study[13] was used for the 2016 emissions inventory update to estimate travel distance characteristics in developing the on-road emission estimates. While now over 10 years old, the study remains the most current information on Port-specific truck travel patterns. 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 in the inventory area. 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.

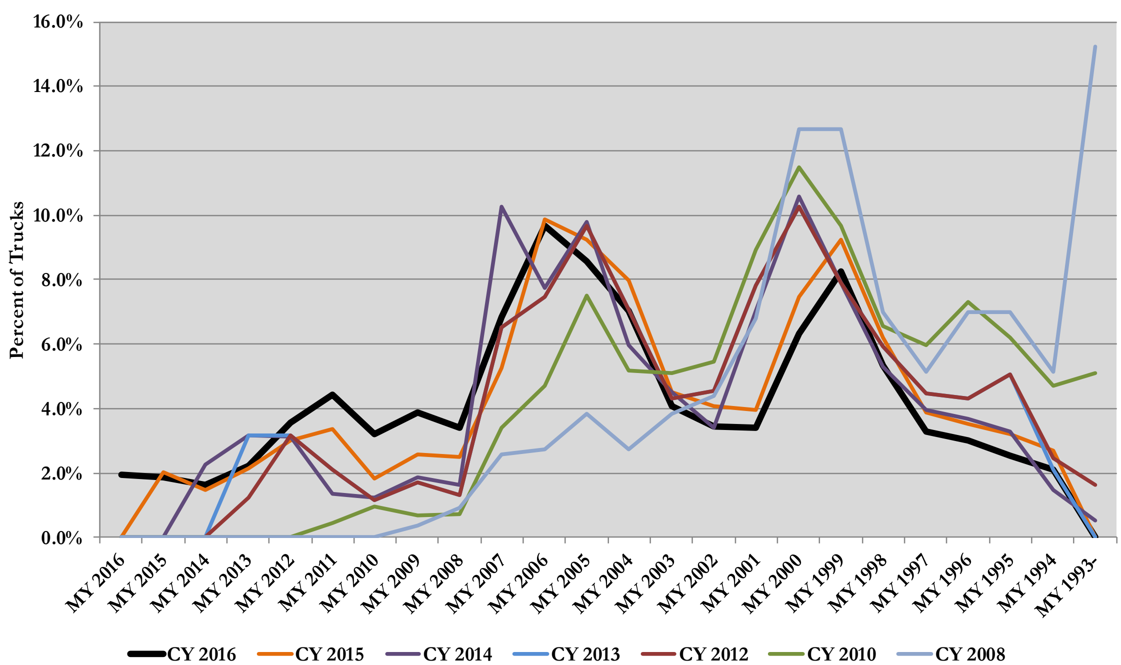
Model Year Distribution

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.

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

The container terminals at the Port Authority marine terminals have implemented 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 PTP combines data from the RFID system and the drayage truck registry, providing a detailed picture of truck calls and model years in a calendar year, providing for a robust model year distribution for a given year. While the data are specifically related to container terminals, the distribution has been used for all truck types covered by the inventory, including automobile transports and trucks calling at the warehouses. While these non-container trucks may differ in age characteristics from the container trucks, they make up a small fraction (approximately 6%) of all truck trips so the inaccuracy introduced by using the container truck distribution to represent all trucks is likely to be insignificant. Figure 3.4 illustrates the model year distributions developed for the trucks serving the Port Authority terminals for the emissions inventories for calendar years 2008, 2010, and 2012 to 2016. This figure shows the gradual turnover to newer trucks and the elimination of older trucks from among the vehicles calling at the terminals.

Figure 3.4: 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 MOVES2014a, 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. MOVES2014a is used to estimate emission factors for the pollutants included in this emission inventory, in grams per mile and grams per hour, for combination short-haul trucks of each model year. Combination short-haul truck is the vehicle type in MOVES2014a 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. The emission factors by model year developed by the model were used to develop composite emission factors that reflect the actual vehicle age distribution for trucks used at the Port Authority marine terminals.

The road types in MOVES2014a 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 MOVES2014a model was also used to develop emission factors for the very slow-speed driving within the tenant 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. MOVES2014a emission factors for exhaust emissions from trucks moving on the road include the incidental idling emissions associated with the drive cycle travel, so these are not estimated separately. The parameters used in a MOVES2014a model run are specified in a dataset known as a "runspec" that is produced during the setup of the model run. Runspecs for the model runs used in this emissions inventory are included in Appendix A.

On-terminal and on-road emissions were calculated in a similar manner, by multiplying the activity value by the relevant NO_x emission factor. As an example, a mileage total of 100,000 VMT would be multiplied by the relevant NO_x emission factor (e.g., 17.901 g/mi for on-road travel):

$$\frac{\mathbf{100,000\ miles/yr \times 17.901 g/mi = 2.0\ tons/yr}}{\mathbf{453.6 g/lb \times 2,000\ lb/ton}}$$

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

$$\frac{\mathbf{100,000\ hours/yr \times 81.390\ g/mi = 9.0\ tons/yr}}{\mathbf{453.6 g/lb \times 2,000\ lb/ton}}$$

The MOVES2014a-derived driving and idling emission factors for the 2016 model year distribution of combination short-haul trucks used in the emission estimates are presented in Table 3.10.

Table 3.10: HDDV Emission Factors (g/hr and g/mi)

Component of Operation	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
Short-Term Idle (g/hr)	75.951	7.324	6.738	11.240	25.845	0.065	8,651	0.000	0.334
Extended Idle (g/hr)	224.082	5.079	4.673	52.087	89.984	0.068	9,109	0.000	10.109
On-Terminal (g/mi)	16.758	1.189	1.094	1.408	5.993	0.020	2,667	0.000	0.052
On-Road (g/mi)	12.750	0.620	0.571	0.717	3.425	0.016	1,808	0.002	0.024

The extended idling emission rates shown in Table 3.10 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 regulations, 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.

Emissions were calculated as tons per year for each maritime operation, with idling and transit activities estimated separately. Table 3.11 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 3.11: 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	34,162	0.25	1.45	8,541	49,535	Yes
Automobile	21,542	0.10	1.56	2,154	33,606	Yes
Automobile	11,500	0.10	1.56	1,150	17,940	Yes
Container	1,485,337	1.50	0.47	2,228,005	690,682	No
Container	939,742	1.00	0.38	939,742	357,102	No
Container	928,473	1.00	0.54	928,473	496,733	No
Container	761,294	1.60	0.39	1,218,071	296,905	No
Container	173,554	0.10	0.46	17,355	78,967	No
Container	75,168	0.50	0.44	37,584	33,074	No
Warehouse	80,000	0.25	0.81	20,000	64,800	No
Warehouse	52,000	0.05	0.61	2,600	31,720	No
Warehouse	40,000	1.50	0.88	60,000	35,200	No
Warehouse	22,500	0.20	0.35	4,500	7,875	No
Warehouse	7,800	1.50	0.08	11,700	624	No
Warehouse	3,120	0.25	0.17	780	530	No
Warehouse	3,120	0.90	0.45	2,808	1,404	No
Warehouse	2,700	0.10	0.34	270	918	No

3.4 Description of Heavy-Duty Diesel Vehicles

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

Table 3.12: 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/ Elizabeth Port Authority Marine Terminal (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 emission 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.

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 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 the 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, the Cross Harbor Barge System, 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.

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

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. Table 4.1 summarizes the line haul and switching emissions.

Table 4.1: Locomotive Emission Estimates, tpy

Locomotive Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Line Haul	131	3.3	3.1	5.5	29	0.1	11,123
Switching	158	6.8	6.4	16.0	31	0.2	11,283
Total	**289**	**10.1**	**9.5**	**22**	**59**	**0.3**	**22,406**

4.2 Locomotive Emission Comparisons

This subsection presents locomotive emission estimates in the context of county-wide and non-attainment area-wide emissions, and presents a comparison of 2016 locomotive emissions with the results of earlier emissions inventories.

4.2.1 Comparisons with County and Regional Emissions

Table 4.2 presents the estimated locomotive criteria pollutant and GHG 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.[14]

Table 4.2: 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	506,572	482,907	175,942	966,642	2,900,237	85,314	230,279,664
NYNJLINA	241,605	130,600	67,408	254,018	1,311,532	22,641	127,000,943
Heavy-Duty Diesel Vehicles	289	10	10	22	59	0.3	22,406
Percent of NYNJLINA Emissions	0.12%	0.01%	0.01%	0.01%	0.00%	0.00%	0.02%

[14] 2014 National Emission Inventory Databases, US EPA, as cited above.

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.[15] Line haul locomotive activity is apportioned to the county level through a determination of the percentage of railroad track transiting individual counties vs. the regional track length. 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.

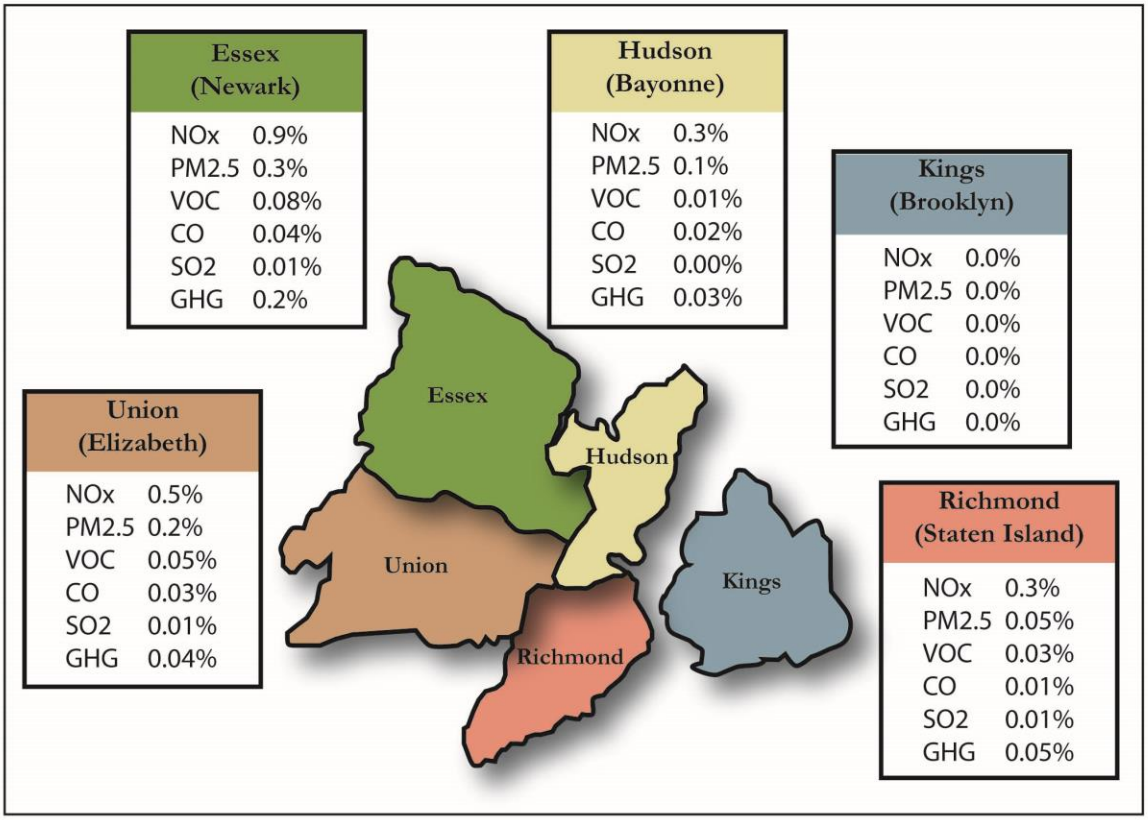
Table 4.3 presents estimated criteria pollutant emissions from the Port Authority marine terminal-related locomotive activity reported in this current inventory, at the county level.

Table 4.3: 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	0.7	0.7	1	6	0.0	2,335
Essex	NJ	108	4.5	4.2	10	20	0.1	7,581
Hudson	NJ	24	0.6	0.6	1	6	0.0	2,250
Middlesex	NJ	6	0.2	0.1	0	1	0.0	512
Monmouth	NJ	0	0.0	0.0	0	0	0.0	0
Union	NJ	62	2.4	2.2	5	12	0.1	4,552
New Jersey subtotal		**228**	**8.3**	**7.8**	**18**	**46**	**0.3**	**17,230**
Bronx	NY	0	0.0	0.0	0	0	0.0	0
Kings	NY	0	0.0	0.0	0	0	0.0	71
Nassau	NY	0	0.0	0.0	0	0	0.0	0
New York	NY	0	0.0	0.0	0	0	0.0	0
Orange	NY	0	0.0	0.0	0	0	0.0	0
Queens	NY	0	0.0	0.0	0	0	0.0	0
Richmond	NY	17	0.7	0.7	2	4	0.0	1,370
Rockland	NY	44	1.1	1.1	2	10	0.0	3,735
Suffolk	NY	0	0.0	0.0	0	0	0.0	0
Westchester	NY	0	0.0	0.0	0	0	0.0	0
New York subtotal		**61**	**1.9**	**1.7**	**4**	**14**	**0.1**	**5,176**
Total		**289**	**10.1**	**9.5**	**22**	**59**	**0.3**	**22,406**

[15] Criteria pollutant emissions are primarily from the 2014 National Emissions Inventory: *https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data*
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 or 2014 Inventory.
https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data
https://www.epa.gov/air-emissions-inventories/2008-national-emissions-inventory-nei-data

Figure 4.1: Locomotive Percent Contribution to Local Air Emissions



4.2.2 Comparisons with Prior Year Emission Estimates

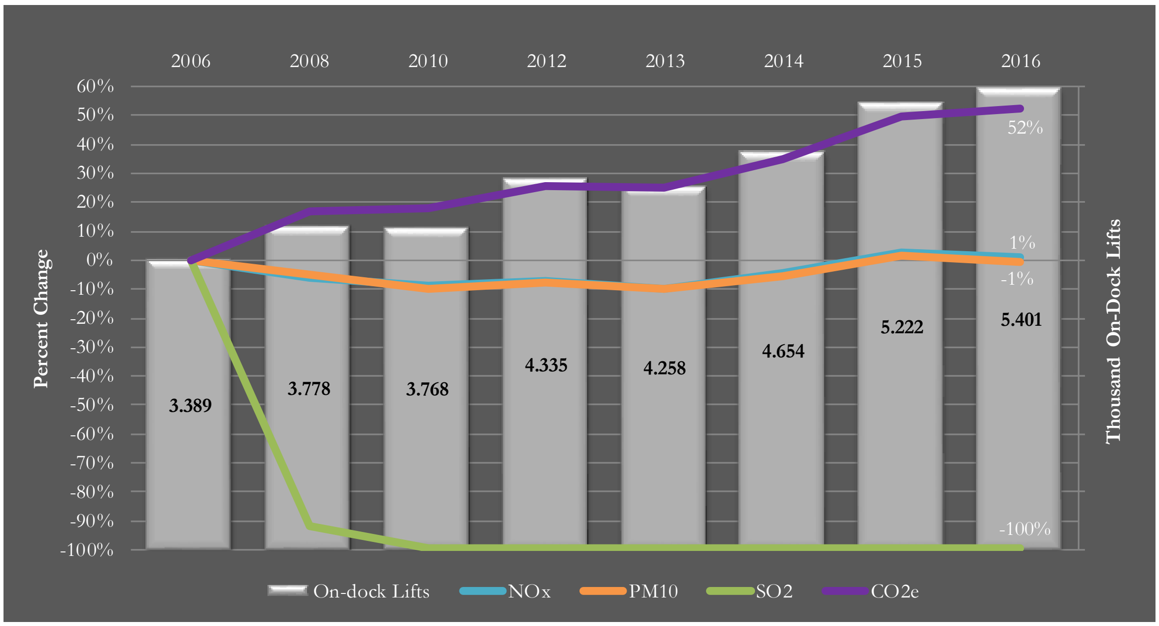
Table 4.4 presents the annual locomotive emissions as estimated in the respective emissions inventories, and the percentage difference between each prior inventory's emissions and the 2016 estimates.

Table 4.4: Locomotive Trends in Emissions over Inventory Years, tpy and %

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e	On-dock Lifts
Tons per year								
2016	289	10	10	22	59	0.3	22,406	540,149
2015	294	10	10	22	58	0.3	22,004	522,244
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	3.8	17,183	377,827
2006	286	10	9	20	44	32.0	14,710	338,884
Percent change relative to 2016 - tons per year								
2015 - 2016	-2%	-2%	-1%	-2%	2%	1%	2%	3%
2014 - 2016	6%	6%	7%	6%	13%	59%	13%	16%
2013 - 2016	12%	11%	11%	13%	21%	50%	22%	27%
2012 - 2016	9%	8%	6%	8%	21%	-76%	21%	25%
2010 - 2016	11%	10%	10%	8%	29%	-92%	29%	43%
2008 - 2016	8%	5%	6%	8%	32%	-92%	30%	43%
2006 - 2016	1%	-1%	1%	8%	35%	-99%	52%	59%

Despite a 3% increase in on-dock rail lifts between 2015 and 2016, most emissions stayed the same or decreased slightly. While emissions from the locomotive source category have generally increased over the years, the increases have been lower than the increases in the amount of cargo moved by rail into and out of the Port. The following figure graphically illustrates the changes in locomotive emissions of NO_x, PM_{10}, SO_2 and CO_2 between the 2006 baseline emissions inventory and the 2016 update, with emission trend lines superimposed over the annual on-dock lift throughput (in thousands).

Figure 4.2: Locomotive Emissions Relative to On-dock Lifts



4.3 Locomotive Emission Calculation Methodology

There is no regulatory model available for estimating locomotive emissions, such as the MOVES2014a model used for CHE and HDDVs; therefore, emissions from locomotives have been estimated using emission factors published by EPA and activity data obtained from the Port. 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,[16] 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.

[16] Information provided by PANYNJ by email 18 April 2017.

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 two 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[17] issued in support of locomotive rulemaking. The emission factors are published for each engine tier level and also (for NO_x, PM, and VOCs) for annual fleet composites representing EPA's projection of fleet turnover and the makeup of the nationwide locomotive fleet annually through calendar year 2040. The fleet composite emission factors for calendar year 2016 have been used in this emissions inventory instead of the tier-specific emission factors because information on the tier levels of the locomotives calling at the Port during 2016 is not available. The annual composite emission factors are published as fuel-based factors in units of grams of pollutant per gallon of fuel (g/gal). The emission factor for CO remains constant across tier levels and is published as g/hp-hr, while 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 assumed diesel fuel sulfur content of 15 ppm in 2016. The emission factors for N_2O and CH_4 were obtained from an EPA publication on greenhouse gases.[18]

The emission factors for line haul locomotives are presented in Table 4.5. The published g/gal emission factors for 2016 are listed as well as energy-based emission factors in grams per horsepower-hour (g/hp-hr) that have been converted from the fuel-based emission factors using a conversion factor of 20.8 horsepower-hours per gallon of fuel, published in the same EPA document cited above.

Table 4.5: 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	121.0	3.10	2.90	5.10	26.67	0.10	10,186	0.250	0.790
g/hp-hr	5.8	0.15	0.14	0.24	1.28	0.00	489	0.012	0.038

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

[18] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2014; April 2016; Table A- 109: Emission Factors for CH_4 and N_2O Emissions from Non-Highway Mobile Combustion (g gas/kg fuel).

The 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.[19]

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 4.6 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 4.6: Line-Haul Train Length Assumptions

Parameters	Outbound	Outbound	Inbound	Outbound	Outbound	Inbound
# of 5-platform cars per train	28	26	28	22	24	20
Length of 5-platform car, feet	300	300	300	300	300	300
Length of cargo, feet	8,400	7,800	8,400	6,600	7,200	6,000
Length of 1 locomotive, feet	70	70	70	70	70	70
# of locomotives per train	2	2	2	2	2	2
Total locomotive length, feet	140	140	140	140	140	140
Total train length	**8,540**	**7,940**	**8,540**	**6,740**	**7,340**	**6,140**

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 the two railroads.

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

Table 4.7 shows 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 4.7. 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 4.7: Line-Haul Train Container Capacities

Parameters	Outbound	Outbound	Inbound	Outbound	Outbound	Inbound
Platforms/car	5	5	5	5	5	5
TEUs/platform (capacity)	4	4	4	4	4	4
TEUs per train (potential)	560	520	560	440	480	400
Average "density"	95%	95%	95%	95%	95%	95%
TEUs per train (adjusted)	532	494	532	418	456	380
Average TEUs per container:	1.74	1.74	1.74	1.74	1.74	1.74
Containers per train (average)	**306**	**284**	**306**	**240**	**262**	**218**

Table 4.8 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 4.7). The total estimated number of containers moved by the train configurations described above (and shown below in Table 4.8) corresponds to the reported actual 2016 on-dock rail throughput to within approximately one-tenth of a percent (estimated total of 540,592, actual 540,149). 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 4.8: Line-Haul Train Schedules and Throughput

Parameters	Outbound	Outbound	Inbound	Outbound	Outbound	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	111,384	103,376	111,384	62,400	95,368	56,680
Total estimated containers:	**326,144**			**214,448**		

The next step in estimating fuel consumption 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 2016 submittals of an annual report known as the "R-1."[20] 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 4.9. In addition to average car weight, Table 4.9 lists the average number of railcars per train, estimated by multiplying the number of 5-platfom cars 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 4.9.

Table 4.9: Line-Haul Train Gross Weight

Parameters	Outbound	Outbound	Inbound	Outbound	Outbound	Inbound
Platforms per train (average)	140	130	140	110	120	100
Gross tons per platform	84	84	84	84	84	84
Gross weight of train	**11,822**	**10,977**	**11,822**	**9,288**	**10,133**	**8,444**

Overall annual gross tonnage for each railroad is the gross weight of each train multiplied by the number of trains per year. These figures total approximately **12.60 million gross tons** for the railroad whose trains are represented by the left three columns in the previous tables, and approximately **8.30 million gross tons** for the railroad whose trains are represented by the three columns to the right.

[20] *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2015* (Norfolk Southern Railroad) and *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2015* (CSX Transportation, Inc.). *https://www.stb.gov/stb/industry/econ_reports.html*

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 4.10. Fuel consumption in each county was estimated by multiplying the ton-miles by the factor of 1.09 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.

Table 4.10: Line Haul Locomotive Ton-Mile and Fuel Use Estimates

County	Track Mileage	Thousand Gross Ton-Miles	Gallons Fuel
North Route			
Essex	3	37,805,354	41,208
Hudson	13	163,823,199	178,567
Bergen	15	189,026,768	206,039
Rockland	24	302,442,829	329,663
South Route			
Essex	5	41,493,681	45,228
Union	15	124,481,042	135,684
Middlesex	5	41,493,681	45,228
Total	80	900,566,554	981,618

The last step is to apply the emission factors (Table 4.5) 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 2015 and 2016. 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, 540,000 containers moved by rail in 2016 divided by 523,000 containers moved by rail in 2015 results in a growth factor of 1.03 or a 3% increase in throughput; this was multiplied by the 2015 operating hours estimate of 53,004 for a 2016 estimate of 54,594 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.[21] 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.

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 low-emission replacement locomotives 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 and probably over-estimate actual 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 4.11. The switching locomotives operated by the rail-to-barge cross-harbor service are new Tier 4 units. The container terminal that operates a single switcher on terminal has also upgraded their locomotive to a Tier 4 engine, so the Tier 4 emission factors have been used for that locomotive's emissions.

Table 4.11: Switching Locomotive Emission Factors

Units	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
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	0.05
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

[21] 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.

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 54,594 hours by the average in-use horsepower of 264 results in a horsepower-hour estimate of approximately 14.4 million 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 2016 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 2016 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. These switchers are used within an area known as the Northern New Jersey Shared Asset Area, which includes rail yards other than those associated with the Port Authority. It is this joint use of switching locomotives that makes it difficult to determine the effect of the use of low-emission locomotives at the Port Authority facilities specifically.

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. Line haul locomotives, especially those in intermodal service (used in transporting containerized cargo) are typically in the range of 4,000 and more horsepower, while locomotives in switching use are smaller, typically under 3,000 horsepower.

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.

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.

- 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).

This section consists of the following subsections:

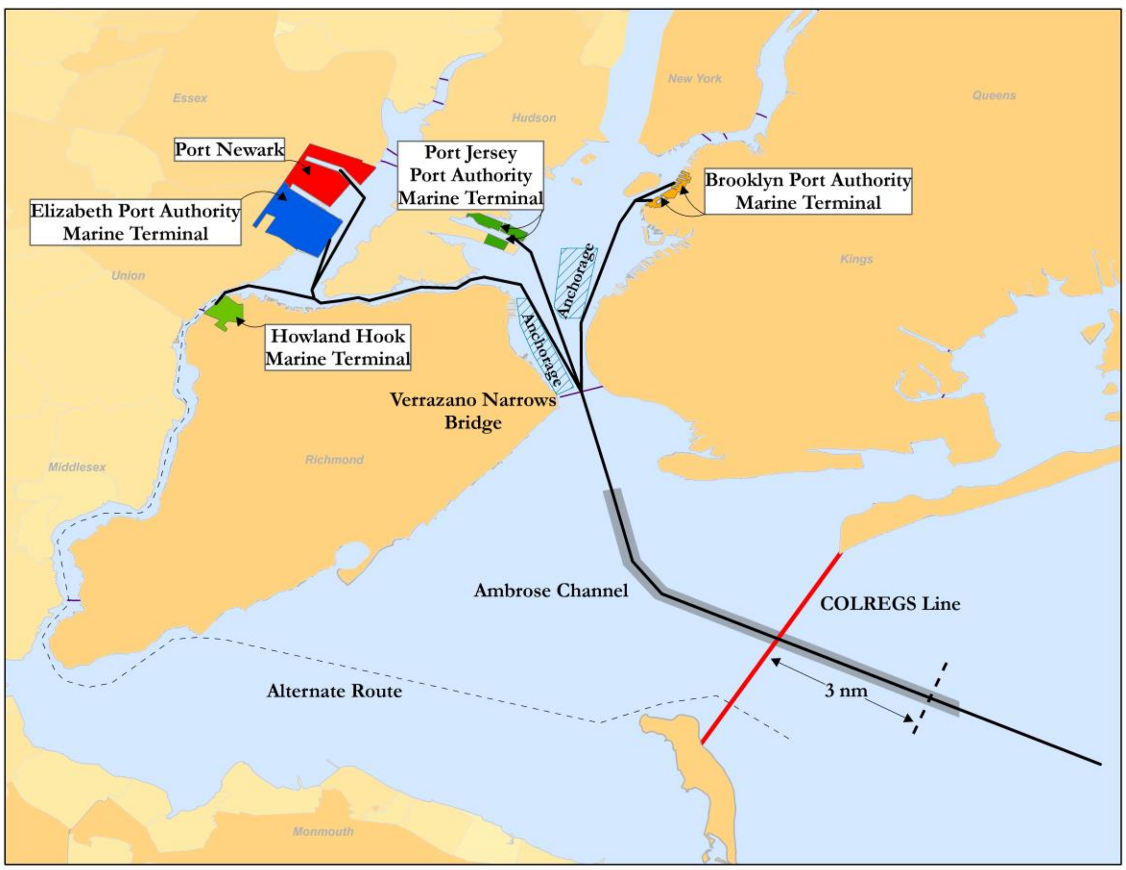
- 5.1 - CMV Emission Estimates
- 5.2 - CMV Emission Comparisons
- 5.3 - CMV Emission Calculation Methodology
- 5.4 - Description of Marine Vessels and Vessel Activity

5.1 CMV Emission Estimates

Emission estimates have been developed for commercial marine vessels (ocean-going vessels and harbor craft) on the basis of vessel type and engine type. The ocean-going vessels (OGVs) vessel types include the following: containerships, cruise ships, automobile and other vehicle carriers, tankers, and bulk carriers. The harbor craft includes vessels assist ocean-going vessels in maneuvering and docking (assist tugs) and the vessels 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 all commercial marine vessels and the typical 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 differentiates emissions according to transiting and dwelling activity. The dwelling emissions include both at berth and anchorage dwelling emissions.

Table 5.1: OGV Emissions by Vessel Type, tpy

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Containership	1,799	35.6	32.9	55.9	176.1	54.7	152,312
Auto Carrier	183	3.6	3.3	5.9	18.1	5.6	13,608
Cruise	124	2.6	2.4	4.4	11.7	4.9	7,792
Tanker	70	1.7	1.6	2.4	6.4	3.8	6,196
Bulk	38	0.8	0.8	1.2	3.3	2.0	3,242
RoRo	36	0.7	0.6	1.2	3.9	1.1	2,658
General Cargo	30	0.7	0.7	1.1	3.0	1.2	2,295
Total	**2,280**	**45.7**	**42.3**	**72.0**	**222.4**	**73.4**	**188,102**

Table 5.2: OGV Emissions by Emission Source Type, tpy

Emission Source Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Main Engines	985	13	12	25	96	16	71,792
Auxiliary Engines	1,207	26	24	43	118	37	74,316
Boilers	88	7	6	4	9	20	41,994
Total	**2,280**	**46**	**42**	**72**	**222**	**73**	**188,102**

Table 5.3: OGV Emissions by Operating Mode, tpy

Operating Mode	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Transit	1,296	20	19	36	126	27	93,907
Dwelling	983	25	24	36	97	47	94,196
Total	**2,280**	**46**	**42**	**72**	**222**	**73**	**188,102**

Table 5.4 presents estimated criteria pollutant and greenhouse gas emissions from the tow boats and assist tugs.

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

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Towboats/Pushboats	222	7	7	9	45	0.2	13,668
Assist Tugs	170	5	5	7	35	0.2	10,529
Totals	**392**	**12**	**12**	**15**	**80**	**0.3**	**24,197**

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 2016 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 database.[22] These emission comparisons are segregated into OGV and harbor craft categories and are presented in sections 5.2.1 and 5.2.2 respectively. Section 5.2.3 presents 2016 OGV and harbor craft emission estimates in comparison with previous year emission estimates to illustrate the changes in emissions over time.

5.2.1 Ocean Going Vessel Emission Comparisons with County and Regional Emissions

Table 5.5 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.

Table 5.5: 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_2	CO_2e
New York and New Jersey	506,572	482,907	175,942	966,642	2,900,237	85,314	230,279,664
NYNJLINA	241,605	130,600	67,408	254,018	1,311,532	22,641	127,000,943
OGV	2,280	46	42	72	222	73	188,102
Harbor Craft	392	12	12	15	80	0	24,197
Total Commercial Marine Vessels	2,672	58	54	87	302	74	212,300
% of NYNJLINA Emissions	**0.9%**	**0.04%**	**0.1%**	**0.0%**	**0.02%**	**0.3%**	**0.15%**

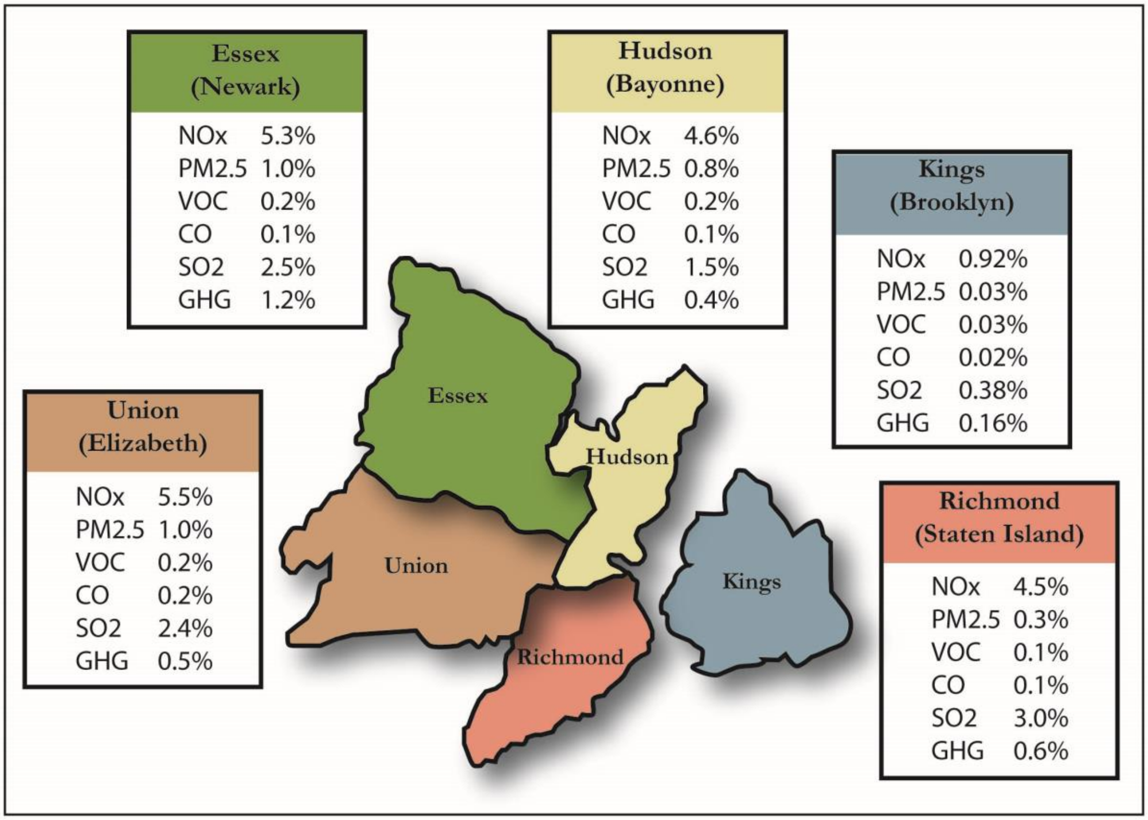
[22] See: 2008 and 2011 National Emission Inventory versions, as noted above.

Table 5.6 summarizes estimated criteria pollutant emissions from OGVs at the county level.

Table 5.6: 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	664	14	13	21	70	23	62,222
Hudson	NJ	405	8	7	13	38	13	29,723
Middlesex	NJ	0	0	0	0	0	0	0
Monmouth	NJ	81	1	1	2	6	2	3,886
Union	NJ	663	15	14	22	70	23	65,231
New Jersey subtotal		**1,813**	**38**	**36**	**58**	**183**	**61**	**161,061**
Bronx	NY	0	0	0	0	0	0	0
Kings	NY	159	2	2	5	13	4	8,904
Nassau	NY	0	0	0	0	0	0	0
New York	NY	35	1	1	1	3	1	2,054
Orange	NY	0	0	0	0	0	0	0
Queens	NY	0	0	0	0	0	0	0
Richmond	NY	273	4	4	8	23	7	16,082
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		**467**	**7**	**7**	**14**	**39**	**12**	**27,041**
Total		**2,280**	**46**	**42**	**72**	**222**	**73**	**188,102**

Figure 5.2: OGV Percent Contribution to Local Air Emissions



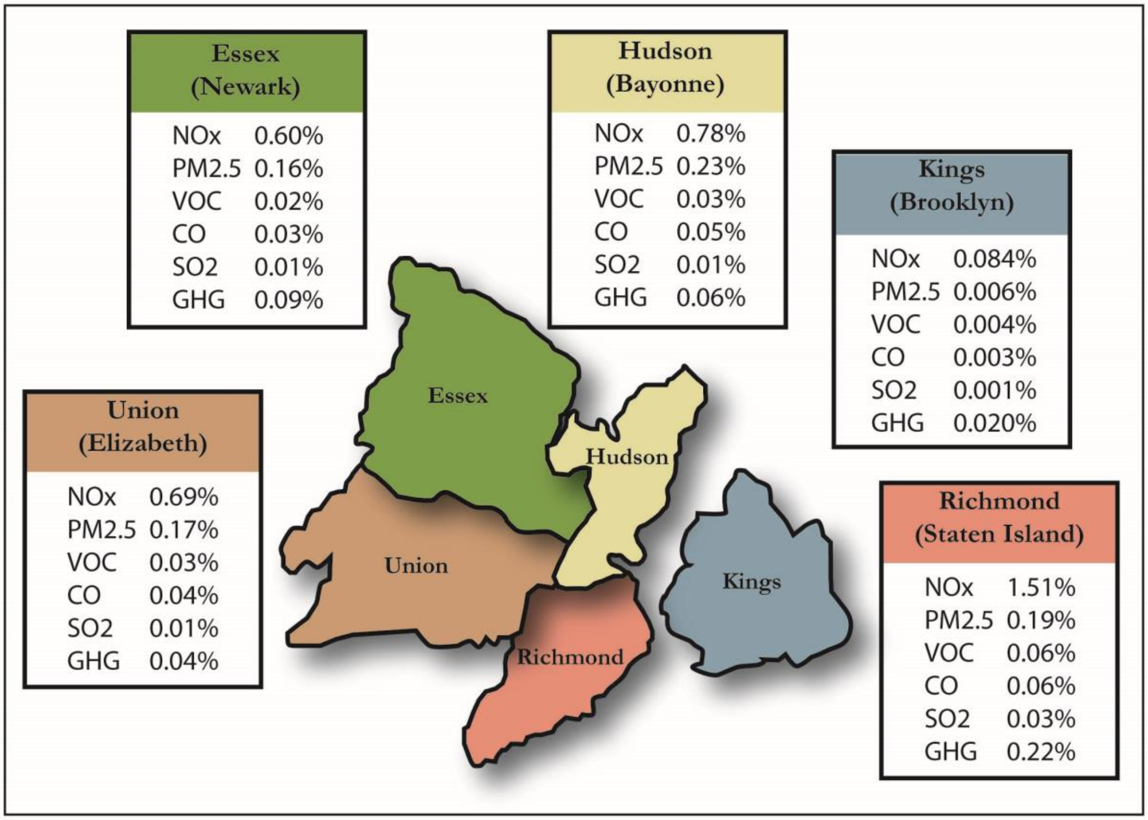
5.2.2 Tug and Tow Boat Emission Comparisons with County and Regional Emissions

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 5.7 summarizes estimated criteria pollutant emissions from these vessels at the county level.

Table 5.7: 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	2	0.1	0.1	0.1	0.4	0.00	132
Essex	NJ	76	2.3	2.3	3.0	15.4	0.07	4,674
Hudson	NJ	68	2.1	2.0	2.7	14.0	0.06	4,228
Middlesex	NJ	15	0.5	0.5	0.6	3.1	0.01	930
Monmouth	NJ	11	0.3	0.3	0.4	2.3	0.01	685
Union	NJ	83	2.6	2.5	3.3	17.0	0.07	5,163
New Jersey subtotal		**256**	**7.9**	**7.6**	**10.0**	**52.2**	**0.23**	**15,811**
Bronx	NY	0	0.0	0.0	0.0	0.1	0.00	24
Kings	NY	14	0.4	0.4	0.6	2.9	0.01	891
Nassau	NY	3	0.1	0.1	0.1	0.6	0.00	176
New York	NY	4	0.1	0.1	0.2	0.8	0.00	246
Orange	NY	2	0.1	0.1	0.1	0.5	0.00	152
Queens	NY	4	0.1	0.1	0.2	0.9	0.00	269
Richmond	NY	91	2.8	2.7	3.6	18.5	0.08	5,609
Rockland	NY	3	0.1	0.1	0.1	0.6	0.00	186
Suffolk	NY	10	0.3	0.3	0.4	2.0	0.01	602
Westchester	NY	4	0.1	0.1	0.1	0.8	0.00	230
New York subtotal		**136**	**4.2**	**4.1**	**5.3**	**27.7**	**0.12**	**8,386**
TOTAL		**392**	**12.1**	**11.7**	**15.3**	**79.9**	**0.35**	**24,197**

Figure 5.3: Harbor Craft Percent Contribution to Local Air Emissions



5.2.3 Comparison of OGV Emissions with Prior Year Emission Estimates

Changes in OGV emissions between 2016 and prior years' emissions are due to several factors. Contributing factors may include changing levels of cargo of different types, higher proportion of calls by newer ships, use of shore power, programs carried out by the Port Authority to lower emissions, such as the Clean Vessel Incentive Program, and the continued implementation of the North American Emission Control Area (ECA), which mandates lower sulfur fuels within a specified distance of the North American coast.

In 2016, methodology changes were made to the quantification of OGV emissions compared with the methods used in previous years:

- Dwelling emissions from vessels at anchorage were included due to improved data processing methods. Anchorage dwelling emissions make up less than one percent of overall OGV emissions so are a minor component of the emissions inventory.
- Default boiler load values were updated based on data collected during the vessel boarding programs (VBP) that Starcrest has conducted over the past several years at various North American ports.

- Based on the test results from a recent emissions test study[23] sponsored by the Ports of Los Angeles and Long Beach on two MAN B&W engines, improvements were made to the methodology regarding emission factors. The test data indicated emissions vary across all loads and the HC and CO emission factors for MAN B&W engines are significantly lower than the emission factors obtained from literature. The following emission factor adjustments (EFA) were applied to CO and HC for which test results were significantly different in magnitude than the default emission factors used in the inventory:
  - ✓ HC/VOC EFA for MAN B&W engines with slide valves = 0.43;
  - ✓ HC/VOC EFA for MAN B&W engines with conventional valves = 1.0;
  - ✓ CO EFA for MAN B&W engines with slide valves = 0.59;
  - ✓ CO EFA for MAN B&W engines with conventional valves = 0.44.
  - ✓ EFA for all the other pollutants is 1.0.

- Load adjustment factors (LAF) specific to MAN 2-stroke engines, also based on the emission testing program, were applied to engines identified as MAN 2-strokes, with the standard Low Load Adjustment (LLA) factors being used for other engine types.

Below are programs that had an impact on emissions in calendar year 2016:

- The North American Emission Control Area (ECA) was in effect in 2016 and it was the second year for the 0.1% S fuel sulfur content limit for OGVs operating within ECA.
- The Port Authority of New York and New Jersey Clean Vessel Incentive (CVI) Program continued to be in effect in 2016. During the year, 1,530 calls were made to the Port Authority marine terminals by vessels enrolled in the program, with 420 individual vessels making 1,058 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 0.1% sulfur ECA requirement while calling at the Port.
- In 2016, cruise vessels calling at the Brooklyn Cruise Terminal used shore power for 9 of the calls. This was the first full year for shore power capable vessels to use shore power at a PANYNJ terminal.

[23] MAN Slide Valve Low-Load Emissions Test, Final Report; June 2013; Prepared by Starcrest Consulting Group, LLC, Mitsui Engineering & Shipbuilders LTD & MAN DieselTurboA/S

Table 5.8 presents a comparison of 2016 OGV emissions, to the three nautical mile boundary, with emissions in the same area for earlier inventory years.

Table 5.8: OGV Trends in Emissions over Inventory Years, tpy and %

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e	Million TEUs
Tons per year, with adjustments								
2016	2,281	46	42	72	222	73	188,101	6.252
2015	2,633	47	44	110	217	99	174,237	6.372
2014	2,550	119	98	101	198	636	159,896	5.772
2013	2,425	126	101	94	183	766	150,378	5.467
2012	2,442	199	158	91	179	2,029	154,690	5.530
2010	2,718	234	188	108	202	2,871	153,769	5.292
2008	3,352	330	264	129	291	3,361	200,576	5.265
2006	4,143	389	312	184	358	3,654	220,426	5.093
Percent change relative to 2016 - tons per year								
2015 - 2016	-13%	-3%	-4%	-34%	2%	-25%	8%	-2%
2014 - 2016	-11%	-62%	-57%	-29%	12%	-88%	18%	8%
2013 - 2016	-6%	-64%	-58%	-24%	22%	-90%	25%	14%
2012 - 2016	-7%	-77%	-73%	-21%	25%	-96%	22%	13%
2010 - 2016	-16%	-80%	-77%	-33%	10%	-97%	22%	18%
2008 - 2016	-32%	-86%	-84%	-44%	-24%	-98%	-6%	19%
2006 - 2016	-45%	-88%	-86%	-61%	-38%	-98%	-15%	23%

The following figure graphically illustrates the percent change in NO_x, PM_{10}, SO_2, and CO_2e emissions from OGVs between the 2006 baseline emissions inventory and the 2016 update, with emission trend lines superimposed over the annual TEU throughput (in millions).

Figure 5.4: OGV Emissions Relative to TEU Throughput

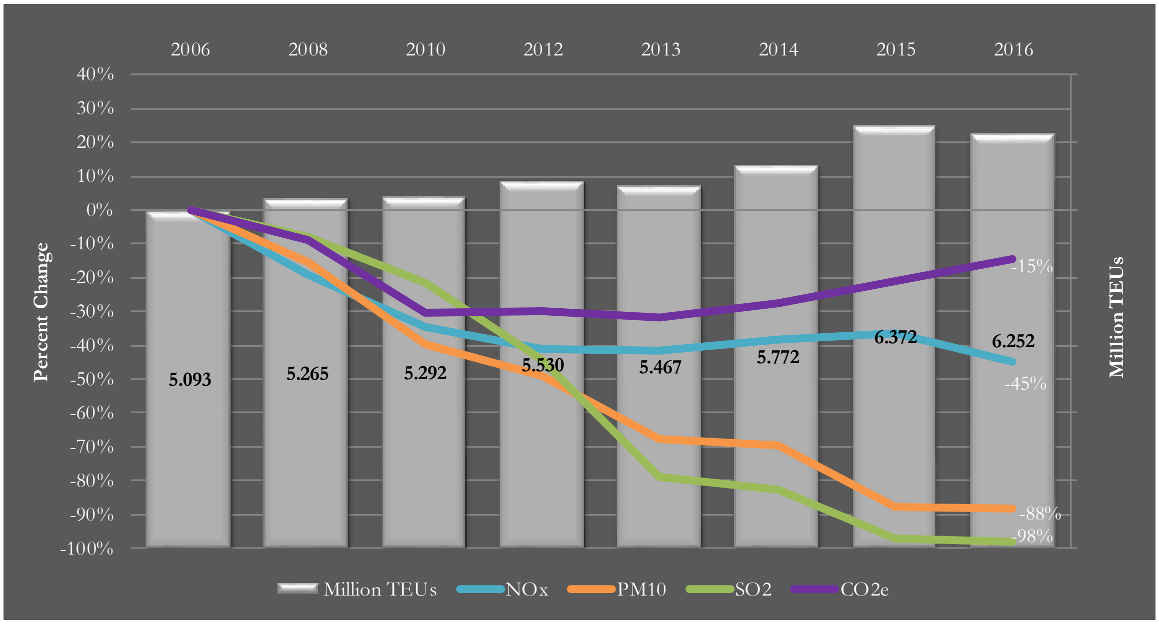


Table 5.9 presents the harbor craft emissions comparison to prior years' emissions.

Table 5.9: Harbor Craft Trends in Emissions over Inventory Years, tpy and %

Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e	Million TEUs
Tons per year, with adjustments								
2016	392	12	12	15	80	0.3	24,197	6.252
2015	400	13	12	15	72	0.3	24,076	6.372
2014	376	12	12	14	63	0.3	22,236	5.772
2013	369	12	12	14	62	0.5	21,839	5.467
2012	378	12	12	14	60	1.7	22,157	5.530
2010	346	11	11	13	55	7.8	20,287	5.292
2008	440	14	13	15	49	9.4	24,398	5.265
2006	505	27	25	19	43	52.0	27,712	5.093
Percent change relative to 2016 - tons per year								
2015 - 2016	-2%	-5%	-5%	3%	11%	1%	1%	-2%
2014 - 2016	4%	-2%	-2%	11%	27%	9%	9%	8%
2013 - 2016	6%	0%	0%	13%	30%	-29%	11%	14%
2012 - 2016	4%	-3%	-4%	9%	32%	-80%	9%	13%
2010 - 2016	13%	5%	5%	19%	45%	-96%	19%	18%
2008 - 2016	-11%	-12%	-12%	-1%	62%	-96%	-1%	19%
2006 - 2016	-22%	-56%	-53%	-19%	86%	-99%	-13%	23%

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 Markit (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

Data sources identify 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 in 5.3.1.1, 5.3.1.2 and 5.3.1.3.

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 2016, which were used to verify the AIS activity data results, when available. 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 or at anchorage. Activity levels have been evaluated based on the number of calls the vessels made to Port Authority marine terminals, duration of dwelling, distance traveled, 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. Starcrest also uses vessel-specific data collected during the vessel boarding programs that Starcrest has conducted.

Vessel call activity and main engine power, 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 OGV calls to Port Authority-owned marine terminals, a subset of all NYNJHS calls. Based on Starcrest's analysis of AIS data, the numbers of calls of each vessel type to Port Authority-owned marine terminals are listed in Table 5.10.

Table 5.10: Vessel Movements for the Port Authority Marine Terminals

Vessel Type	Arrivals/ Calls	Departures	Shifts	Total
Auto Carrier	395	394	51	840
Bulk Carrier	81	79	36	196
Containership	2,084	2,087	105	4,276
Cruise Ship	68	68	0	136
General Cargo	40	41	11	92
RoRo	87	87	39	213
Tanker	78	74	47	199
Total	**2,833**	**2,830**	**289**	**5,952**

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 5.11 lists the minimum, maximum, and average dwell times at berth (hours) for the different vessel types and sizes that called at Port Authority terminals.

Table 5.11: Average Dwell Times at Berth, hours

Vessel Type	Min	Max	Average
Auto Carrier	0	131	16
Bulk	2	390	123
Container - 1000	0	150	16
Container - 2000	7	48	18
Container - 3000	0	55	22
Container - 4000	1	204	22
Container - 5000	4	49	24
Container - 6000	2	54	26
Container - 7000	26	119	38
Container - 8000	0	81	37
Container - 9000	21	85	42
Container - 10000	1	73	40
Cruise	2	68	11
General Cargo	2	251	51
RoRo	4	52	12
Tanker - Chemical	0	240	55

5.3.1.2 Assist Tugs (Harbor Craft)

Assist tug emissions have been estimated based on 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 5.12 lists the number of vessel assists and the average number of assist tugs per arrival or departure for the various vessel types.

Table 5.12: Assist Tug Operating Data and Assumptions

Vessel Type	Inbound trips	Outbound trips	Shifts	Total trips	Average Assists per Movement	Total Assists
Auto Carrier	395	394	51	840	2	1,680
Bulk Carrier	81	79	36	196	2	392
Containership	2,084	2,087	105	4,276	2	8,552
Cruise Ship	68	68	0	136	1	136
General Cargo	40	41	11	92	2	184
RoRo	87	87	39	213	2	426
Tanker	78	74	47	199	2	398
Total	**2,833**	**2,830**	**289**	**5,952**		**11,768**

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. The estimates were made assuming that all OGVs calling the port terminals used marine diesel oil (MDO) with an average sulfur content of 0.1% per IMO's requirement for the ECA. Exceptions were made for vessels that participated in the Clean Vessel Incentive program using MDO with lower sulfur content during transiting and dwelling, and for other vessels with Environmental Ship Index (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:

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

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)

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

5.3.2.2 OGV Fuel Correction Factors and Emission Factors

Fuel correction factors are applied to reflect the effect of fuel on emissions when the actual fuel used is different from the fuel used to develop the emission factors. Table 5.13 shows the FCF[24] used to adjust the base emission factors (shown in Table that are based on HFO with 2.7% sulfur.

The North American Emission Control Area (ECA) was in effect in 2016 and it was the second year to change the sulfur content limit for fuel oil for OGVs operating in the ECA from 1% sulfur content to 0.1% sulfur content. For this report, it was assumed that all vessels that called the Port complied with the ECA fuel requirement and all of the engines and boiler burned fuel with a maximum sulfur content of 0.1% sulfur.

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

In addition, several vessels under the CVI program used cleaner fuel with lower sulfur content than what is required under the ECA. The vessels used fuel with varying sulfur contents that were below 0.1% 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. Information on NO_x emission factors for maim and auxiliary engines was also obtained for vessels participating in the CVI program. These emission factors were used for specific participating vessels in lieu of the more general emission factors listed below.

Table 5.13: Fuel Correction Factors (unitless)

Actual Fuel Used Content	Sulfur Content by weight %	Fuel Correction Factor						
		NOx	PM	VOC	CO	SO_2	CO_2	N_2O
MDO/MGO	0.10%	0.940	0.170	1.000	1.000	0.037	0.950	0.940
MDO/MGO	0.05%	0.940	0.160	1.000	1.000	0.019	0.950	0.940
MDO/MGO	0.02%	0.940	0.154	1.000	1.000	0.007	0.950	0.940
MDO/MGO	0.01%	0.940	0.152	1.000	1.000	0.004	0.950	0.940

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 Table 5.14.

Table 5.14: OGV Emission Factors (g/kW-hr)

Engine Category	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Slow Speed Main (Tier 0)	1999 and older	18.1	1.4	1.1	0.6	1.4	10.3
Slow Speed Main (Tier 1)	2000 to 2011	17.0	1.4	1.1	0.6	1.4	10.3
Slow Speed Main (Tier 2)	2011 to 2016	15.3	1.4	1.1	0.6	1.4	10.3
Medium Speed Main (Tier 0)	1999 and older	14.0	1.4	1.1	0.5	1.1	11.4
Medium Speed Main (Tier 1)	2000 to 2011	13.0	1.4	1.1	0.5	1.1	11.4
Medium Speed Main (Tier2)	2011 to 2016	11.2	1.4	1.1	0.5	1.1	11.4
Steam Main and Boiler	All	2.1	0.9	0.7	0.1	0.2	16.1
Medium Auxiliary (Tier 0)	1999 and older	14.7	1.4	1.2	0.4	1.1	12.0
Medium Auxiliary (Tier 1)	2000 to 2011	13.0	1.4	1.2	0.4	1.1	12.0
Medium Auxiliary (Tier 2)	2011 to 2016	11.2	1.4	1.2	0.4	1.1	12.0

5.3.2.3 OGV Auxiliary Engines Load Defaults

OGVs are equipped with two or more auxiliary engines that 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(s) to run at optimal (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.[25]

Table 5.15 lists the OGV auxiliary load factor assumptions used in this inventory.

Table 5.15: OGV Auxiliary Engine Load by Mode, kW

Vessel Type	Transit (kW)	Manuevering (kW)	Berth Hoteling (kW)	Anchorage Hoteling (kW)
Auto Carrier	503	1,508	838	503
Bulk	255	675	150	255
Container - 1000	545	1,058	429	545
Container - 2000	981	2,180	1,035	981
Container - 3000	602	2,063	516	602
Container - 4000	1,434	2,526	1,161	1,434
Container - 5000	1,725	3,367	900	1,725
Container - 6000	1,453	2,197	990	1,453
Container - 7000	1,444	3,357	1,372	1,444
Container - 8000	1,494	2,753	902	1,494
Container - 9000	1,501	2,942	1,037	1,501
Container - 10000	1,618	3,210	1,500	1,618
Cruise	7,058	9,718	5,353	7,058
General Cargo	516	1,439	722	516
RoRo	132	396	229	132
Tanker - Chemical	658	890	816	658

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

House load defaults for diesel electric cruise ships are listed in Table 5.16. Most cruise ships that called the cruise terminal were diesel-electric.

Table 5.16: Diesel-Electric Cruise Ship Auxiliary Engine Load, kW

Vessel Type	Passenger Count	Transit (kW)	Maneuvering (kW)	Berth Hoteling (kW)
Cruise, Diesel Electric	0-1,499	5,733	6,800	3,267
Cruise, Diesel Electric	1,500-1,999	7,000	9,000	5,613
Cruise, Diesel Electric	2,000-2,499	11,000	11,350	6,900
Cruise, Diesel Electric	2,500-2,999	9,781	8,309	6,089
Cruise, Diesel Electric	3,000-3,499	8,313	10,116	8,313
Cruise, Diesel Electric	3,500-3,999	9,934	11,764	10,600
Cruise, Diesel Electric	4,000-4,599	12,500	14,000	12,000
Cruise, Diesel Electric	4,500-4,999	13,000	14,500	13,000
Cruise, Diesel Electric	5,000-5,499	13,500	15,500	13,500
Cruise, Diesel Electric	5,500-5,999	14,000	16,000	14,000
Cruise, Diesel Electric	6,000-6,499	14,500	16,500	14,500
Cruise, Diesel Electric	6,500-999,9	15,000	17,000	15,000

5.3.2.4 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 heat for steam while the ship is under way. 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 5.17.

Table 5.17: Auxiliary Boiler Load Defaults, kW

Vessel Type	Transit (kW)	Maneuvering (kW)	Berth Hoteling (kW)	Anchorage Hoteling (kW)
Auto Carrier	87	184	314	305
Bulk	35	94	125	125
Container - 1000	106	213	273	270
Container - 2000	141	282	361	358
Container - 3000	164	328	420	416
Container - 4000	195	371	477	472
Container - 5000	247	473	579	572
Container - 6000	182	567	615	611
Container - 7000	259	470	623	619
Container - 8000	228	506	668	673
Container - 9000	381	613	677	675
Container - 10000	330	575	790	790
Cruise	282	361	612	306
General Cargo	56	124	160	160
RoRo	67	148	259	251
Tanker - Chemical	59	136	568	255

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,[26] and which has been used widely since that time. The 43% factor for auxiliary engines is based on the EPA NONROAD model guidance[27] 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[28] and has been used in previous inventories.

As discussed above, the operating time of assist tugs has been estimated based on 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.

[26] 2001 POLA Baseline Emissions Inventory

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

[28] 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 5.18.

Table 5.18: Harbor Craft Emission Factors, g/kW-hr

Engine	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
Main Engines	11.4	0.35	0.34	0.45	2.31	0.01	690	0.031	0.01
Auxiliary Engines	9.10	0.30	0.29	0.25	2.28	0.01	690	0.031	0.01

The base emission factors[29] 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 the 2016 emissions inventory, 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). Eleven vessels had newer main engines due to vessel repower, new vessels in the fleet, or had engine remanufacture kits installed. Four of the vessels had engines that fell into Tier 1 (IMO regulation for NO_x starting in the year 2000) and four of the vessels had engines that were Tier 2 (EPA regulation that affects engines starting in 2005), and three vessels had engines that were Tier 3 (EPA regulation applying in 2012-2014 depending on size). For auxiliary engines, two vessels had engines that fell into Tier 1, four vessels with engines that fell into Tier 2, and three vessels 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 2016.

[29] *Appendix 1 of [73 FR 37243, June 30, 2008, as amended at 75 FR 23012, Apr. 30, 2010.*