The Port Authority of New York and New Jersey
Port Department
2019 Multi-Facility Emissions Inventory

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

December 2020

Prepared by:
STARCREST CONSULTING GROUP, LLC

THE PORT AUTHORITY OF NY & NJ

PORT DEPARTMENT

2019 MULTI-FACILITY EMISSIONS INVENTORY

DECEMBER 2020

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

Prepared by:

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

STARCREST CONSULTING GROUP, LLC
ENVIRONMENTAL MANAGEMENT · AIR QUALITY · CLIMATE · SUSTAINABILITY

TABLE OF CONTENTS

LIST OF FIGURES

List of Tables

LIST OF ACRONYMS

Act	activity
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
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
HDV	heavy-duty 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 for non-road mobile emission sources

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 2019 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 vehicles, and locomotives) and marine mobile sources or commercial marine vessels (ocean-going vessels and harbor craft). This 2019 EI report is an update of the 2018 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 2019 calendar year emissions inventory report is to provide an update to the emission estimates, the report also discusses additional findings. The report includes emissions estimated for the previous years' inventories back to 2006, adjusted to account for emission estimating changes from year to year so the previous years' estimates are comparable to the current year estimates. Table ES.1 summarizes the emissions for 2019, the previous year (2018), and baseline 2006. Please note the 2018 emissions changed from the previously published emissions included in the 2018 EI report due to a change in the 2018 CHE emissions.

Table ES.1: Emission Comparison, tons per year and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2019	5,311	194	180	315	1,268	87	709,069	7.47
2018	5,573	210	195	333	1,271	91	697,733	7.18
2006	8,890	783	669	481	1,746	4,025	685,659	5.09
2018-2019, Change (%)	**-5%**	**-7%**	**-7%**	**-5%**	**-0.3%**	**-5%**	**2%**	**4%**
2006-2019, Change (%)	**-40%**	**-75%**	**-73%**	**-35%**	**-27%**	**-98%**	**3%**	**47%**

For comparison to the previous year, it should be noted that there was a 2% increase in greenhouse gas (CO_2e) emissions in 2019 as compared to 2018 due to the increase in activity resulting from the record throughput of over 7.47 million TEUs which was 4% higher than the 2018 TEU throughput. All other emissions were lower in 2019 as compared to 2018.

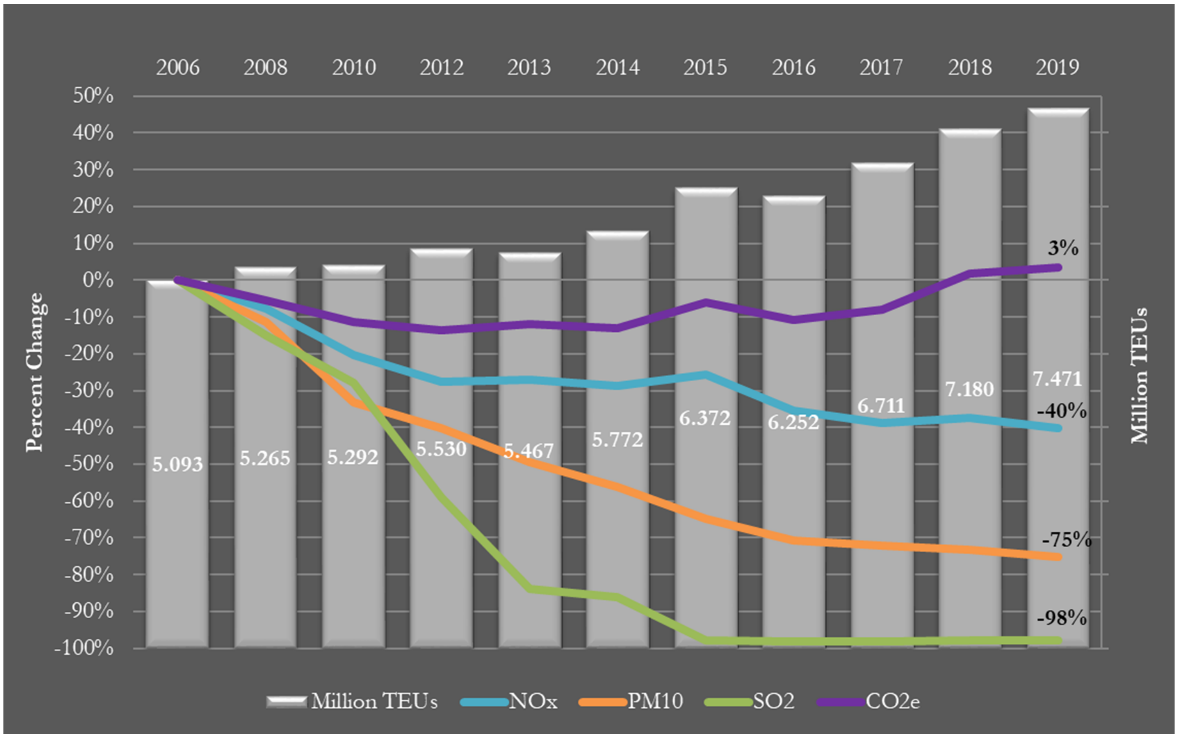
Despite the 47% increase in TEU throughput since 2006, the overall emissions were lower in 2019 as compared to 2006, except for the GHG emissions which increased by 3%. Key reasons for the emission reductions include regulatory items, voluntary actions, and measures from the PANYNJ Clean Air Strategy[1] that have been implemented to date.

- The North American Emissions Control Area[2] (ECA) continued in effect. The ECA requires vessels to burn low sulfur fuel while transiting within 200 nm of the North American coast. The use of fuels with sulfur content of 0.1% or less lowers emissions of SO_2, NO_x and PM emissions from OGVs.
- Cruise ships at one of the cruise terminals continued to use shore power which reduces at-berth OGV emissions for all pollutants.
- The PANYNJ Clean Vessel Incentive (CVI) Program[3] continued in 2019. The CVI program provides financial incentive to OGVs that comply with Vessel Speed Reduction (VSR) and those that exceed the current vessel emission standards through the Environmental Ship Index (ESI).
- Use of ultra-low sulfur diesel fuel (ULSD) by all land-based emission sources has reduced SO_2, NO_x and PM emissions.
- The PANYNJ cargo handling equipment (CHE) modernization program and fleet turnover continued to introduce new equipment at the terminals, plus using electric-powered equipment when possible.
- The PANYNJ Truck Replacement Program has provided incentives to replace old drayage trucks with cleaner, newer alternatives.
- A truck appointment system at container terminals that reduced truck turn times and queuing.
- Some terminals modernized their gate operations which reduces truck idling at the in- and out-gates.
- Tier 4i switchers used for rail-to-barge cross-harbor service.
- The rail-to-barge cross-harbor service takes 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 has reduced assist tug emissions.
- The new Intermodal Container Terminal Facility provided near-dock rail access for GCT Bayonne, which reduced truck trips and vehicle miles traveled (VMT) to/from Elizabeth's Millennium Marine Rail.

[1] *https://www.panynj.gov/about/pdf/PANYNJ_CAS_2014_FINAL2.pdf*
[2] *https://www.epa.gov/regulations-emissions-vehicles-and-engines/designation-north-american-emission-control-area-marine*
[3] *https://www.panynj.gov/about/clean-vessel-incentive-program.html*

Figure ES.1 graphically illustrates the changes in port-wide emissions of NO_x, PM_{10}, SO_2 and CO_2e between the 2006 baseline emissions inventory and the 2019 update, with emission trend lines superimposed over the silver columns illustrating annual TEU throughput (in millions). The figure shows that TEU throughput has increased by 47% since 2006 and emissions of NO_x, PM_{10}, SO_2 are lower than in 2006. The CO_2e emissions are 3% higher than in 2006 due to the increased activity.

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



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

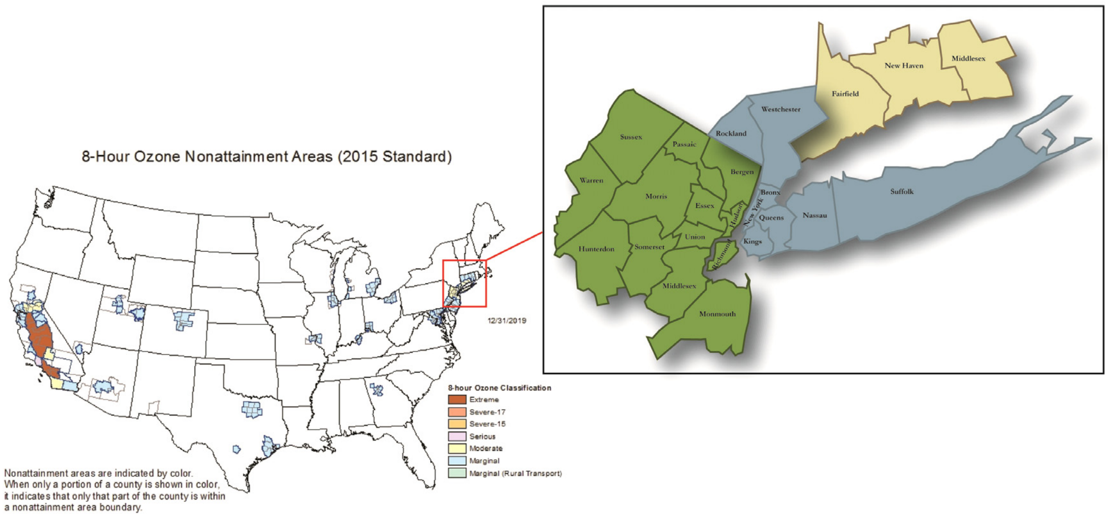
- Port Authority throughput increased by 4% in 2019 as compared to the previous year (2018) and it was higher by 47% in 2019 as compared to the baseline year (2006). Please note that 2019 was another record throughput year for PANYNJ and surpassed the 7 million TEU mark for the second year in a row.
- Port Authority maritime emissions of oxides of nitrogen (NO_x) related to the Port Authority marine terminals were 5% lower in 2019 than in 2018, and 40% lower than in 2006. On an emissions-per-TEU basis, emissions in 2019 were 8% lower than the 2018 estimates and 59% 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 7% lower in 2019 than in 2018 and 75% lower than in 2006. On an emissions-per-TEU basis, emissions in 2019 were 10% lower than the 2018 estimates and 83% 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 7% lower in 2019 than in 2018 and 73% lower than in 2006. On an emissions-per-TEU basis, emissions in 2019 were 10% lower than the 2018 estimates and 82% lower than the 2006 estimates.
- Port Authority maritime emissions of volatile organic compounds (VOCs) related to the Port Authority marine terminals were 5% lower in 2019 than in 2018 and 35% lower than in 2006. On an emissions-per-TEU basis, emissions in 2019 were 9% lower than the 2018 estimates and 55% lower than the 2006 estimates.
- Port Authority maritime emissions of carbon monoxide (CO) related to the Port Authority marine terminals were slightly lower (0.3%) in 2019 compared to 2018 and 27% lower than in 2006. On an emissions-per-TEU basis, emissions in 2019 were 4% lower than the 2018 estimates and 50% lower than the 2006 estimates.
- Port Authority maritime emissions of sulfur dioxide (SO_2) related to the Port Authority marine terminals were 5% lower in 2019 than in 2018 and 98% lower than in 2006. On an emissions-per-TEU basis, emissions in 2019 were 8% lower than the 2018 estimates and 98% lower than the 2006 estimates.
- Emissions of greenhouse gases[4] (GHG), presented as carbon dioxide equivalent (CO_2e), related to the Port Authority marine terminals were 2% higher in 2019 as in 2018 and 3% higher as compared to 2006. On an emissions-per-TEU basis, emissions in 2019 were 2% lower than the 2018 estimates and 30% lower than the 2006 estimates.

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

ES.2 Emission Estimates and Comparison to Regional Emissions

The Port Authority marine terminals included in this report are in an ozone nonattainment area for designated counties in New York, northern New Jersey, and Connecticut.[5] Figure ES.2 illustrates the counties that are within this nonattainment area.

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.

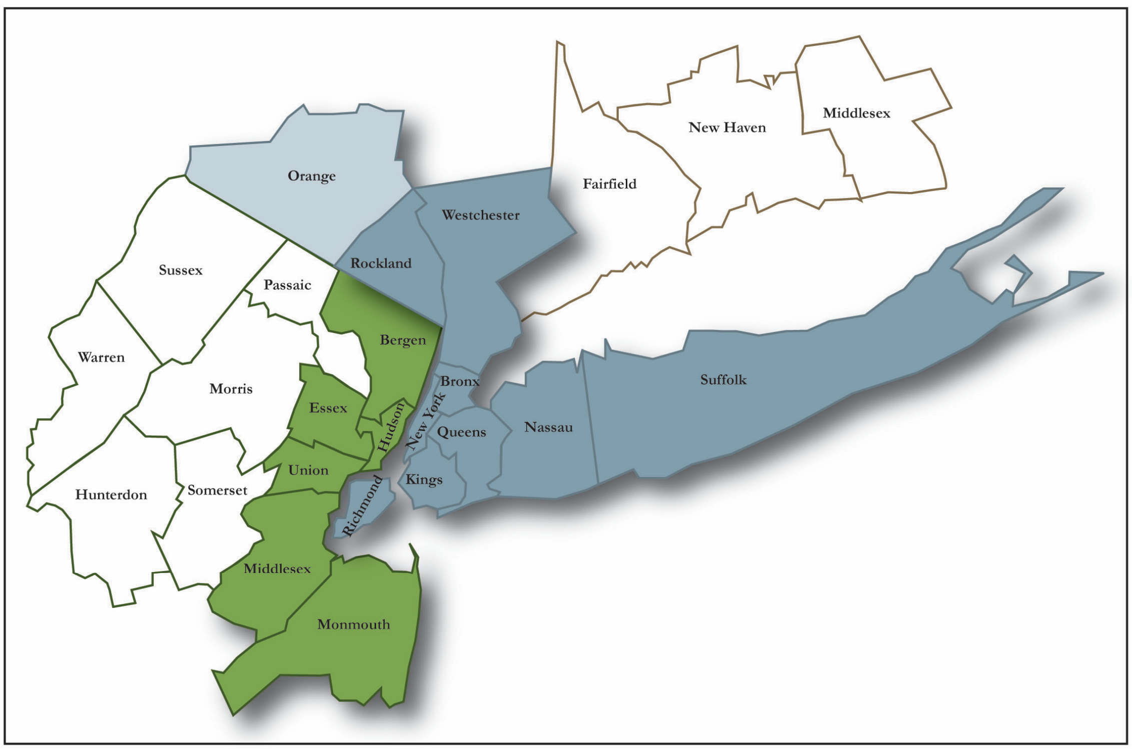
[5] For example, *https://www.epa.gov/airquality/greenbook/map8hr_2015.html*

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

New Jersey Counties	New York Counties
Bergen	Bronx
Essex	Kings
Hudson	Nassau
Middlesex	New York
Monmouth	Orange[6]
Union	Queens
	Richmond
	Rockland
	Suffolk
	Westchester

Figure ES.3 shows the counties in the nonattainment area for the 2008 and 2015 8-hr ozone standard with shading that highlights the counties included in this emissions inventory for emissions comparison to regional emissions. Note that Orange County, New York is included in the emissions inventory and in the regional comparisons although it is no longer within the nonattainment area. It is included because it was historically within the nonattainment area and included in the original NYNJLINA counties.

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



[6] Orange County is included in the emissions inventory and in the regional comparisons although it is no longer within the nonattainment area.

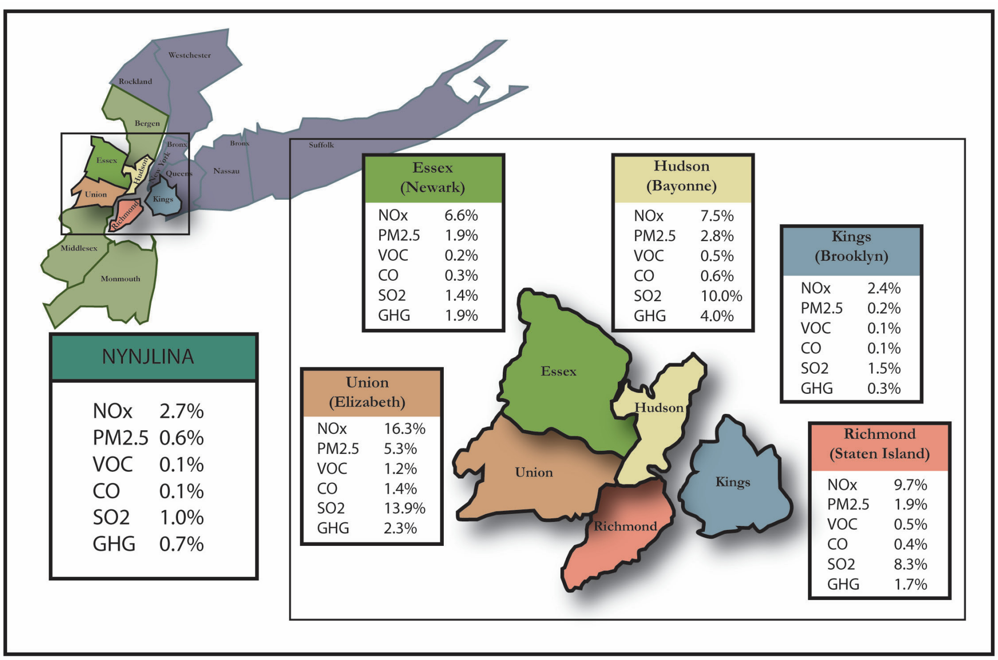
Table ES.2 presents the criteria pollutant and GHG (as CO_2e) emissions by source category, the total PANYNJ emissions, the total emissions in the NYNJLINA[7] in tons per year, and the percentage that the PANYNJ emissions made up of the total NYNJLINA emissions in 2019.

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	483	33	32	51	381	1.0	132,966
Heavy-Duty Vehicles	1,723	84	77	110	469	2.9	348,776
Railroad Locomotives	321	11	11	25	70	0.3	26,335
Ocean-Going Vessels	2,439	52	48	116	244	82.4	176,046
Harbor Craft	345	13	12	13	104	0.2	24,946
Total PANYNJ Emissions	**5,311**	**194**	**180**	**315**	**1,268**	**86.8**	**709,069**
NYNJLINA Emissions	**195,448**	**70,552**	**31,889**	**252,955**	**1,011,780**	**8,568**	**106,102,779**
PANYNJ Percentage	**2.7%**	**0.3%**	**0.6%**	**0.1%**	**0.1%**	**1.0%**	**0.7%**

Figure ES.4 illustrates the PANYNJ percentage of emissions in the context of the NYNJLINA emissions (table on the left of the figure) and the percentage that the 2019 PANYNJ emissions make up of all emissions in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure ES.4: Mobile Source Emissions at PANYNJ Marine Terminals Contribution to NYNJLINA and Local Air Emissions



[7] Criteria pollutant and GHG emissions are primarily from the 2017 National Emissions Inventory, downloaded July 2020. *https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data*

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 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).[8]

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 vehicles (HDV, 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 ($PM_{2.5}$).[9]

The purpose of this 2019 emissions inventory is to update the emission estimates with a focus on the Port Authority marine terminals. This current study has evaluated the CHE, HDV, railroad locomotive, and CMV emission source categories for the year 2019, 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, HDV, 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.
- 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.

[8] The terminals are listed and discussed below in subsection 1.1.2 Facilities.

[9] In December of 2012, New Jersey submitted a request to the EPA for re-designation to attainment of the annual 24-hour standards. On August 13, 2013, the USEPA re-designated New Jersey's 13 nonattainment counties to attainment for the annual and the 24-hr NAAQS, effective September 4, 2013, *https://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 with the NYNJLINA emissions and with 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 used to estimate emissions for each of the source categories use methods consistent with the latest estimating practices. 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 2019 and reported in tons per year. Emissions of the following criteria pollutants or precursors include:

- 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: 1990-2018*[10]. 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

[10] *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018*

1.1.2 Facilities

The Port Authority leases to private terminal operators five of the Port of New York and New Jersey's marine terminals, three in New Jersey and two in New York (Figure 1.1). 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. This EI report includes the air emissions generated 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.

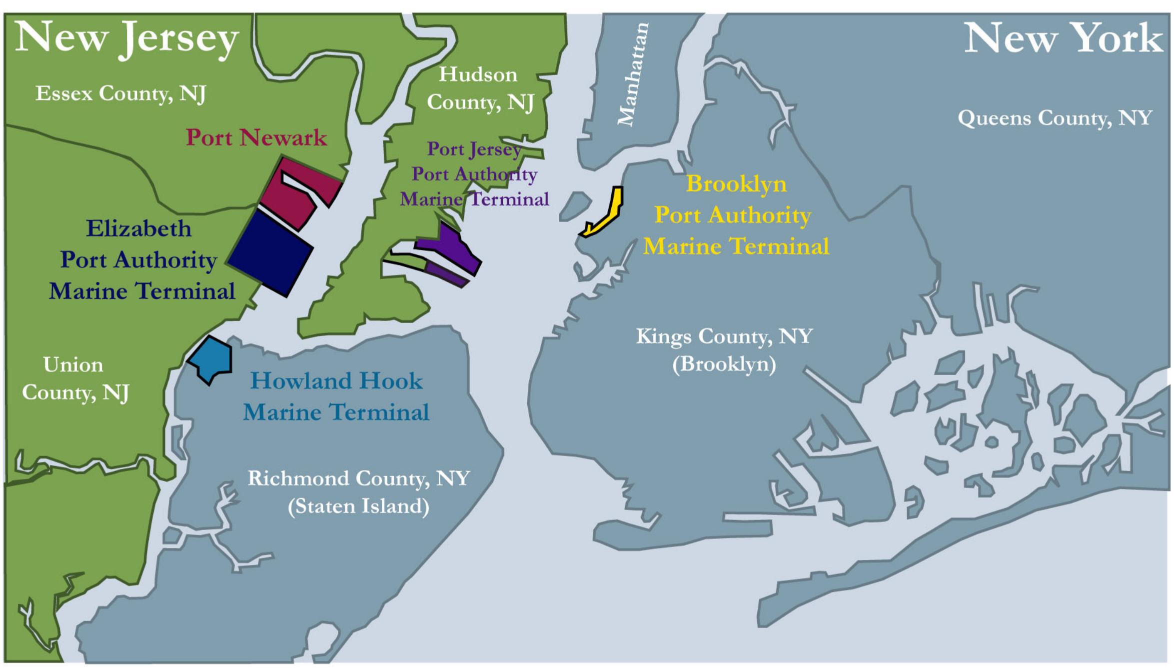
The Port Authority's New Jersey marine terminals are:

- 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 2019

There were no major changes to Port Authority facilities or emission calculation methodologies in 2019, but there were two improvements for CHE and towboats. For CHE, the terminals provided improved data for the 2019 inventory with more detailed engine parameters. The previous year emissions were re-estimated considering the improved equipment data to have an accurate comparison of 2019 to 2018 emissions. There was no need to re-estimate the 2006 inventory since the older equipment was not impacted by the improved engine data collected in 2019. For towboats, detailed engine information available through processing AIS data was used to estimate 2019 emissions. The 2019 towboat data did not affect the previous years' activity or emissions, therefore there was no need to re-estimate.

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 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 totals to the total emissions in the NYNJLINA[11] in tons per year (tpy). It should be noted that the NYNJLINA emissions are the using latest NEI emissions available (2017 NEI), which are lower than the 2014 emissions used in the previous PANYNJ 2018 EI report. Comparing 2019 PANYNJ emissions to the latest 2017 NEI is not a complete like-to-like comparison since they are different inventory years which represent different activity levels. 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 1.1: Emission Summary by Source Category, tpy

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Cargo Handling Equipment	483	33	32	51	381	1.0	132,966
Heavy-Duty Vehicles	1,723	84	77	110	469	2.9	348,776
Railroad Locomotives	321	11	11	25	70	0.3	26,335
Ocean-Going Vessels	2,439	52	48	116	244	82.4	176,046
Harbor Craft	345	13	12	13	104	0.2	24,946
Total PANYNJ Emissions	**5,311**	**194**	**180**	**315**	**1,268**	**86.8**	**709,069**
NYNJLINA Emissions	**195,448**	**70,552**	**31,889**	**252,955**	**1,011,780**	**8,568**	**106,102,779**
PANYNJ Percentage	**2.7%**	**0.3%**	**0.6%**	**0.1%**	**0.1%**	**1.0%**	**0.7%**

[11] Criteria pollutant and GHG emissions are from the 2017 National Emissions Inventory: *https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data*

Table 1.2 illustrates the percentage contribution of each source category to the total PANYNJ emissions of each pollutant. The ocean-going vessels and heavy-duty trucks contribute most emissions for the sources included in this inventory.

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%	17%	18%	16%	30%	1%	19%
Heavy-Duty Vehicles	32%	43%	43%	35%	37%	3%	49%
Railroad Locomotives	6%	6%	6%	8%	6%	0%	4%
Ocean-Going Vessels	46%	27%	27%	37%	19%	95%	25%
Harbor Craft	6%	7%	7%	4%	8%	0%	4%
Totals	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

1.4 Overall Comparison of PANYNJ Emissions

This section compares overall Port Authority marine terminal-related emissions with county level emission totals as reported in the 2017 NEI. Figure 1.2 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: Mobile Source Emissions at PANYNJ Marine Terminals Contribution to NYNJLINA and Local Air Emissions

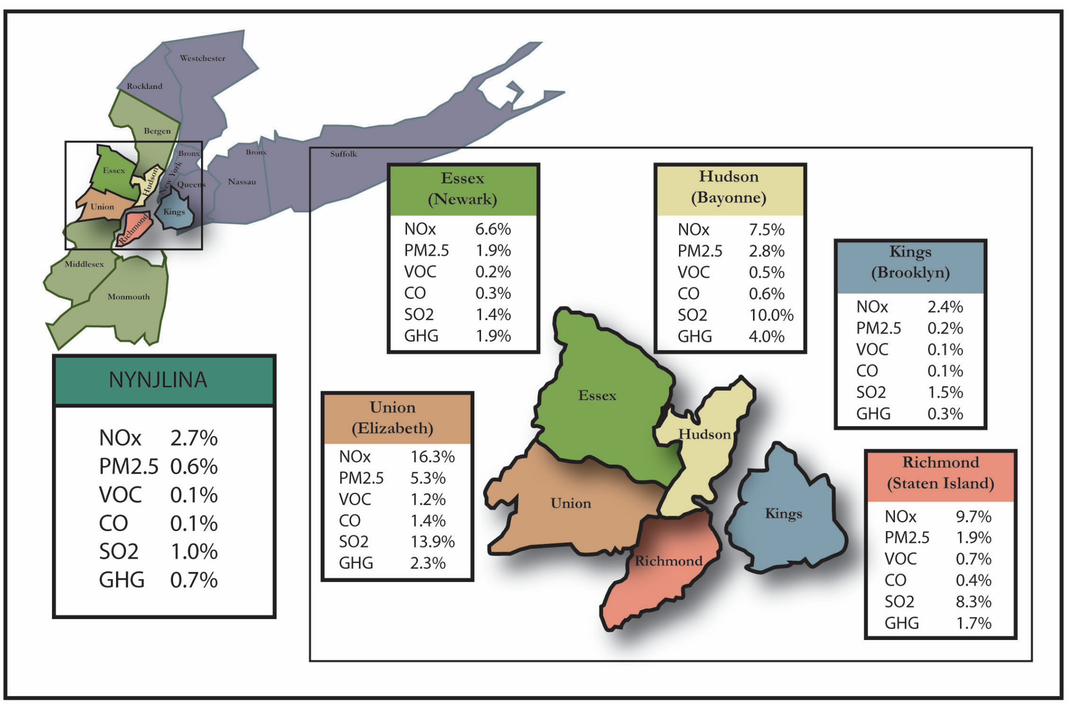


Table 1.3 summarizes by county the estimated emissions from the Port Authority marine terminal-related activities covered by this report.

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	134	5	5	7	35	0	24,869
Essex	NJ	1,092	42	39	63	229	20	164,943
Hudson	NJ	747	26	24	43	154	14	92,926
Middlesex	NJ	265	12	11	14	69	0	52,549
Monmouth	NJ	260	4	3	9	23	5	11,253
Union	NJ	1,501	73	68	107	533	24	260,231
New Jersey subtotal		**3,999**	**162**	**151**	**243**	**1,044**	**64**	**606,771**
Bronx	NY	15	1	1	1	4	0	2,828
Kings	NY	325	7	6	19	67	7	19,021
Nassau	NY	7	0	0	0	2	0	1,184
New York	NY	65	1	1	2	7	2	4,505
Orange	NY	73	3	3	4	19	0	14,934
Queens	NY	193	3	3	7	18	4	9,543
Richmond	NY	540	14	13	35	82	10	36,879
Rockland	NY	67	2	2	3	18	0	9,342
Suffolk	NY	13	1	0	1	4	0	1,617
Westchester	NY	14	1	1	1	4	0	2,445
New York subtotal		**1,312**	**32**	**30**	**72**	**223**	**23**	**102,298**
PANYNJ Total		**5,311**	**194**	**180**	**315**	**1,268**	**87**	**709,069**

Table 1.4 lists total emissions of each criteria pollutant by county and state, as reported in the most recent National Emissions Inventory (2017 NEI), which is updated by EPA as reports come in from the states and represents the best source of area-wide emissions data. It should be noted that the 2017 NYNJLINA emissions, which are the latest available, are lower than the 2014 emissions used in the previous PANYNJ EI report. This shows an overall regional emissions reduction from all sources, not just those emission sources pertaining to the PANYNJ.

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 County	NJ	13,039	2,951	1,887	15,100	87,035	172	6,684,339
Essex County	NJ	16,670	4,552	2,067	26,480	70,930	1,454	8,873,281
Hudson County	NJ	9,946	1,494	845	8,264	27,068	143	2,315,613
Middlesex County	NJ	12,498	3,410	1,894	15,466	67,744	231	10,423,700
Monmouth County	NJ	8,988	2,966	1,638	14,384	59,951	154	3,871,333
Union County	NJ	9,235	2,148	1,298	8,957	39,340	174	11,284,879
New Jersey subtotal		**70,375**	**17,520**	**9,629**	**88,651**	**352,068**	**2,329**	**43,453,144**
Bronx County	NY	6,005	2,445	1,118	9,919	29,900	183	2,718,567
Kings County	NY	13,572	4,708	2,560	17,660	59,474	478	5,642,275
Nassau County	NY	15,047	5,959	2,479	19,678	94,281	499	8,346,699
New York County	NY	18,827	11,983	3,903	16,026	82,794	884	6,807,408
Orange County	NY	5,850	3,527	1,414	15,635	33,590	439	2,811,874
Queens County	NY	23,501	6,322	3,035	21,546	85,913	1,736	14,591,117
Richmond County	NY	5,578	1,426	660	5,227	20,511	121	2,112,516
Rockland County	NY	4,553	1,948	852	7,248	24,593	181	2,485,734
Suffolk County	NY	20,379	9,309	3,890	32,692	146,840	1,204	11,626,640
Westchester County	NY	11,763	5,404	2,351	18,672	81,816	515	5,506,804
New York subtotal		**125,073**	**53,032**	**22,260**	**164,303**	**659,712**	**6,240**	**62,649,635**
TOTAL		**195,448**	**70,552**	**31,889**	**252,955**	**1,011,780**	**8,568**	**106,102,779**

1.5 Comparison of 2019 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 influences the emissions from specific emission sources through 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.

Emission estimates from prior years have been adjusted to account for changes in emission estimating methodology to make them comparable with the current year estimates. 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, 2018, and 2019 as adjusted to be compatible with the latest estimates for 2019. The emissions are expressed as tons per year and as the percentage increases or decreases between 2019 and previous years. The last column includes the throughput in million TEUs to compare the increased activity to the emission changes.

Table 1.5: Port Related Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2019	5,311	194	180	315	1,268	87	709,069	7.47
2018	5,573	210	195	333	1,271	91	697,733	7.18
2006	8,890	783	669	481	1,746	4,025	685,659	5.09
2018-2019, Change (%)	**-5%**	**-7%**	**-7%**	**-5%**	**0%**	**-5%**	**2%**	**4%**
2006-2019, Change (%)	**-40%**	**-75%**	**-73%**	**-35%**	**-27%**	**-98%**	**3%**	**47%**

Please note the 2018 emissions are different from the emissions previously included in the 2018 EI report because 2018 CHE emissions were re-estimated due to a change in the available 2018 CHE data. This is discussed in Section 2: Cargo Handling Equipment.

Table 1.6 presents the 2019 and 2006 emissions comparison by source category. Despite a 47% increase in TEU throughput in 2019 as compared to 2006, emission reductions occurred for most pollutants, except for overall CO_2e emissions. Since 2006, 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 (PM_{10} and $PM_{2.5}$), due to a combination of factors including the Port Authority's truck program that has brought many newer trucks into the fleet of trucks serving the Port's terminals, and lower sulfur fuels.

Table 1.6: Port Related 2019-2006 Emissions Comparison by Source Category

	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons
2019							
Ocean-going vessels	2,439	52	48	116	244	82.4	176,046
Harbor craft	345	13	12	13	104	0.2	24,946
Cargo handling equipment	483	33	32	51	381	1.0	132,966
Locomotives	321	11	11	25	70	0.3	26,335
Heavy-duty vehicles	1,723	84	77	110	469	2.9	348,776
Total	**5,311**	**194**	**180**	**315**	**1,268**	**86.8**	**709,069**
2006							
Ocean-going vessels	4,165	392	314	185	360	3,681	221,638
Harbor craft	505	27	25	17	79	50	26,938
Cargo handling equipment	1,503	100	92	132	495	233	154,184
Locomotives	286	10	9	20	44	32	14,710
Heavy-duty vehicles	2,431	254	229	127	768	29	268,189
Total	**8,890**	**783**	**669**	**481**	**1,746**	**4,025**	**685,659**
Change between 2006 and 2019 (percent)							
Ocean-going vessels	-41%	-87%	-85%	-37%	-32%	-98%	-21%
Harbor craft	-32%	-51%	-51%	-26%	31%	-100%	-7%
Cargo handling equipment	-68%	-67%	-65%	-61%	-23%	-100%	-14%
Locomotives	12%	12%	12%	23%	59%	-99%	79%
Heavy-duty vehicles	-29%	-67%	-66%	-13%	-39%	-90%	30%
Total	**-40%**	**-75%**	**-73%**	**-35%**	**-27%**	**-98%**	**3%**

Table 1.7 presents the 2019 and 2018 emissions comparison by source category. Overall, 2019 emissions are lower as compared to the previous year, with the exception of a small increase in CO_2e, despite another record year with 7.47 million TEUs moved in 2019.

Table 1.7: Port Related 2019-2018 Emissions Comparison by Source Category

	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons
2019							
Ocean-going vessels	2,439	52	48	116	244	82.4	176,046
Harbor craft	345	13	12	13	104	0.2	24,946
Cargo handling equipment	483	33	32	51	381	1.0	132,966
Locomotives	321	11	11	25	70	0.3	26,335
Heavy-duty vehicles	1,723	84	77	110	469	2.9	348,776
Total	**5,311**	**194**	**180**	**315**	**1,268**	**86.8**	**709,069**
2018							
Ocean-going vessels	2,443	52	48	118	243	86.5	173,488
Harbor craft	413	17	16	17	125	0.2	28,859
Cargo handling equipment*	514	35	34	52	320	1.0	131,552
Locomotives	320	11	11	24	68	0.3	25,812
Heavy-duty vehicles	1,882	94	86	122	516	2.9	338,022
Total*	**5,573**	**210**	**195**	**333**	**1,271**	**91.0**	**697,733**
Change between 2018 and 2019 (percent)							
Ocean-going vessels	0%	1%	0%	-1%	1%	-5%	1%
Harbor craft	-17%	-23%	-22%	-23%	-17%	-14%	-14%
Cargo handling equipment	-6%	-6%	-6%	-2%	19%	-2%	1%
Locomotives	0%	0%	0%	1%	2%	0%	2%
Heavy-duty vehicles	-8%	-11%	-11%	-10%	-9%	-1%	3%
Total	**-5%**	**-7%**	**-7%**	**-5%**	**-0.3%**	**-5%**	**2%**

Please note that 2018 cargo handling equipment emissions listed in this report are different from the emissions listed in the previous 2018 EI report. This is due to a change made in 2019 as part of a scope change that included the addition of emissions from CHE operated at the RHCT barge depot. In addition, during 2019 data collection, one of the terminals provided information on additional equipment that was also operating in 2018 but not previously reported. For comparison purposes, the previous year (CY 2018) emissions were adjusted for the RHCT barge depot and the newly reported equipment at the other terminal. This resulted in adding equipment to the 2018 CHE inventory and thus emissions changed for 2018 CHE and the resulting total 2018 emissions.

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 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.

The limited amount of cargo handling equipment used at bulk terminal is not included in the cargo handling equipment inventory, but emissions from commercial marine vessels calling at bulk terminals are included in Section 5.

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

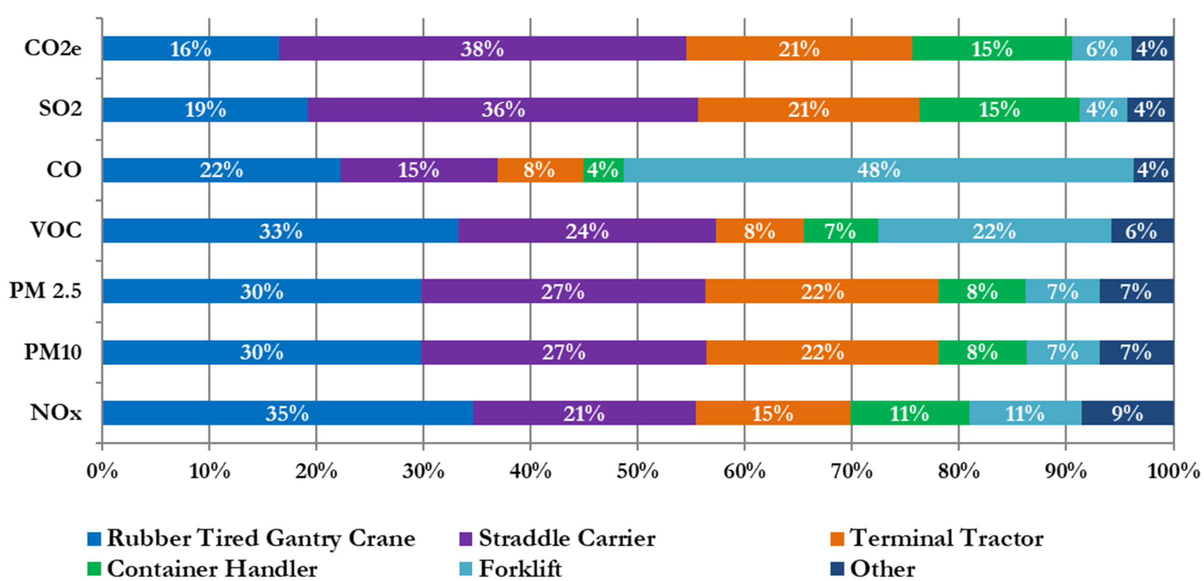
Table 2.1 presents emissions sorted by equipment type for all terminals combined. The equipment types are described later in this section.

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	70	7.2	7.0	4.2	30	0.21	28,116
Straddle Carrier	100	8.8	8.6	12.3	56	0.37	50,524
Forklift	51	2.3	2.2	11.1	181	0.05	7,403
Empty Container Handler	34	1.8	1.7	2.3	9	0.07	9,142
Loaded Container Handler	20	1.0	0.9	1.3	6	0.08	10,724
Rubber Tired Gantry Crane	167	9.9	9.6	17.0	85	0.20	21,920
Other Primary Equipment	15	0.6	0.6	0.8	4	0.03	3,232
Ancillary Equipment	26	1.6	1.6	2.2	10	0.02	1,903
Totals	**483**	**33.2**	**32.3**	**51.1**	**381**	**1.02**	**132,966**

Figure 2.1 shows the emissions distribution for various pollutants and types of CHE. RTG cranes and straddle carriers contribute approximately half of the emissions from CHE equipment, followed by terminal tractors, forklifts and container handlers. Forklifts contribute almost half of the CO emissions due to the use of propane engines.

Figure 2.1: Distribution of CHE 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 2019 CHE emissions with the results of earlier emissions inventories.

2.2.1 Comparisons with County and Regional Emissions

Table 2.2 presents the estimated PANYNJ Marine Terminals 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 2.2: Comparison of PANYNJ Marine Terminals 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	391,399	243,410	88,019	839,013	2,184,903	30,760	200,748,788
NYNJLINA	195,448	70,552	31,889	252,955	1,011,780	8,568	106,102,779
CHE	483	33	32	51	381	1.0	132,966
% of NYNJLINA Emissions	**0.25%**	**0.05%**	**0.10%**	**0.02%**	**0.04%**	**0.012%**	**0.13%**

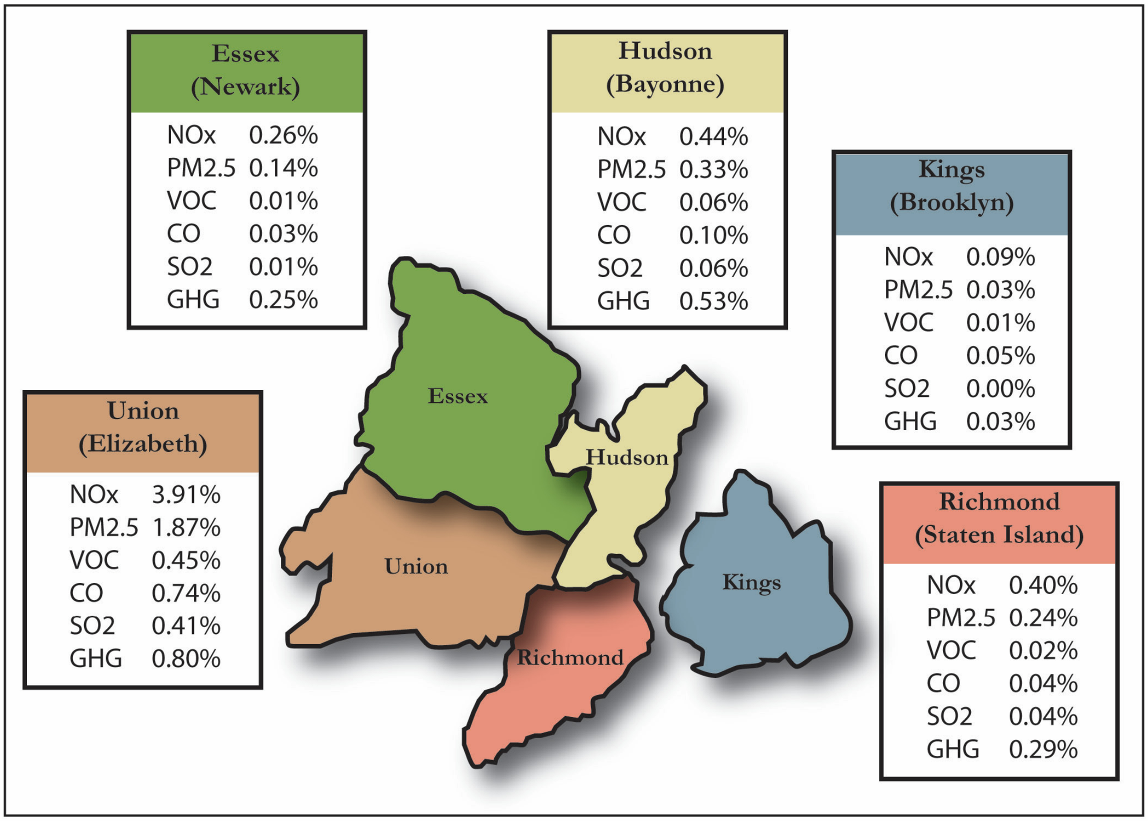
Table 2.3 summarizes the PANYNJ Marine Terminals CHE emissions by county and state.

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	0
Essex	NJ	44	3.1	3.0	3.3	21	0.16	22,150
Hudson	NJ	44	2.9	2.8	5.1	28	0.09	12,261
Middlesex	NJ	0	0	0	0	0	0	0
Monmouth	NJ	0	0	0	0	0	0	0
Union	NJ	361	25.0	24.3	39.9	292	0.71	90,585
New Jersey subtotal		**449**	**31.0**	**30.0**	**48.2**	**340**	**0.95**	**124,996**
Bronx	NY	0	0	0	0	0	0	0
Kings	NY	12	0.7	0.6	1.6	32	0.01	1,930
Nassau	NY	0	0	0	0	0	0	0
New York	NY	0	0	0	0	0	0	0
Orange	NY	0	0	0	0	0	0	0
Queens	NY	0	0	0	0	0	0	0
Richmond	NY	23	1.6	1.6	1.3	8	0.05	6,040
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		**35**	**2.3**	**2.2**	**2.9**	**40**	**0.06**	**7,970**
TOTAL		**483**	**33.2**	**32.3**	**51.1**	**381**	**1.02**	**132,966**

The following figure illustrates the PANYNJ marine terminals percentage of CHE emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 2.2: PANYNJ Marine Terminals 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 and the percentage difference between 2019, the previous year, and 2006 estimates.

Table 2.4: CHE Emissions Comparison, tpy and %

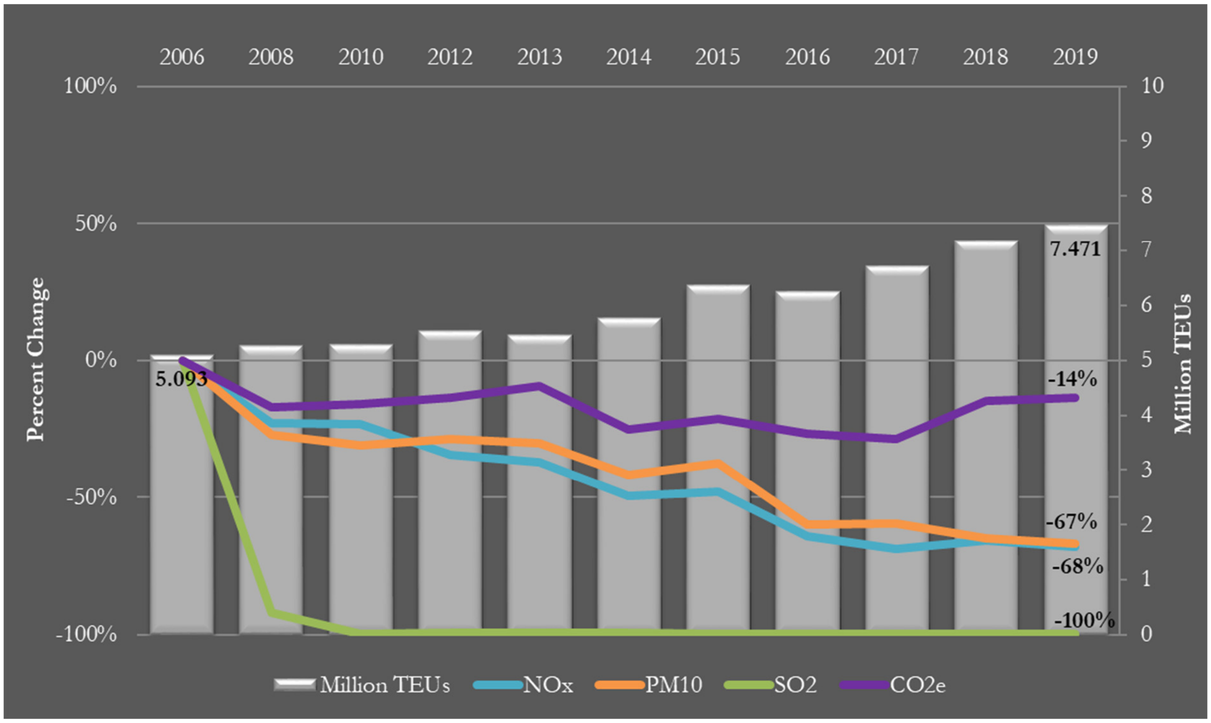
Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2019	483	33	32	51	381	1	132,966	7.47
2018	514	35	34	52	320	1	131,552	7.18
2006	1,503	100	92	132	495	233	154,184	5.09
2018-2019, Change (%)	**-6%**	**-6%**	**-6%**	**-2%**	**19%**	**-2%**	**1%**	**4%**
2006-2019, Change (%)	**-68%**	**-67%**	**-65%**	**-61%**	**-23%**	**-100%**	**-14%**	**47%**

Please note that 2018 cargo handling equipment emissions listed in this report are different from the emissions listed in the previous 2018 EI report. This is due to a change made in 2019 as part of a scope change that included the addition of emissions from CHE operated at the RHCT barge depot. In addition, during 2019 data collection, one of the terminals provided information on additional equipment that was also operating in 2018 but not previously reported. For comparison purposes, the previous year (CY 2018) emissions were adjusted for the RHCT barge depot and the newly reported equipment at the other terminal. This resulted in adding equipment to the 2018 CHE inventory and thus emissions changed for 2018 CHE.

Emissions from cargo handling equipment were lower in 2019 as compared to 2006 despite the 47% TEU throughput increase. Lower emissions can be attributed to factors such as fleet turnover to cleaner equipment, and increased use of Tier 4 equipment. Compared to the previous year (2018), TEU throughput in 2019 increased by 4% and the overall CHE emissions are lower for NO_x, PM, VOC, and SO_2. Compared to previous year, the CO and GHG (CO_2e) emissions are higher due to increased activity and use of propane forklifts and lack of emissions control for CO and CO_2e.

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 2019 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. The Port is improving its collaboration with tenants to raise awareness on importance the equipment inventory. This resulted in robust data received for 2019.

2.3.2 Emission Estimating Model

Emissions were estimated using equipment specific emission factors output of EPA's MOVES2014b emission estimating model.[12] The cargo handling equipment identified by survey was categorized into the most closely corresponding MOVES2014b equipment type. For example, cargo handling equipment described by various names by the terminals were grouped together; such as, straddle carriers, empty container handlers and top loaders were categorized under the modeling category "other industrial equipment" because the model does

[12] *https://www.epa.gov/otaq/models/moves/*

not include a more specific category for these equipment types. Table 2.5 presents equipment types by Source Classification Code (SCC), load factor, and MOVES2014b category 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	2270003020	0.59	Forklift
Propane Forklift	2267003020	0.59	LPG Forklift
Sweeper	2270003030	0.43	Sweeper / scrubber
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	0.39*	Terminal tractor

*The load factor for terminal tractors is based on actual test data collected at the Port of Los Angeles and Port of Long Beach.

Table 2.6 lists the population of diesel and propane powered 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	2018 Count	2019 Count
Aerial lift	2270003010	11	13	17
Crane	2270002045	13	4	4
Diesel forklift	2270003020	0	107	113
Propane forklift	2267003020	87	85	108
Other industrial equipment	2270003040	143	218	182
Other material handling equipment	2270003050	260	432	413
Offroad truck	2270002051	9	22	5
Signal board / light plant	2270002027	12	12	12
Skid-steer Loader	2270002072	0	2	2
Sweeper / scrubber	2270003030	2	10	4
Terminal tractor	2270003070	350	432	434
Totals		**887**	**1,337**	**1,294**

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

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

Where:

E = emissions, grams or tons/year
EF = emission factor, grams of pollutant per unit of work, g/hp-hr or g/kW-hr
Power = rated power of the engine, hp or kW
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
Act = equipment's engine activity, hr/year
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 MOVES2014b model is run to output emission factors in grams/hp-hr for each of the MOVES2014b equipment types by fuel type, 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 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 MOVES2014b model contains a load factor and default conditions for each source category. 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 majority (84%) of equipment is diesel powered, as illustrated in Figure 2.4. The inventory also includes 108 propane powered forklifts and 121 pieces of electric equipment. The electric equipment is not included in the equipment counts in the tables that follow because they do not contribute to emissions at the terminal facilities.

Figure 2.4: Equipment Count by Fuel Type

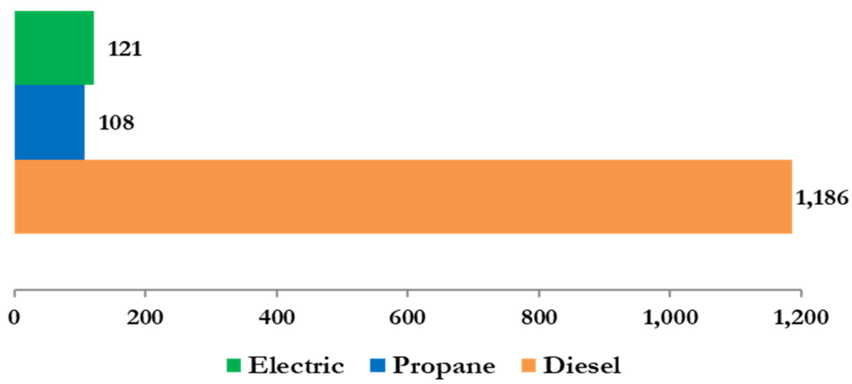


Table 2.7 summarizes the 2019 fleet characteristics of primary and ancillary non-road equipment, respectively, in terms of equipment count, and averages of model year, horsepower, and annual operating hours. As noted above, emissions were estimated using equipment-specific values for each piece of equipment.

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	434	33.5%	2012	173	1,629
Straddle Carrier	352	27.2%	2012	298	2,847
Forklift	221	17.1%	2009	134	662
Empty Container Handler	72	5.6%	2011	203	2,446
Rubber Tired Gantry Crane	61	4.7%	2005	568	4,585
Loaded Container Handler	82	6.3%	2013	357	1,439
Reach Stacker	27	2.1%	2007	317	1,412
Subtotal Primary Equipment	1,249	96.5%	2011	238	1,975
Ancillary Equipment					
Portable Light Set	12	0.9%	2001	50	301
Aerial Platform	17	1.3%	2010	58	109
Sweeper	4	0.3%	2011	51	361
Diesel Fuel Truck	5	0.4%	2007	242	706
Crane	4	0.3%	1991	925	1,601
Skid Steer Loader	2	0.2%	2004	38	411
Chassis Flipper	1	0.1%	2013	155	0
Subtotal Ancillary Equipment	45	3.5%	2005	154	393
Total	**1,294**				
Electric Equipment Count	**121**				
Total	**1,415**				

Figure 2.5 illustrates the total population distribution of the CHE by equipment type. Ancillary equipment were grouped together for the figure.

Figure 2.5: Population Distribution of CHE

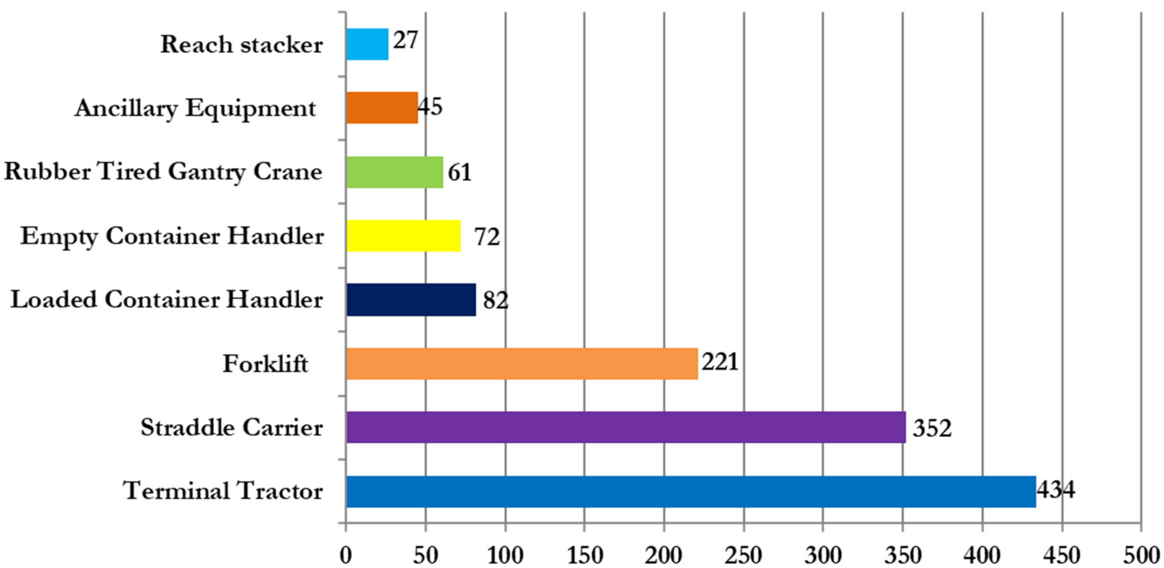


Table 2.8 presents summary data on the diesel engines in the 2019 inventory for the 1,186 diesel engines. In 2019, 17% of the diesel equipment were equipped with Tier 0 through Tier 2 engines. About 78% of diesel equipment were equipped with Tier 3 or Tier 4 engines. About 60% of total equipment energy usage in terms of hp-hr is from Tier 4 equipment. The newer pieces of equipment are being used more and produce lower emissions. Please note that the table includes diesel equipment count only and does not match the overall equipment count since electric and propane equipment is not included in the diesel tier count table.

Table 2.8: CHE Diesel Equipment Tier Count

Equipment Type	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4i	Tier 4f	Onroad	Unknown	Total
Empty Container Handler	1	0	7	21	15	28	0	0	72
Forklift	11	15	15	13	35	24	0	0	113
Loaded Container Handler	0	0	3	20	8	51	0	0	82
Reach Stacker	1	2	8	7	0	1	0	8	27
RTG Crane	0	0	36	20	3	2	0	0	61
Straddle Carrier	0	0	39	87	47	179	0	0	352
Terminal Tractor	3	11	21	76	62	217	44	0	434
Other	0	17	10	2	3	8	5	0	45
Total	**16**	**45**	**139**	**246**	**173**	**510**	**49**	**8**	**1,186**
Percent	**1%**	**4%**	**12%**	**21%**	**15%**	**43%**	**4%**	**1%**	

The following Figures 2.6 through 2.10 show examples of the most common types of CHE: terminal tractor, straddle carrier, loaded container handler, empty container handler, and forklift.

Figure 2.6: Example Terminal Tractor

Figure 2.7: Example Straddle Carrier

Figure 2.8. Example Loaded Container Handler

Figure 2.9. Example Empty Container Handler

Figure 2.10. Example Forklift

SECTION 3: HEAVY-DUTY VEHICLES

This section presents estimated emissions from heavy-duty vehicles (HDVs) that visit the container terminals, warehouses, and automobile handling facilities within the Port Authority marine terminals. An example of an HDV included in the inventory is the diesel-powered road truck that calls at a marine terminal to pick up or drop off a container. This type of HDV is by far the most common vehicle operating at the Port Authority marine terminals. The following subsections present the HDV emission estimates, describe the methodologies used to collect information and estimate emissions, and present a description of the equipment types. This Section 3 consists of the following subsections:

- 3.1 - HDV Emission Estimates
- 3.2 - HDV Emission Comparisons
- 3.3 - HDV Emission Calculation Methodology
- 3.4 - Description of HDVs

3.1 Heavy-Duty Vehicle Emission Estimates

Emissions have been estimated for HDVs traveling within the marine terminals associated with the Port Authority and on public roads within the inventory domain. 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, also, the 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 HDV operation.

The HDV emissions were estimated using the MOVES2014b emission estimating model. As such, the estimates are not comparable with estimates presented in previous emissions inventory reports before the 2013 inventory report, which presents earlier year inventories normalized to the MOVES2014 emission model.[13] Section 3.2 contains a more detailed description of the comparison of estimated 2019 emissions with earlier year estimates. The totals of on-terminal and on-road emissions 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	80	5	5	6	27	0.16	18,204
On-Terminal Idling	161	12	11	23	56	0.19	22,925
On-Road Driving	1,482	67	61	81	386	2.57	307,647
Totals	**1,723**	**84**	**77**	**110**	**469**	**2.92**	**348,776**

[13] Versions MOVES2014a and MOVES2014b did not differ in their estimates of HDV emissions so results from both are comparable.

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 MOVES2014b 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 HDV On-Terminal Emissions, tpy

Facility Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Auto Terminals	28	0.4	0.4	5.4	11.3	0.01	1,235
Container Terminals	208	16.3	15.0	23.6	69.6	0.33	38,909
Warehouses	6	0.5	0.4	0.7	1.9	0.01	985
Overall Total	**241**	**17.2**	**15.8**	**29.8**	**82.7**	**0.35**	**41,129**

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

Facility Type	VMT	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Auto Terminals	14,106	0.2	0.01	0.01	0.01	0.1	0.00	41
Container Terminals	6,130,379	79.2	4.94	4.55	6.24	26.1	0.16	17,922
Warehouses	82,658	1.1	0.07	0.06	0.08	0.4	0.00	242
Overall Total	**6,227,143**	**80.4**	**5.02**	**4.62**	**6.34**	**26.5**	**0.16**	**18,204**

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

Facility Type	Idling Hours	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Auto Terminals	114,155	27	0.4	0.4	5.4	11.2	0.01	1,194
Container Terminals	2,210,912	129	11.3	10.4	17.4	43.5	0.18	20,987
Warehouses	78,271	5	0.4	0.4	0.6	1.5	0.01	743
Overall Total	**2,403,338**	**161**	**12.2**	**11.2**	**23.4**	**56.2**	**0.19**	**22,925**

3.1.2 On-Road Emissions

Table 3.5 presents estimates of on-road emissions in tons per year by state from container terminal trucks. As noted above, the estimates were prepared using the MOVES2014b model and are only comparable with prior-year estimates presented in the 2013 and later emissions inventory reports.

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

State	VMT	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
New Jersey	139,490,635	1,331	60.0	55.2	72.4	347.0	2.3	276,353
New York	15,796,168	151	6.8	6.3	8.2	39.3	0.3	31,295
Total	**155,286,803**	**1,482**	**66.8**	**61.5**	**80.6**	**386.3**	**2.6**	**307,647**

3.2 HDV Emission Comparisons by County and Region

In this section, 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 NEI numbers,[14] which are from the 2017 NEI. The extent to which the NEI estimates of on-road emissions were prepared using either the MOVES2014a/b or MOVES2010 models 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 presented here should be considered as approximate.

This section also presents a comparison of 2019 heavy-duty truck emission estimates with the results of earlier emissions inventories. The 2012 and earlier emissions have been adjusted to reflect the relative differences between the models used for those inventories (MOBILE6.2 and MOVES2010) to make them comparable to the MOVES2014b results. 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 HDV emissions associated with GCT Bayonne during those earlier years, as discussed below in Subsection 3.2.2.

[14] Accessed at: *https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data*

3.2.1 Comparisons with County and Regional Emissions

Table 3.6 presents the estimated HDV 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 HDV 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 Marine Terminals HDV Emissions with State and NYNJLINA Emissions, tpy

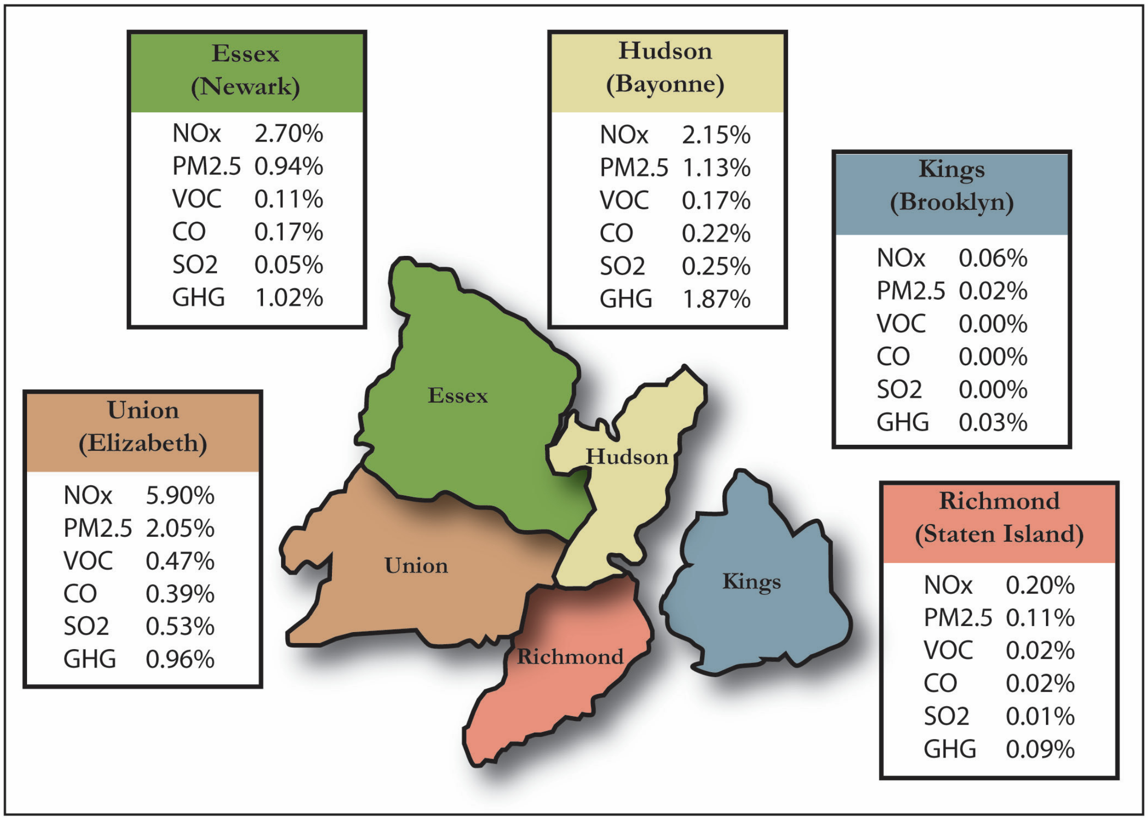
Geographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
New York and New Jersey	391,399	243,410	88,019	839,013	2,184,903	30,760	200,748,788
NYNJLINA	195,448	70,552	31,889	252,955	1,011,780	8,568	106,102,779
Heavy-Duty Diesel Vehicles	1,723	84	77	110	469	3	348,776
Percent of NYNJLINA Emissi	**0.88%**	**0.12%**	**0.24%**	**0.04%**	**0.05%**	**0.03%**	**0.33%**

Table 3.7: Summary of Heavy-duty 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	107	4.8	4.4	6	28	0.19	22,259
Essex	NJ	451	21.2	19.5	29	123	0.76	90,468
Hudson	NJ	214	10.3	9.5	14	58	0.36	43,252
Middlesex	NJ	246	11.1	10.2	13	64	0.43	50,998
Monmouth	NJ	1	0.0	0.0	0	0	0.00	216
Union	NJ	544	28.9	26.6	39	153	0.91	108,704
New Jersey subtotal		**1,563**	**76**	**70**	**101**	**427**	**2.64**	**315,897**
Bronx	NY	13	0.6	0.5	1	3	0.02	2,753
Kings	NY	8	0.5	0.4	1	2	0.01	1,688
Nassau	NY	5	0.2	0.2	0	1	0.01	1,013
New York	NY	2	0.1	0.1	0	1	0.00	423
Orange	NY	71	3.2	3.0	4	19	0.12	14,787
Queens	NY	9	0.4	0.4	0	2	0.01	1,789
Richmond	NY	11	0.8	0.7	1	3	0.02	1,981
Rockland	NY	25	1.1	1.0	1	7	0.04	5,191
Suffolk	NY	5	0.2	0.2	0	1	0.01	1,032
Westchester	NY	11	0.5	0.4	1	3	0.02	2,222
New York subtotal		**160**	**8**	**7**	**9**	**42**	**0.27**	**32,879**
Total		**1,723**	**84**	**77**	**110**	**469**	**2.92**	**348,776**

The following figure illustrates the PANYNJ marine terminals percentage of HDV emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 3.1: PANYNJ Marine Terminals HDV Percent Contribution to Local Air Emissions



3.2.2 Comparisons with Prior Year Emission Estimates

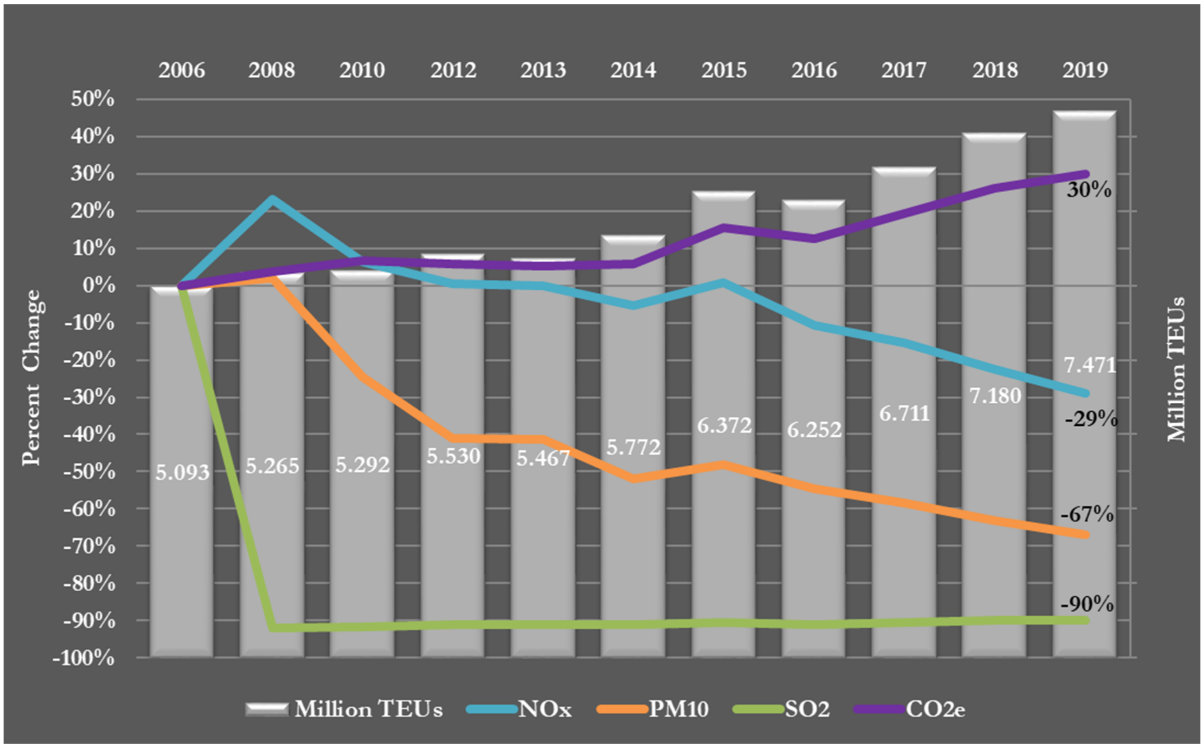
Table 3.8 presents annual HDV emissions for 2019, previous year and 2006. The table also shows the percentage differences for 2018-2019 and 2006-2019.

Table 3.8: HDV Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2019	1,723	84	77	110	469	3	348,776	7.47
2018	1,882	94	86	122	516	3	338,022	7.18
2006	2,431	254	229	127	768	29	268,189	5.09
2018-2019, Change (%)	**-8%**	**-11%**	**-11%**	**-10%**	**-9%**	**-1%**	**3%**	**4%**
2006-2019, Change (%)	**-29%**	**-67%**	**-66%**	**-13%**	**-39%**	**-90%**	**30%**	**47%**

The following figure graphically illustrates the changes in HDV emissions of NO_x, PM_{10}, SO_2 and CO_2 between the 2006 baseline emissions inventory and the 2019 update, with emission trend lines superimposed over columns representing the annual TEU throughput (in millions).

Figure 3.2: HDV Emissions Relative to TEU Throughput



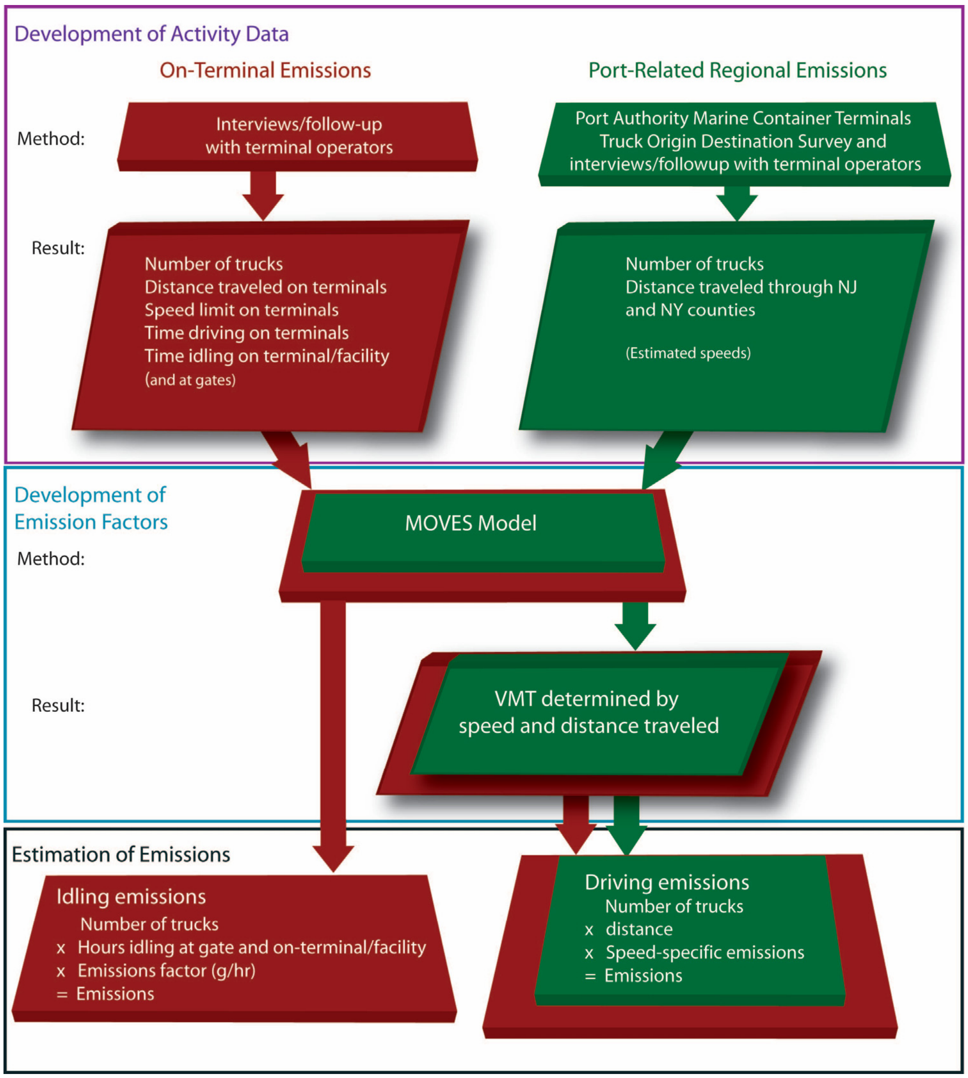
The effects of the progressively newer fleet over the recent few years, discussed later in this section, show up in the decreases of NO_x and PM compared with earlier inventories. In addition, despite the 4% increase in the Port's TEU throughput between 2018 and 2019, with a corresponding increase in HDV activity, NO_x and PM emissions continued to decrease between 2018 and 2019. The new Intermodal Container Transfer Facility provided near-dock rail access for GCT Bayonne which reduced truck trips and vehicle miles traveled (VMT) to Elizabeth's Millennium Marine Rail.

Continued renewal of the drayage truck fleet as a result of the Port Authority's Truck Replacement Program is expected to lead to continued decreases in criteria pollutants for at least a few years, and the enhanced model year data collection discussed below provides up-to-date model year distributions that reflect the effectiveness of the program. Emissions of CO_2 and SO_2, which are directly tied to fuel consumption, increased by approximately the same amount as the throughput increase, because the fuel consumption rate of diesel trucks (miles per gallon) does not significantly change from year to year.

3.3 Vehicle Emission Calculation Methodology

This section contains a description of the methodology used to collect data and the process by which emission estimates were developed for HDVs. Figure 3.3 illustrates this process in a flow diagram for on-terminal and on-road activity.

Figure 3.3: HDV Emission Estimating Process



3.3.1 Data Acquisition

Activity data for the HDV 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 requested of facility operators, such as the number of truck visits during the year, the average time that trucks spend on their terminals and the average speed at which they travel, is provided 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 number of truck visits for which emissions are calculated is based on actual changes in cargo throughput from year to year (with more cargo resulting in more truck calls). The characteristics of on-terminal HDV activities used to estimate emissions at the Port Authority marine terminals leased to private operators, are listed in Table 3.9. The table includes three auto handling terminals, six container terminals, and seven warehouse facilities.

Table 3.9: Summary of Reported On-Terminal Operating Characteristics

Terminal Type	Number Truck Calls (annual)	Distance on Facility (miles)	Average Idle Time Each Visit	Total Distance (miles)	Total Idle Time (hours)	Extended Idling? (>15 mins)
Automobile	43,224	0.25	1.45	10,806	62,675	Yes
Automobile	22,000	0.10	1.56	2,200	34,320	Yes
Automobile	11,000	0.10	1.56	1,100	17,160	Yes
Container	1,788,677	1.50	0.47	2,683,016	831,735	No
Container	1,161,080	1.00	0.54	1,161,080	621,178	No
Container	898,311	1.60	0.39	1,437,298	350,341	No
Container	787,151	1.00	0.33	787,151	259,760	No
Container	254,725	0.10	0.46	25,473	115,900	No
Container	72,722	0.50	0.44	36,361	31,998	No
Warehouse	52,000	0.05	1.75	2,600	31,720	No
Warehouse	40,000	1.50	2.52	60,000	35,200	No
Warehouse	22,500	0.20	0.99	4,500	7,875	No
Warehouse	7,800	1.50	0.23	11,700	624	No
Warehouse	3,120	0.25	0.48	780	530	No
Warehouse	3,120	0.90	1.30	2,808	1,404	No
Warehouse	2,700	0.10	0.98	270	918	No

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 conducted in 2008, 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 3-minute idling limit rule is in place on and around the terminals, the aggregate of several 3-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

Vehicle miles of travel (VMT) were estimated for regional HDV activity by estimating the average distances between the terminals and origin or destination locations in the NYNJLINA or, for trips that start in or extend into adjacent counties or states, to/from the boundary of the NYNJLINA. These VMT estimates were used with the number of truck trips and appropriate emission factors to estimate on-road emissions of drayage trucks traveling to and from the container terminals. On-road transport associated with 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. Truck travel patterns, in terms of where trucks arrive from and depart to, were obtained from a survey of drayage truck origins and destinations (O&D survey) conducted by the engineering firm Hatch[15] in 2017. Starting with the 2017 emissions inventory, these survey results replaced the previous O&D information used for the past several emissions inventories. Overall, the new information resulted in VMT estimates about 3% lower than the previous information, due to drayage truck travel patterns having changed in the intervening years.

Model Year Distribution

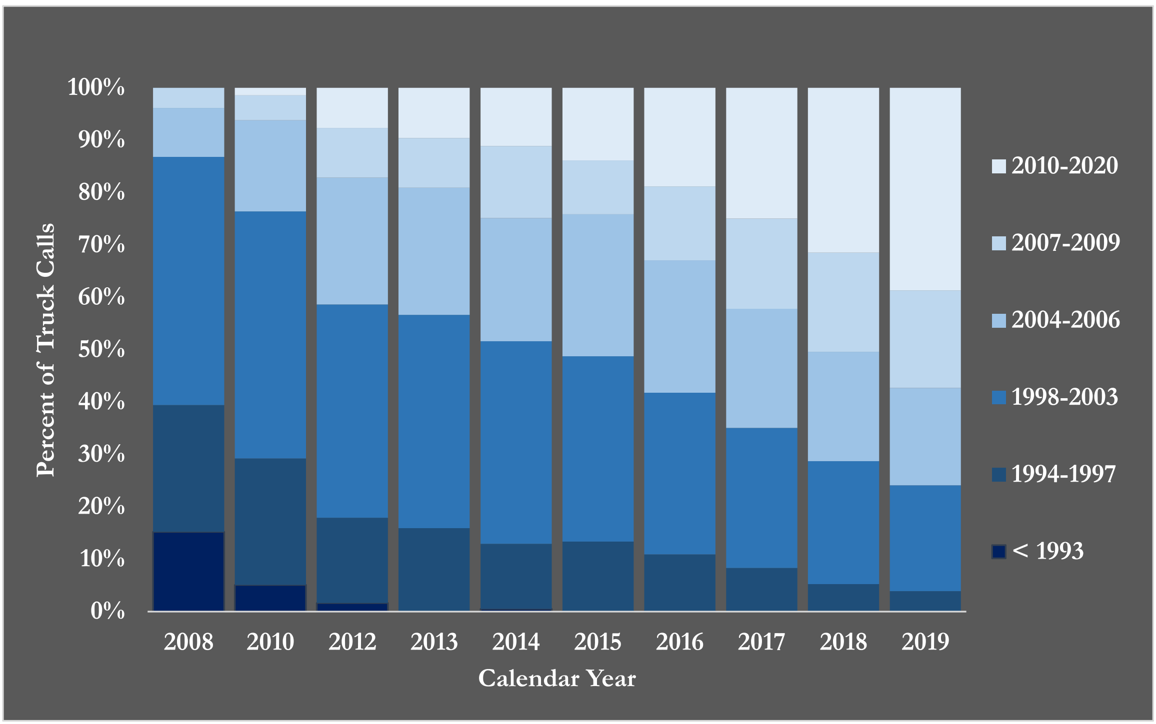
Model year is an important characteristic of drayage trucks because emission standards are applicable on a model year basis. Since newer trucks are subject to stricter (lower) emission standards than older trucks, newer trucks generally emit less than older trucks. A model year distribution characterizes the percentage that each model year makes up of the total number of terminal visits during the inventory year. The distribution is used to develop emission factors that appropriately reflect the specific mixture of model years in the trucks that called at the terminals.

The container terminals at the Port Authority marine terminals 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 3%) of all truck trips so any inaccuracy introduced by using the container truck distribution to represent all trucks is likely to be insignificant.

[15] 2017 Origin & Destination Study. Hatch, draft report 2017.

Figure 3.4 below illustrates the changes in model year distributions of the trucks serving the Port Authority terminals in calendar years 2008, 2010, and 2012 through 2019. For clarity, the model year percentages have been classified into years that were subject to similar emission standards and that therefore have similar emission characteristics. For example, the 2007-2009 group is subject to stricter particulate standards, while the 2010 and later group is subject to tighter NOx requirements in addition to maintaining the particulate standards. The figure shows the gradual increase of trucks in the newer model year groups and the reduction of older trucks from among the vehicles calling at the terminals. This turnover has been responsible for much of the emissions benefit seen in the HDV emission source category.

Figure 3.4: Changes in Distribution of Model Years



3.3.2 Emission Estimating Methodology

While specifics vary, the general form of the equation for estimating vehicle emissions is:

$$E = EF * Act$$

Where:

E = Emissions
EF = Emission Factor
Act = Activity

Two types of activity are considered in estimating drayage truck emissions: engine running with vehicle moving at a given speed or speed profile, 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 MOVES2014b, 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. MOVES2014b has been used to estimate emission factors for the pollutants included in this emissions 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 MOVES2014b most closely associated with the trucks serving the marine terminals, 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 developed by the model by model year 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 MOVES2014b 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 MOVES2014b 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. MOVES2014b 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 MOVES2014b 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 emission factor. As an example, a mileage total of 100,000 VMT would be multiplied by the relevant NO_x emission factor (e.g., 11.283 g/mi for on-road travel):

$$\frac{\mathbf{100,000\ miles/yr \times 11.283}}{\mathbf{453.59 g/lb \times 2,000\ lb/ton}}$$

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

$$\frac{\mathbf{100,000\ hours/yr \times 67.732\ g/mi = 9.0\ tons/yr}}{\mathbf{453.59 g/lb \times 2,000\ lb/ton}}$$

The MOVES2014b-derived driving and idling emission factors for the 2019 EI model year distribution of combination short-haul trucks used in the emission estimates are presented in Table 3.10. The on-terminal (g/mi) EF are based on 15 mph average speed, while the on-road (g/mi) EF are based on MOVES2014a highway/local average speeds.

Table 3.10: HDV 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)	52.900	4.653	4.281	7.137	17.838	0.073	8,598	0.000	0.533
Extended Idle (g/hr)	217.815	3.299	3.035	42.913	89.032	0.077	9,054	0.000	17.476
On-Terminal (g/mi)	11.720	0.731	0.673	0.924	3.863	0.023	2,650	0.000	0.083
On-Road (g/mi)	8.658	0.390	0.359	0.471	2.257	0.015	1,796	0.002	0.039

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. 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 Hatch origin-destination study for HDVs servicing the container terminals.

3.4 Description of Heavy-Duty Vehicles

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

Table 3.11: Maritime Facilities by Type of HDV Operation

Type of Operation	Marine Facility
Container Terminals	➢ Port Newark Container Terminal (PNCT) at Port Newark ➢ Maher Terminal at the Elizabeth-PA Marine Terminal (EPAMT) ➢ APM Terminal at EPAMT ➢ Global Container Terminal New York at Howland Hook Marine Terminal ➢ Red Hook Container Terminal, LLC secondary barge depot at Port Newark ➢ Global Terminal Bayonne at the Port Jersey-Port Authority Marine Terminal
Auto Marine Terminals	➢ Toyota Logistics at Port Newark ➢ Foreign Auto Preparation Services (FAPS) at Port Newark ➢ BMW at the Port Jersey Port Authority Auto Marine Terminal
On-Terminal Warehouses at Port Newark/EPAMT/BPAMT	➢ Phoenix Beverage ➢ Harbor Freight Transport ➢ Eastern Warehouse ➢ ASA Apple Inc. ➢ Courier Systems ➢ TRT International Ltd. ➢ East Coast Warehouse & Distribution Corp.

3.4.1 Operational Modes

HDVs 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. HDVs deliver goods to local, regional, and national destinations. Over the course of the day, HDVs are driven onto and through a 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 HDV 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, HDVs 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 HDVs because these are by far the most prevalent type of vehicle in this service. The most common configuration of HDV 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 intermodal 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 HDVs 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 HDV model year surveys, most of the HDVs were in the heaviest category, 60,000 to 80,000 pounds GVWR, with the remainder being in the 33,000 – 60,000-pound category.

Figure 3.5 is an illustration of a container truck transporting a container in a container terminal, while Figure 3.6 illustrates a truck without an attached trailer, known as a bobtail. These are typical of trucks in use at Port Authority marine terminals and are provided for illustrative purposes.

Figure 3.5: HDV with Container

Figure 3.6: HDV - Bobtail

SECTION 4: RAIL LOCOMOTIVES

This section presents estimated emissions from the locomotives that visit and serve the Port Authority's marine container terminals and discusses the methodologies used in developing the estimates. For 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 to this switching activity, one container terminal operates a single switching locomotive to move rail cars on their terminal and the Port Authority operates a service, the Cross Harbor Barge System, that uses switching locomotives to move rail cars in a barge/rail 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 subsection 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	123	3.0	2.7	4.7	32	0.1	12,315
Switching	198	8.4	7.8	19.9	38	0.2	14,020
Totals	**321**	**11.4**	**10.6**	**24.5**	**70**	**0.3**	**26,335**

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 2019 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.[16]

Table 4.2: Comparison of PANYNJ Marine Terminals 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	391,399	243,410	88,019	839,013	2,184,903	30,760	200,748,788
NYNJLINA	195,448	70,552	31,889	252,955	1,011,780	8,568	106,102,779
Locomotive	321	11	11	25	70	0.3	26,335
% of NYNJLINA Emissions	**0.16%**	**0.02%**	**0.03%**	**0.01%**	**0.01%**	**0.004%**	**0.02%**

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.[17] 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 subsection 4.3.

[16] 2014 National Emission Inventory Databases, US EPA, as cited above.
[17] Accessed at: *https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data*

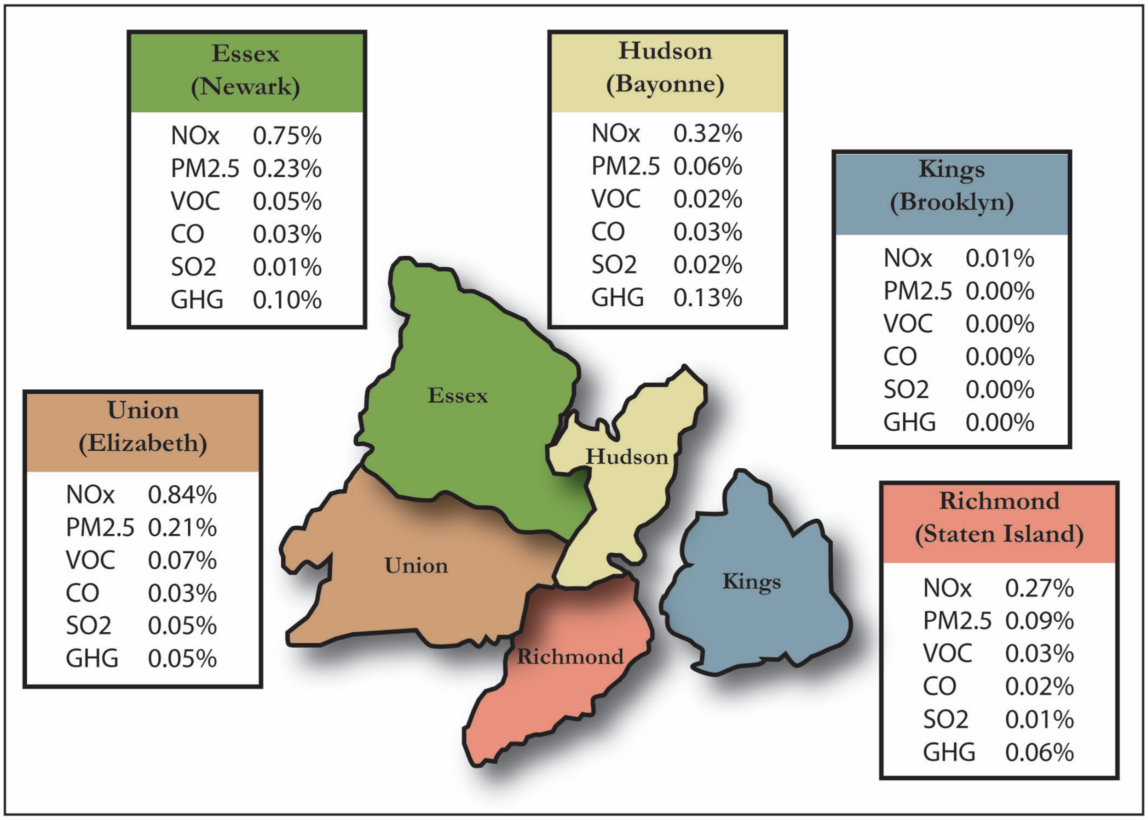
Table 4.3 presents estimated criteria pollutant emissions from the Port Authority marine terminal-related locomotive activity reported in this current inventory, at the county level.

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	25	0.6	0.6	0.9	6.4	0.02	2,481
Essex	NJ	125	5.2	4.8	12.0	23.9	0.13	8,889
Hudson	NJ	32	0.9	0.8	1.6	8.0	0.03	3,036
Middlesex	NJ	6	0.2	0.1	0.2	1.7	0.01	644
Monmouth	NJ	0	0	0	0	0	0	0
Union	NJ	77	3.0	2.8	6.7	15.7	0.08	5,907
New Jersey subtotal		**265**	**9.8**	**9.1**	**21**	**56**	**0.27**	**20,957**
Bronx	NY	0	0	0	0	0	0	0
Kings	NY	1	0.0	0.0	0.0	0.4	0.00	161
Nassau	NY	0	0	0	0	0	0	0
New York	NY	0	0	0	0	0	0	0
Orange	NY	0	0	0	0	0	0	0
Queens	NY	0	0	0	0	0	0	0
Richmond	NY	15	0.6	0.6	1.5	3.4	0.02	1,247
Rockland	NY	40	1.0	0.9	1.5	10.3	0.04	3,970
Suffolk	NY	0	0	0	0	0	0	0
Westchester	NY	0	0	0	0	0	0	0
New York subtotal		**56**	**1.6**	**1.5**	**3**	**14**	**0.06**	**5,378**
Total		**321**	**11.4**	**10.6**	**25**	**70**	**0.33**	**26,335**

The following figure illustrates the PANYNJ marine terminals percentage of locomotive emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 4.1: PANYNJ Marine Terminals Locomotive Percent Contribution to Local Air Emissions



4.2.2 Comparisons with Prior Year Emission Estimates

Table 4.4 presents the 2019 locomotive emissions, along with previous year and 2006 locomotive emissions.

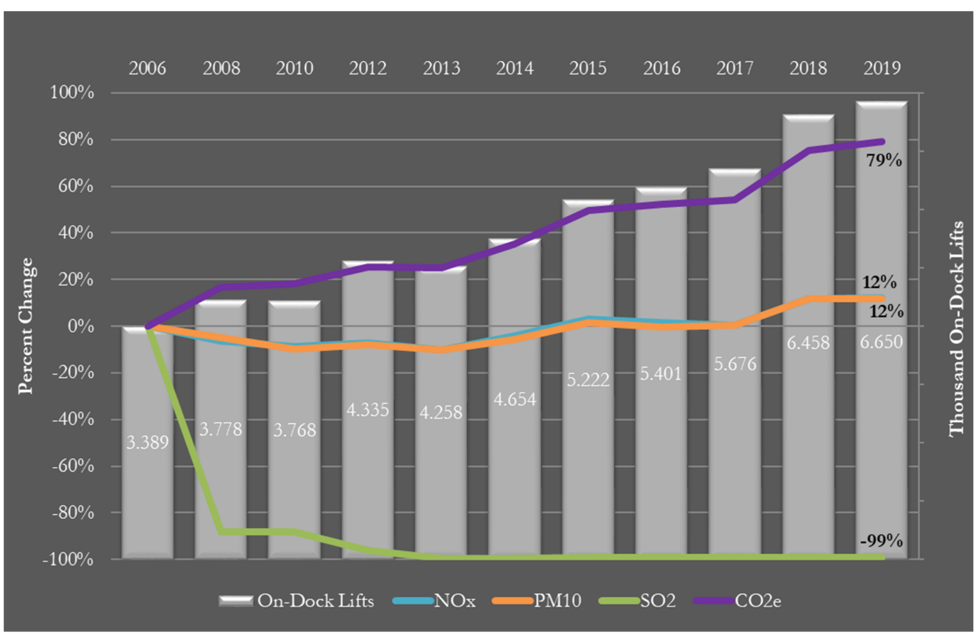
Table 4.4: Locomotive Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	On-dock Lifts
2019	321	11	11	25	70	0.3	26,335	664,987
2018	320	11	11	24	68	0.3	25,812	645,760
2006	286	10	9	20	44	32.0	14,710	338,884
2018-2019, Change (%)	**0.3%**	**0.1%**	**-0.3%**	**1%**	**2%**	**-0.3%**	**2%**	**3%**
2006-2019, Change (%)	**12%**	**12%**	**12%**	**23%**	**59%**	**-99%**	**79%**	**96%**

Between 2018 and 2019, while there was a 3% increase in on-dock rail lifts the emissions increased by up to 2%, or were essentially unchanged, varying by pollutant. Between 2006 and 2019, the locomotive emissions increased, with the exception of SO_2, at a lower rate than the increases in the amount of cargo moved by rail into and out of the Port. The SO_2 emissions have decreased due to the use of lower sulfur fuel. The on-dock rail throughput almost doubled between 2006 and 2019 (a 96% increase). But the increases in the unregulated CO and CO_2 were lower, at 59% and 79%, respectively, likely due to incremental efficiency improvements implemented by the railroads and the Port Authority.

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 2019 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 MOVES2014b model used for CHE and HDVs; 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,[18] the rail line routes used to transport these goods, an approximate schedule for these trains, and the average length of primary scheduled trains. This data has been used to estimate the total amount of fuel used by the locomotives and hence the associated emissions.

The basis of the line haul emission estimates is the amount of fuel used in the transport of cargo to and from the Port Authority marine terminals, which has been estimated using the number of train trips, train weights, and distance. Step one in this process estimates the number and average lengths of trains used to transport this cargo. Step two estimates the average 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[19] 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 2019 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 2019 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 assumes diesel fuel sulfur content of 15 ppm in 2019. The emission factors for N_2O and CH_4 were obtained from an EPA publication on greenhouse gases.[20]

---

[18] Information provided by PANYNJ by email 2 June 2020.

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

[20] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2018; April 2020; Table A- 114: Emission Factors for N_2O Emissions from Non-Highway Mobile Combustion (g gas/kg fuel) and Table A- 115: Emission Factors for CH_4 Emissions from Non-Highway Mobile Combustion (g gas/kg fuel).

The emission factors for line haul locomotives are presented in Table 4.5. The published g/gal emission factors for 2019 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	103	2.5	2.3	3.9	26.7	0.10	10,186	0.25	0.79
g/hp-hr	4.9	0.12	0.11	0.19	1.28	0.005	489	0.012	0.038

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. The inbound trains are transporting export cargo to be loaded onto ships while the outbound trains are transporting imports that have been brought to the port on ships. 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.[21]

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.

Table 4.6: Line-Haul Train Length Assumptions

Parameters	Outbound	Outbound	Inbound	Outbound	Outbound	Inbound
# of 5-platform cars per train	30	30	30	30	30	26
Length of 5-platform car, feet	300	300	300	300	300	300
Length of cargo, feet	9,000	9,000	9,000	9,000	9,000	7,800
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	**9,140**	**9,140**	**9,140**	**9,140**	**9,140**	**7,940**

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

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.

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 may be 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)	600	600	600	600	600	520
Average "density"	100%	100%	100%	100%	100%	100%
TEUs per train (adjusted)	600	600	600	600	600	520
Average TEUs per container:	1.75	1.75	1.75	1.75	1.75	1.75
Containers per train (average)	**343**	**343**	**343**	**343**	**343**	**297**

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 2019 on-dock rail throughput to within approximately 12-hundredths of a percent (estimated total of 665,808, actual 664,987). 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	124,852	124,852	124,852	89,180	124,852	77,220
Total estimated containers:	**374,556**			**291,252**		

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 reports submitted by the Norfolk Southern and CSX railroads to the U.S. Surface Transportation Board in the 2019 submittals of an annual report known as the "R-1."[22] 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. The term "railcar" as listed in the R-1 reports is analogous to a "platform" as described in this report rather than the 5-platform railcar commonly used in container service. Dividing gross ton-miles by railcar-miles provides an estimate of the average weight of a railcar (platform) in normal service (gross ton-miles/railcar-miles = gross tons/railcar). The average platform weight estimated in this manner is shown in Table 4.9. In addition to average platform weight, Table 4.9 lists the average number of platforms per train, estimated by multiplying the number of 5-platfom cars by 5. The average gross weight of each train type is the number of railcars multiplied by the average gross weight per platform, 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)	150	150	150	150	150	130
Gross tons per platform	86	86	86	86	86	86
Gross weight of train	**12,850**	**12,850**	**12,850**	**12,850**	**12,850**	**11,137**

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 **14.03 million gross tons** for the railroad whose trains are represented by the left three columns in the previous tables, and approximately **10.91 million gross tons** for the railroad whose trains are represented by the three columns to the right.

[22] *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2019* (Norfolk Southern Railroad) and *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2019* (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 1.04 gallons of fuel per thousand gross ton-miles (the same as the 2018 average), derived from information in the 2019 R-1 reports on fuel consumption and 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	42,096,663	43,781
Hudson	13	182,418,871	189,716
Bergen	15	210,483,313	218,903
Rockland	24	336,773,301	350,244
South Route			
Essex	5	54,569,748	56,753
Union	15	163,709,243	170,258
Middlesex	5	54,569,748	56,753
Total	**80**	**1,044,620,887**	**1,086,406**

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 on-rail cargo throughputs at Port Newark, Elizabeth PA Marine Terminal, Staten Island, and Bayonne between 2018 and 2019. 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, 664,000 containers moved by rail in 2019 divided by 646,000 containers moved by rail in 2018 results in a growth factor of 1.03 or a 3% increase in throughput; this was multiplied by the 2018 operating hours estimate of 65,349 for a 2019 estimate of 67,309 hours.

A variety of switchers operate in ExpressRail service, 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.[23] While these reductions have been projected for the non-attainment area as a whole, 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 4i 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	0.258	0.76
g/hp-hr	9.9	0.43	0.40	1.01	1.83	0.01	672	0.017	0.05
Tier 4i emission factors									
g/gal	68	0.2	0.2	1.2	27.7	0.10	10,182	0.26	0.76
g/hp-hr	4.5	0.015	0.015	0.08	1.83	0.01	672	0.017	0.05
Tier 4 emission factors									
g/gal	15	0.2	0.2	1.2	27.7	0.15	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

[23] 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 expressed 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 in this dataset varies from 159 to 349 horsepower, with an average of 264 horsepower. Multiplying the estimate of 67,309 hours by the average in-use horsepower of 264 results in an estimate of approximately 17.8 million horsepower-hours 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 2019 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 2019 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), at the Howland Hook Marine Terminal on Staten Island, New York, operated by Global Container Terminal – New York, and, new for 2019, at the Global Container Terminal – Bayonne terminal. 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, except for the genset switchers, 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 larger than 4,000 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.

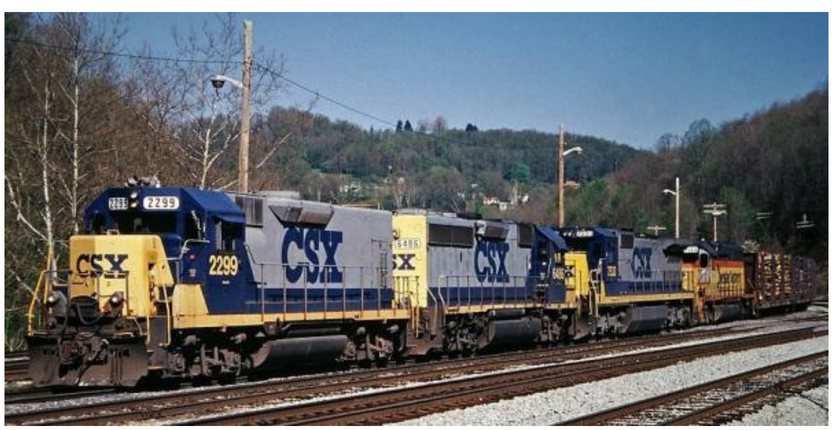
Figure 4.3: Example Switching Locomotives at On-Dock Rail Facility

Photo courtesy of PANYNJ

Figure 4.4: Example Switching Locomotive

Photo courtesy of PANYNJ

Figure 4.5: Example Line Haul Locomotive



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

SECTION 5: COMMERCIAL MARINE VESSELS

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

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

The berths at these marine terminals handle many cargoes, such as container, cruise, auto, liquid and break bulk. Thus, there is a wide variety of the ocean-going vessel types along with assist tugs and barges included under this category.

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 are 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:

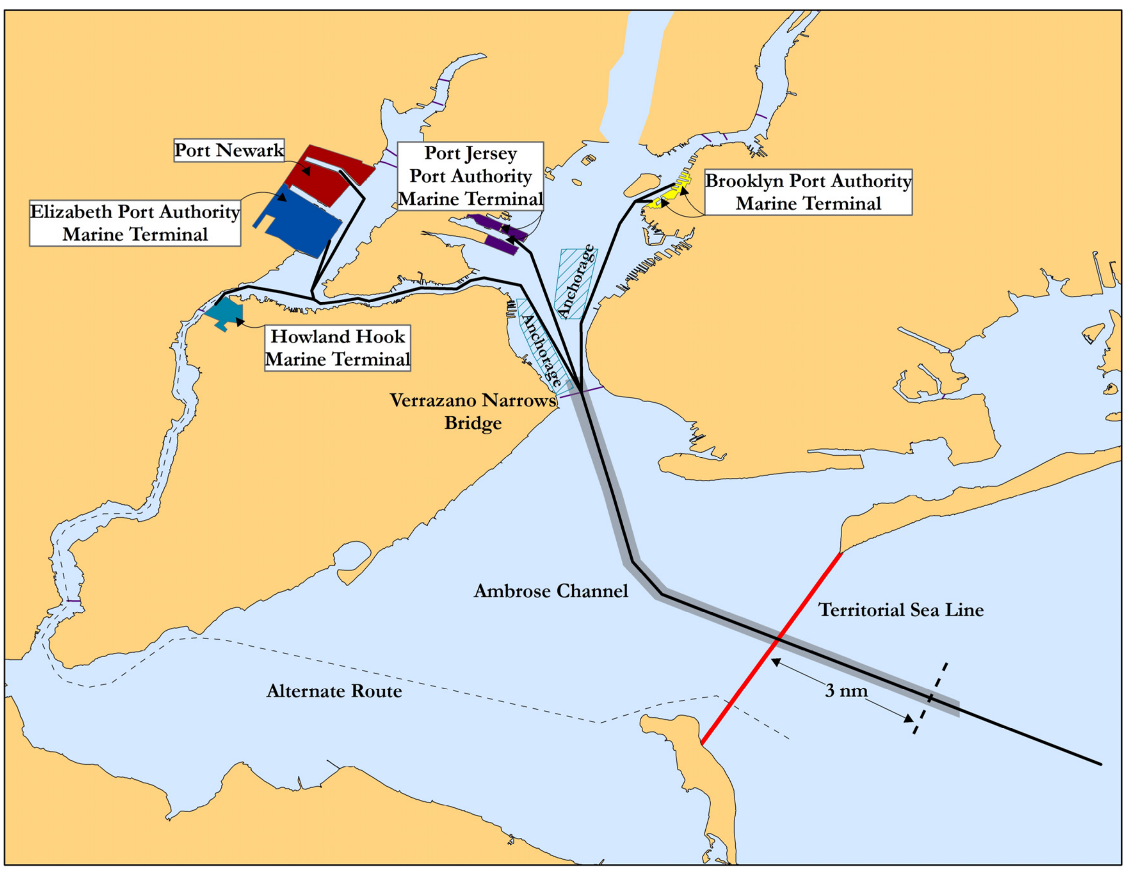
- 5.1 - CMV Emission Estimates
- 5.2 - CMV Emission Comparisons
- 5.3 - CMV Emission Calculation Methodology
- 5.4 - Description of CMV and Vessel Activity

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 following ocean-going vessels (OGV) types are included: containerships, cruise ships, automobile and other vehicle carriers, tankers, and bulk carriers. The harbor craft includes vessels that assist ocean-going vessels in maneuvering and docking (assist tugs) and the vessels that move cargo barges within the NYNJHS (towboats and push boats). Barges are not self-propelled and therefore, their emissions are not included. Emissions have been estimated for 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 (nm) beyond the line indicated on the figure as the Territorial Sea Line, off the eastern coast of the U.S.

Figure 5.1: Outer Limit of Study Area



The following tables present the estimated OGV emissions in several different aspects. Table 5.1 lists the emissions from OGVs by vessel type. The containership and tankers emissions are shown by subcategories.

Table 5.1: OGV Emissions by Vessel Type, tpy

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Auto Carrier	199	4.1	3.8	8.7	20.0	6.0	13,493
Bulk Carrier	48	1.1	1.0	1.6	4.3	2.4	4,128
Container - 1000	61	1.3	1.2	2.0	5.8	2.5	4,807
Container - 2000	104	2.1	2.0	4.4	10.3	3.3	6,877
Container - 3000	49	0.8	0.7	1.4	3.5	1.4	3,024
Container - 4000	206	4.0	3.7	9.8	20.0	5.9	13,218
Container - 5000	148	2.9	2.7	7.3	14.4	4.4	9,884
Container - 6000	242	5.5	5.0	17.8	29.5	8.0	16,032
Container - 7000	45	0.9	0.9	2.4	4.4	1.5	3,189
Container - 8000	444	8.9	8.2	19.9	40.2	13.5	32,210
Container - 9000	107	2.3	2.1	4.3	9.8	3.9	8,673
Container - 10000	55	1.2	1.1	2.0	5.2	2.1	4,528
Container - 11000	106	2.5	2.3	8.6	14.2	3.5	7,206
Container - 12000	3	0.1	0.1	0.1	0.2	0.1	214
Container - 13000	170	3.6	3.3	6.0	14.4	5.5	14,021
Container - 14000	69	1.8	1.6	4.2	8.6	2.7	5,487
Cruise Ship	267	6.2	5.8	10.4	27.6	9.7	19,172
General Cargo	14	0.4	0.3	0.6	1.6	0.7	1,202
RoRo	34	0.7	0.6	2.1	3.9	1.3	2,062
Tanker - Chemical	65	1.6	1.5	2.4	6.1	3.7	6,019
Tanker - Handysize	1	0.0	0.0	0.0	0.1	0.1	106
Tanker - Panamax	2	0.1	0.1	0.1	0.2	0.3	497
Total	**2,439**	**52.2**	**48.2**	**116.1**	**244.4**	**82.4**	**176,046**

Table 5.2 presents the OGV emissions by engine type. Table 5.3 differentiates emissions according to hoteling, maneuvering, and transiting activity.

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	937	12	11	57	86	15	31,376
Auxiliary Engines	1,393	32	29	54	147	44	92,929
Boilers	108	8	8	5	11	24	51,741
Total	**2,439**	**52**	**48**	**116**	**244**	**82**	**176,046**

Table 5.3: OGV Emissions by Operating Mode, tpy

Operating Mode	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Hotelling - Anchorage	1	0	0	0	0	0	131
Hotelling - Berth	1,175	32	30	47	124	56	119,898
Maneuvering	588	11	10	46	64	13	28,006
Transit	674	9	8	24	56	13	28,011
Total	**2,439**	**52**	**48**	**116**	**244**	**82**	**176,046**

Table 5.4 presents estimated emissions for tow boats and assist tugs. The towboats/pushboats emissions include the barge call activity at the bulk berths and two container terminals. The assist tugs provide assist and escort services for the ocean-going vessels that call Port Authority marine terminals.

Table 5.4: Harbor Craft Emissions, tpy

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Towboats/Pushboats	184	7	6	7	53	0.1	13,273
Assist Tugs	160	6	6	6	51	0.1	11,673
Totals	**345**	**13**	**12**	**13**	**104**	**0.2**	**24,946**

5.2 CMV Emission Comparisons

This subsection presents the CMV emission estimates detailed in Section 5.1 in the context of overall county-wide and area-wide emissions and a comparison of 2019 emission estimates with the previous years inventories. First, Port Authority marine terminal-related OGV and 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 (2017 NEI). These emission comparisons are segregated into OGV and harbor craft categories and are presented in subsections 5.2.1 and 5.2.2 respectively. Subsection 5.2.3 presents 2019 OGV and harbor craft emission estimates in comparison with previous year emission estimates to illustrate the changes in emissions over time.

Table 5.5 presents the estimated CMV 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 Marine Terminals 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
NY and NJ	391,399	243,410	88,019	839,013	2,184,903	30,760	200,748,788
NYNJLINA	195,448	70,552	31,889	252,955	1,011,780	8,568	106,102,779
OGV	2,439	52	48	116	244	82	176,046
Harbor Craft	345	13	12	13	104	0.2	24,946
Total Commercial Marine Vessels	2,783	65	60	129	348	83	200,992
% of NYNJLINA Emissions	**1.4%**	**0.09%**	**0.19%**	**0.05%**	**0.03%**	**1.0%**	**0.2%**

5.2.1 OGV Emission Comparisons with County and Regional Emissions

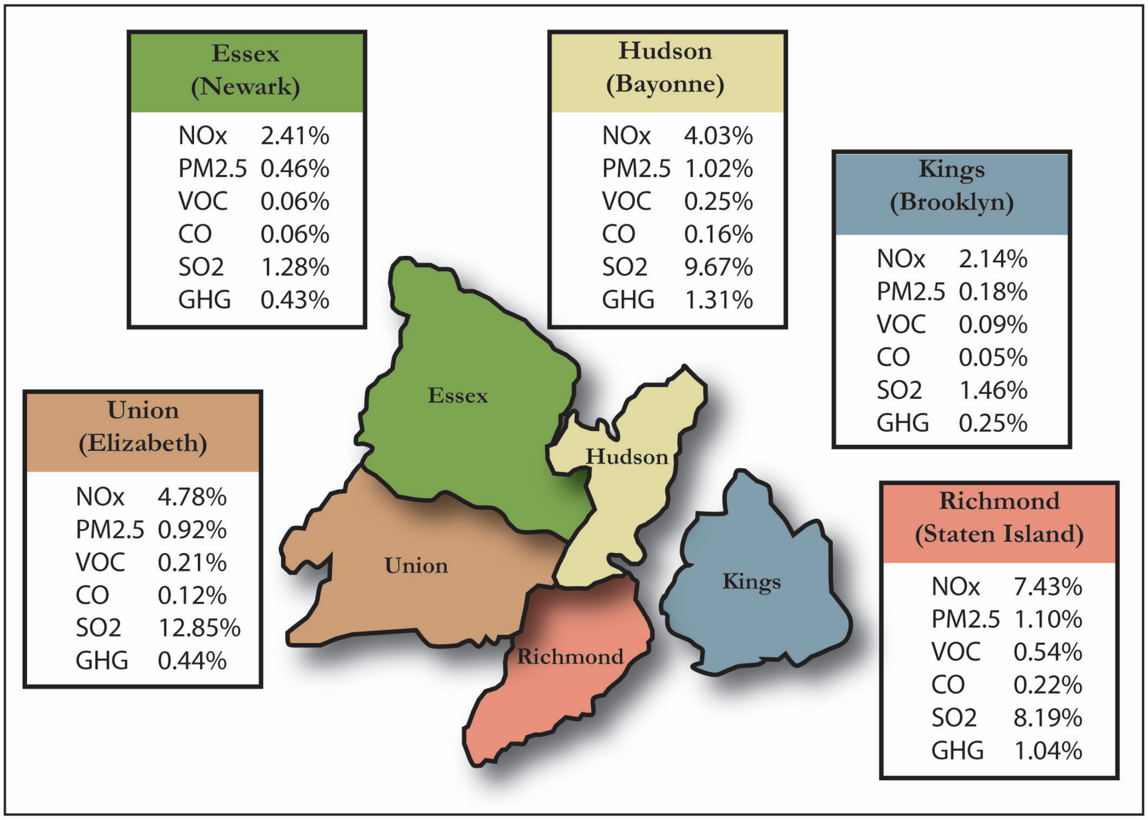
Table 5.6 summarizes estimated criteria pollutant and GHG emissions from OGVs at the county level. All counties within the inventory area are listed, so counties without associated OGV emissions are shown with zero emissions. The percent allocation per county for transit changed and so did the maneuvering allocation.

Table 5.6: Summary of PANYNJ Marine Terminals OGV Emissions by County, tpy

County	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	0	0	0	0	0	0	0
Essex	401	10	9	16	39	19	38,211
Hudson	401	9	9	20	43	14	30,262
Middlesex	0	0	0	0	0	0	5
Monmouth	250	3	3	9	20	5	10,372
Union	442	13	12	19	49	22	49,434
New Jersey subtotal	**1,493**	**36**	**33**	**64**	**152**	**60**	**128,284**
Bronx	1	0	0	0	0	0	52
Kings	290	5	5	16	28	7	14,301
Nassau	0	0	0	0	0	0	0
New York	59	1	1	2	5	2	3,844
Orange	0	0	0	0	0	0	0
Queens	180	2	2	6	15	4	7,492
Richmond	415	8	7	28	44	10	22,074
Rockland	0	0	0	0	0	0	0
Suffolk	0	0	0	0	0	0	0
Westchester	0	0	0	0	0	0	0
New York subtotal	**946**	**16**	**15**	**52**	**93**	**23**	**47,763**
Total	**2,439**	**52**	**48**	**116**	**244**	**82**	**176,046**

The following figure illustrates the PANYNJ marine terminals percentage of OGV emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 5.2: PANYNJ Marine Terminals OGV Percent Contribution to Local Air Emissions



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

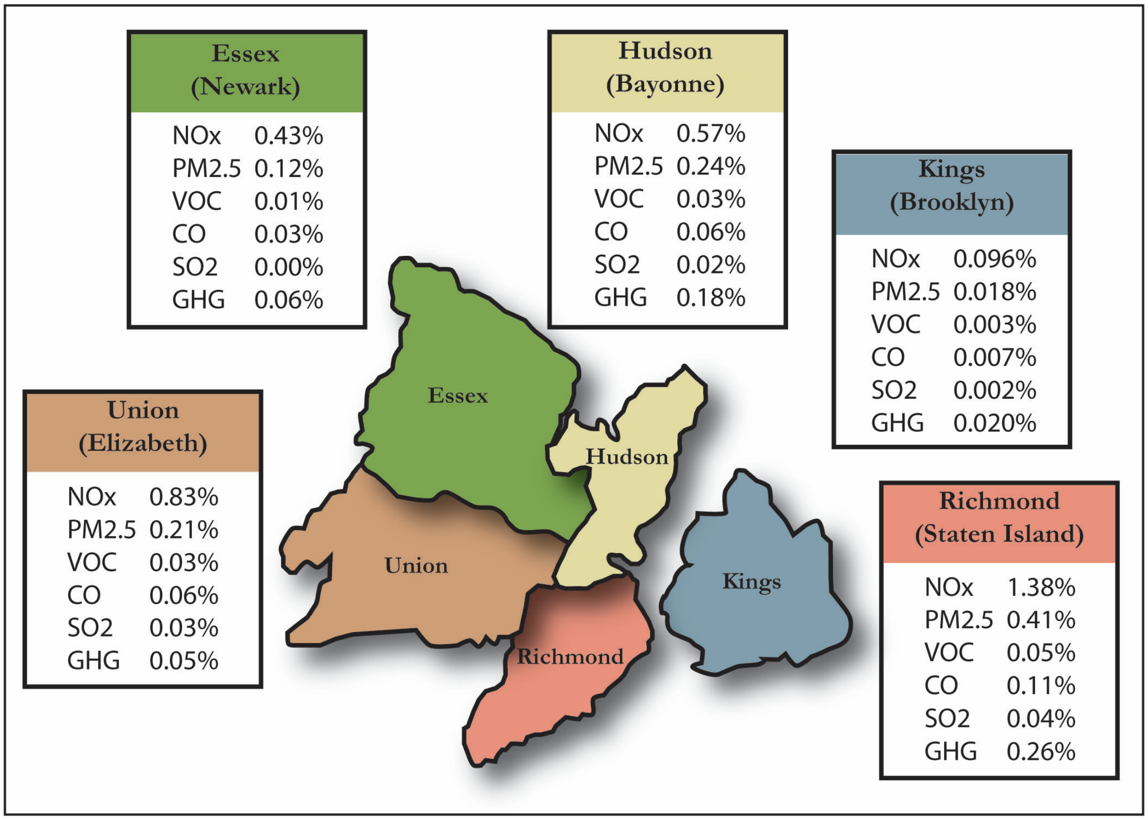
Table 5.7 summarizes estimated emissions from assist tugs and tow boats at the county level.

Table 5.7: Summary of PANYNJ Marine Terminals 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	0.5	0.00	128.31
Essex	NJ	72	2.8	2.6	2.7	22.4	0.04	5,224.07
Hudson	NJ	57	2.2	2.0	2.1	16.8	0.04	4,115.62
Middlesex	NJ	13	0.5	0.4	0.4	3.6	0.01	902.90
Monmouth	NJ	9	0.4	0.3	0.3	2.7	0.01	665.29
Union	NJ	77	3.0	2.8	2.9	23.8	0.05	5,600.99
New Jersey subtotal		**229**	**8.9**	**8.2**	**8.5**	**69.8**	**0.14**	**16,637**
Bronx	NY	0	0.0	0.0	0.0	0.1	0.00	23.76
Kings	NY	13	0.5	0.5	0.5	3.9	0.01	940.39
Nassau	NY	2	0.1	0.1	0.1	0.7	0.00	171.08
New York	NY	3	0.1	0.1	0.1	1.0	0.00	238.12
Orange	NY	2	0.1	0.1	0.1	0.6	0.00	147.31
Queens	NY	4	0.1	0.1	0.1	1.0	0.00	261.36
Richmond	NY	77	2.9	2.7	2.8	22.5	0.05	5,537.90
Rockland	NY	3	0.1	0.1	0.1	0.7	0.00	180.58
Suffolk	NY	8	0.3	0.3	0.3	2.3	0.01	584.51
Westchester	NY	3	0.1	0.1	0.1	0.9	0.00	223.35
New York subtotal		**115**	**4.4**	**4.0**	**4.2**	**33.7**	**0.07**	**8,308**
TOTAL		**345**	**13.3**	**12.2**	**12.7**	**103.6**	**0.21**	**24,946**

The following figure illustrates the PANYNJ marine terminals percentage of harbor craft emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 5.3: PANYNJ Marine Terminals Harbor Craft Percent Contribution to Local Air Emissions



5.2.3 Comparison of OGV Emissions with Prior Year Emission Estimates

Changes in 2019 OGV emissions and prior years' emissions can be attributed to changing levels of cargo throughput, different vessel types calling the terminals during different years, 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 2019, there were no changes to the emission estimating methodology compared with the methods used in 2018. For 2019, the default auxiliary engine and boiler load values remained the same as those used in 2018.

Programs that had an impact on OGV emissions in calendar year 2019 are listed below.

- In June 2017, the Bayonne Bridge Navigational Clearance Project raised the bridge to 215 feet above high mean waters in Kill Van Kull, allowing for the passage of larger vessels than had previously been able to maneuver under the bridge. A primary goal of the bridge raising project is to attract newer, larger vessels that have the potential to increase goods movement efficiency and ultimately decrease emissions by reducing the number of vessel calls. Calendar year 2019 was the second full year allowing for larger vessels to maneuver under the Bayonne Bridge, which was reflected in an increased number of calls by larger vessels in 2019 than previous years.
- All vessels used 0.1% or less S fuel sulfur content per the ECA requirement.
- The Port Authority of New York and New Jersey CVI Program continued to be in effect in 2019. The CVI program aims to reward ocean-going vessels with Vessel Speed Reduction (VSR) points for steaming at 10 knots or less from 20 nm outside of the Territorial Sea Line. Additional points are rewarded to vessels that exceed current international vessel emissions standards represented through the Environmental Ship Index (ESI). In addition, ships enrolled under ESI reported the actual sulfur level of the fuel used which in several instances was lower than the 0.1% sulfur limit under ECA. In 2019, 1,814 calls were made to the Port Authority marine terminals by vessels enrolled in the program, with 384 individual vessels making 1,199 calls that earned incentive payments.
- In 2019, 12 of the 42 cruise ship calls at the Brooklyn Cruise Terminal used shore power. This was the fourth year for shore power capable vessels to use shore power at a PANYNJ terminal.
- Newer vessels with Tier III engines are calling the Port Authority. These vessels comply with IMO Tier III NO_x limits while in US waters which achieve NO_x reductions 80% below Tier 1 levels.

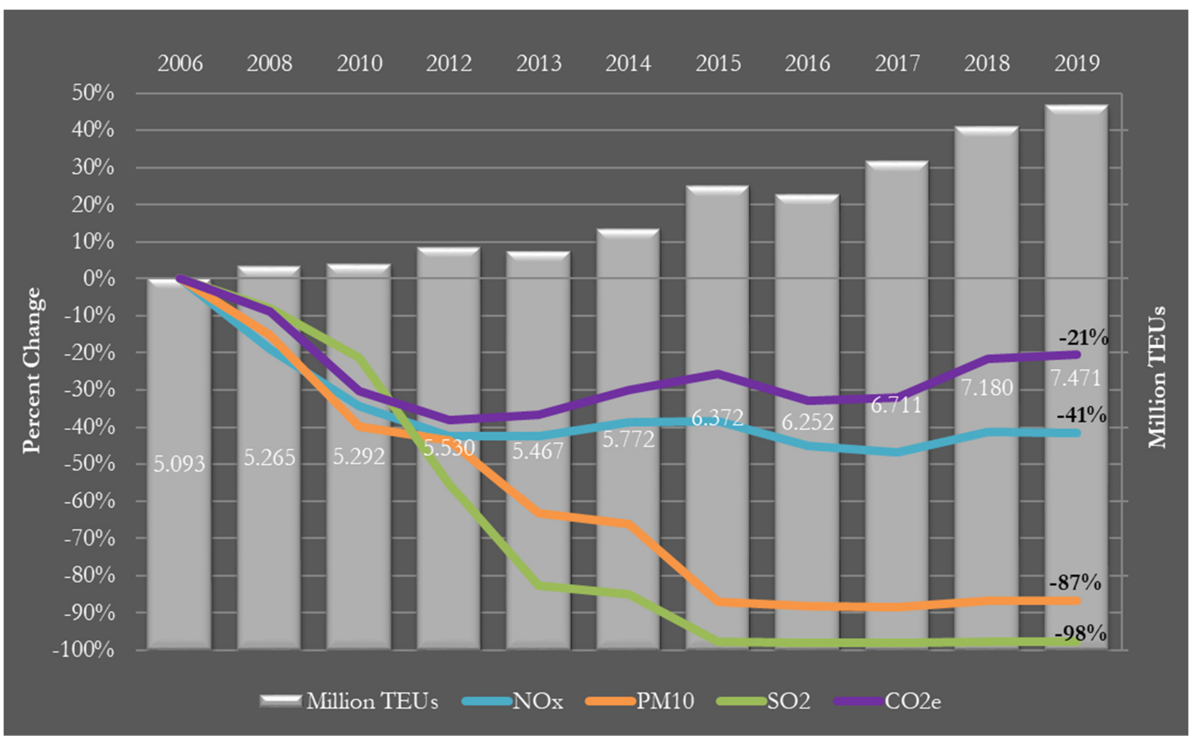
Table 5.8 presents a comparison of 2019 OGV emissions out to the three nautical mile boundary, with emissions in the same area for previous year and 2006 baseline year. Compared to 2006, the emissions are lower due to the lower sulfur fuel used to comply with the North American ECA and the CVI program. OGV emissions in 2019 were similar to emissions in 2018 despite the 4% increase in TEU throughput.

Table 5.8: OGV Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2019	2,439	52	48	116	244	82	176,046	7.47
2018	2,443	52	48	118	243	86	173,488	7.18
2006	4,165	392	314	185	360	3,681	221,638	5.09
2018-2019, Change (%)	**-0.2%**	**1%**	**0.4%**	**-1%**	**1%**	**-5%**	**1%**	**4%**
2006-2019, Change (%)	**-41%**	**-87%**	**-85%**	**-37%**	**-32%**	**-98%**	**-21%**	**47%**

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 2019 update, with emission trend lines superimposed over the annual TEU throughput (in millions).

Figure 5.4: OGV Emissions Relative to TEU Throughput



5.2.4 Comparison of Harbor Craft Emissions with Prior Year Emission Estimates

Table 5.9 presents the harbor craft emissions comparison to prior years' emissions. Although there was fleet turnover to newer assist tugs, overall harbor craft emissions increased due to increased activity of the assist tugs in assisting the larger number of vessel calls.

Table 5.9: Harbor Craft Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2019	345	13	12	13	104	0	24,946	7.47
2018	413	17	16	17	125	0	28,859	7.18
2006	505	27	25	17	79	50	26,938	5.09
2018-2019, Change (%)	**-17%**	**-23%**	**-22%**	**-23%**	**-17%**	**-14%**	**-14%**	**4%**
2006-2019, Change (%)	**-32%**	**-51%**	**-51%**	**-26%**	**31%**	**-100%**	**-7%**	**47%**

For towboat/pushboat engine characteristics, a more robust data set was used to estimate the 2019 emissions which is an improvement compared to previous years. The details are explained in subsection 5.3.1.3.

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, which were used to verify the AIS activity data results, when available. The AIS vessel data for the Port Authority marine terminals was used in conjunction with other data sources, such as IHS Markit and Vessel Boarding Program (VBP) data, 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 are 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 that are all based on information developed from the AIS data using geographical information system (GIS) data analysis. The vessel specific data was used in conjunction with IHS Markit and VBP data to profile each vessel type's characteristics such as engine type, propulsion horsepower, onboard auxiliary horsepower, nation of registry, and other parameters.

Vessel call activity and main engine 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.

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. Larger container vessels with a carrying capacity above 10,000 TEUs were 16% of total movements for containerships. Vessel movements were 1% lower in 2019 than 2018, despite a 4% increase in TEU throughput.

Table 5.10: Vessel Movements for the Port Authority Marine Terminals

Vessel Type	Arrivals	Departures	Shifts	Total
Auto Carrier	431	431	69	931
Bulk Carrier	103	104	31	238
Container - 1000	236	237	1	474
Container - 2000	183	183	23	389
Container - 3000	96	96	2	194
Container - 4000	251	252	2	505
Container - 5000	174	174	5	353
Container - 6000	245	246	9	500
Container - 7000	37	38	1	76
Container - 8000	405	406	31	842
Container - 9000	98	96	3	197
Container - 10000	49	49	1	99
Container - 11000	91	91	0	182
Container - 12000	2	2	0	4
Container - 13000	130	130	0	260
Container - 14000	63	63	2	128
Cruise Ship	131	131	2	264
General Cargo	24	23	3	50
RoRo	93	94	35	222
Tanker - Chemical	73	74	21	168
Tanker - Handysize	1	1	0	2
Tanker - Panamax	1	1	1	3
Total	**2,917**	**2,922**	**242**	**6,081**

Operating hours (activity) are based on the same distance/speed calculation as for main engines for periods that the vessels are in motion and on the specific dwell times calculated for each vessel call from AIS data. 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. It is interesting to note that the average dwell time increases by the increasing containership capacity.

Table 5.11: Average Dwell Times at Berth, hours

Vessel Type	Min	Max	Average
Auto Carrier	2	267	17
Bulk Carrier	0	453	111
Container - 1000	2	196	18
Container - 2000	4	50	18
Container - 3000	3	50	20
Container - 4000	6	161	24
Container - 5000	3	124	25
Container - 6000	2	99	28
Container - 7000	3	76	39
Container - 8000	2	178	36
Container - 9000	4	94	41
Container - 10000	27	86	48
Container - 11000	21	111	45
Container - 12000	2	70	36
Container - 13000	26	108	56
Container - 14000	8	99	50
Cruise Ship	3	63	12
General Cargo	3	177	57
RoRo	4	86	17
Tanker - Chemical	3	362	53
Tanker - Handysize	28	28	28
Tanker - Panamax	114	114	114

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 for the various vessel types for the calendar year of the study.

Table 5.12: Assist Tug Operating Data and Assumptions

Vessel Type	Total Assists
Auto Carrier	1,856
Bulk Carrier	452
Containership	8,356
Cruise Ship	262
General Cargo	98
RoRo	444
Tanker	306
Total	**11,774**

5.3.1.3 Towboats/Pushboats (Harbor Craft)

The barge activity at the Port Authority are included under the towboat/pushboat for the sake of completeness. Barges are not self-propelled and therefore require to be towed or pushed. The emissions for the towboats/pushboats used for the barge activity that called at a PANYNJ berth are included in this category. The public berths at Port Newark have the majority of barge calls since these berths handle a wide range of bulk cargo such as oil, scrap metal, cement, orange juice, and salt. There are also two container terminals with known barge calls that provide barge trips each year that are included in the barge activity for towboat emissions. The Cross-Harbor Barge service was initiated in late 2016 to reduce the number of trucks trips. In addition, there are barges that transfer sealed container city waste to rail yard to also reduce truck trips.

For 2019, a list of discrete harbor craft, including towboats and pushboats, was identified from AIS non-processed data routinely obtained for OGV activity. It was a list of harbor craft (i.e. vessels not included in OGV inventory) that transited through New York/New Jersey harbor area in 2019. Those vessels listed as "tug", "towing", "towing/pushing", and/or "pusher tug" were separated into a towboat list. It was assumed that a subset of these vessels were used to push or tow the barges that called at one of the PANYNJ terminals. A website search was used to look up the engine/vessel information needed to calculate emissions. The engine information included engine make/model, model year, and horsepower. The vessel search was able to determine auxiliary engine or generator kW and if the vessel engine(s) was repowered. The engine category (category 1 or 2) was based on the engine make/model which follows similar protocol used by EPA in their category 1 and 2 marine engine studies.

For prior years' towboat emissions estimates, the only source of towboat engine information available was from ten vessels owned by one tug company operating in New York/New Jersey harbor. Use of 2019 AIS based data provided an opportunity to utilize information from close to 200 towboat vessels which is a much more robust source of information and it provided a mechanism to update towboat fleet information every year as more vessels get replaced with lower tier engines or repowered for future emission inventories. For prior years, emission estimates were based on emission factors of category 2 engines as the ten vessels were equipped with category 2 propulsion engines. For 2019 emissions estimates, AIS based updated towboat engine data revealed close to 40% of the towboat propulsion engines are category 2 engines and the remaining engines are category 1. This change resulted in decrease in average HP rating assumption of towboat propulsion engines by 24%.

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 divided into transit (arrival/departure) and dwelling (at-berth and anchorage) components. Operating data and the methods of estimating emissions are discussed below, including differences between transit and dwelling methodologies. The estimates assume 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 than required for the ECA during transiting and dwelling, and for other vessels with Environmental Ship Index (ESI) bunker data.

5.3.2.1 OGV Engines

Main engine emissions are only estimated for transiting mode because a vessel's main engines are typically turned off while the vessel is tied up at berth or at anchorage. The emissions calculation can be described using the following equation:

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

Where:

E_i = Emissions
EF = emission factor, expressed in terms of g/kW-hr
$Energy_i$ = Energy demand, calculated using the equation below as the energy output of the main engine(s) or auxiliary boiler(s) over the period of time, 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

The propulsion engine load factor is estimated using the Propeller Law, which states that propulsion engine load varies with the cube of the ratio of actual speed to the ship's maximum rated speed, as illustrated by the following equation.

$$LF = (Speed_{Actual} / Speed_{Maximum})^3$$

Where:

LF = load factor, dimensionless
SpeedActual = actual speed, knots
SpeedMaximum = maximum speed, knots

5.3.2.2 OGV Fuel Correction Factors and Emission Factors

Pollutant specific 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 used to adjust the base emission factors (shown in Table 5.14) that are based on HFO with 2.7% sulfur.[24]

The ECA was in effect in 2019 with the fuel oil sulfur content limit for OGVs operating in the ECA at 0.1%. 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 auxiliary boiler burned fuel with a maximum sulfur content of 0.1% sulfur. In addition, several vessels under the CVI program used cleaner fuel with lower sulfur content than what is required under the ECA. The FCF was estimated accordingly for the vessels that used fuel with varying sulfur contents that were below 0.1%. 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 main 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 default emission factors listed below.

Table 5.13: Fuel Correction Factors (unitless)

Actual Fuel Used Content	Sulfur Content by weight %	Fuel Correction Factor							
		NO_x	PM_{10}	VOC	CO	SO_2	CO_2	N_2O	CH_4
MDO/MGO	0.10%	0.940	0.170	1.000	1.000	0.037	0.950	0.940	1.000
MDO/MGO	0.05%	0.940	0.160	1.000	1.000	0.019	0.950	0.940	1.000
MDO/MGO	0.02%	0.940	0.154	1.000	1.000	0.007	0.950	0.940	1.000
MDO/MGO	0.01%	0.940	0.152	1.000	1.000	0.004	0.950	0.940	1.000

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

The emission factors used for main engines, auxiliary engines and for auxiliary boilers based on HFO with a sulfur content of 2.7% are listed in Table 5.14 and 5.15.

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 I)	2000 to 2011	17.0	1.4	1.1	0.6	1.4	10.3
Slow Speed Main (Tier II)	2011 to 2016	15.3	1.4	1.1	0.6	1.4	10.3
Slow Speed Main (Tier III)	2016+	3.6	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 I)	2000 to 2011	13.0	1.4	1.1	0.5	1.1	11.4
Medium Speed Main (Tier II)	2011 to 2016	11.2	1.4	1.1	0.5	1.1	11.4
Medium Speed Main (Tier III)	2016+	2.8	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 Speed Auxiliary (Tier 0)	1999 and older	14.7	1.4	1.2	0.4	1.1	12.0
Medium Speed Auxiliary (Tier I)	2000 to 2011	13.0	1.4	1.2	0.4	1.1	12.0
Medium Speed Auxiliary (Tier II)	2011 to 2016	11.2	1.4	1.2	0.4	1.1	12.0
Medium Speed Auxiliary (Tier III)	2016+	2.8	1.4	1.2	0.4	1.1	12.0

Table 5.15: OGV GHG Emission Factors (g/kW-hr)

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

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, so instead of running the three engines at a greatly reduced load, typically only one or two will be operated at a higher load. This saves wear and tear on the other auxiliary engines and allows the operating engine(s) to run at optimal (higher) operating levels. In practice, actual auxiliary engine and auxiliary boiler loads are not readily available for specific vessels. The information used for these estimates has been collected by Starcrest during their

VBP in which ships' operators are interviewed to collect actual engine load information, and summaries have been published by the port(s) sponsoring these programs.[25]

Table 5.16 lists the OGV auxiliary engine load assumptions by vessel type and mode that are used in this inventory.

Table 5.16: OGV Auxiliary Engine Load by Mode, kW

Vessel Type	Transit (kW)	Manuevering (kW)	Berth Dwelling (kW)	Anchorage Dwelling (kW)
Auto Carrier	503	1,508	838	622
Bulk	255	675	150	253
Container - 1000	545	1,058	429	1,000
Container - 2000	981	2,180	1,035	1,008
Container - 3000	602	2,063	516	559
Container - 4000	1,434	2,526	1,161	1,200
Container - 5000	1,725	3,367	900	967
Container - 6000	1,453	2,197	990	1,645
Container - 7000	1,444	3,357	1,372	1,000
Container - 8000	1,494	2,753	902	986
Container - 9000	1,501	2,942	1,037	968
Container - 10000	2,300	2,350	1,450	1,129
Container - 11000	1,611	2,660	1,202	1,503
Container - 12000	2,500	4,500	2,000	2,000
Container - 13000	1,865	3,085	982	1,015
Container - 14000	1,367	2,200	1,200	1,200
General Cargo	516	1,439	722	180
RoRo	132	396	229	434
Tanker - Chemical	658	890	816	402
Tanker - Handysize	537	601	820	560
Tanker -Panamax	561	763	623	379

[25] Port of Los Angeles Inventory of Air Emissions, 2018; and Port of Long Beach 2018 Emissions Inventory.

House load defaults for cruise ships (diesel electric and non-diesel electric) are listed in Table 5.17. The majority of the cruise ships that called the cruise terminal were diesel-electric. Cruise ships typically do not spend any time dwelling at anchorage, so auxiliary engine loads at anchorage were not utilized in the calculations and are therefore not included in the table below.

Table 5.17: Cruise Ship Auxiliary Engine Load, kW

Vessel Type	Passenger Count	Transit (kW)	Maneuvering (kW)	Berth Dwelling (kW)
Cruise	0-1,499	3,994	5,268	3,069
Cruise	1,500-1,999	7,000	9,000	5,613
Cruise	2,000-2,499	11,000	11,350	6,900
Cruise	2,500-2,999	9,781	8,309	6,089
Cruise	3,000-3,499	8,292	10,369	8,292
Cruise	3,500-3,999	9,945	11,411	10,445
Cruise	4,000-4,499	12,500	14,000	12,000
Cruise	4,500-4,999	13,000	14,500	13,000

5.3.2.4 OGV Auxiliary Boilers

The auxiliary 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 for distillate fuel is 290 grams of fuel per kW-hour, and for residual fuel it is 305 grams per kW-hour. The average kW for auxiliary boilers using distillate fuel was calculated using the following equation.

$$\boldsymbol{Average\ kW = ((daily\ fuel/24) \times 1{,}000{,}000)/290}$$

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 for auxiliary boilers 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 IHS Markit database by mode of operation. For vessels that have not been boarded through the VBP and that do not have a sister vessel that has been boarded, average load defaults have been developed by vessel class from the most recent data that is available from the VBP.

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 auxiliary boiler load defaults shown in the table are used, depending on operating mode. Table 5.18 presents auxiliary boiler energy defaults in kilowatts for each vessel type by mode.

Table 5.18: Auxiliary Boiler Load Defaults by Mode, kW

Vessel Type	Transit (kW)	Maneuvering (kW)	Berth Dwelling (kW)	Anchorage Dwelling (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	384	458	581	581
Container - 11000	342	527	647	647
Container - 12000	330	575	790	790
Container - 13000	203	420	612	612
Container - 14000	205	453	287	287
Cruise	282	361	612	306
General Cargo	56	124	160	160
RoRo	67	148	259	251
Tanker - Chemical	59	136	568	255
Tanker - Handysize	144	144	2,586	144
Tanker -Panamax	167	351	3,421	451

Table 5.19 presents the load defaults for the auxiliary boilers for diesel electric cruise ships and tankers.

Table 5.19: Auxiliary Boiler Load Defaults by Mode for Diesel Electric Vessels, kW

Vessel Type	Transit	Maneuvering	Berth Hotelling	Anchorage Hotelling
Cruise - Diesel-Electric	0	0	1,414	0
Tanker - Diesel-Electric	0	145	220	220

5.3.2.5 Assist Tugs, Towboats, Pushboats (Harbor Craft)

The emission estimating methodology is similar for assist tugs and towboats/push boats (as a group, termed harbor craft), 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 illustrated below.

$$E = EF \times Power \times LF \times Act \times FCF$$

Where:

E = emission, g/year
EF = emission factor, grams of pollutant per unit of work, g/hp-hr or g/kW-hr
Power = rated power of the engine, hp or kW
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
Act = vessel's engine(s) activity, hr/year
FCF = fuel correction factor to reflect changes in fuel properties that have occurred over time on emissions, dimensionless

The load factor used for assist tug main engines is 31% and for auxiliary engines it is 43%. The assist tugs' main engine load factor of 31% based on empirical data first published in the Port of Los Angeles' 2001 vessel emissions inventory,[26] 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 push boats is 68%, based on a California Air Resources Board report[28] and has been used in previous inventories.

[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 estimated operating time of assist tugs has been based on the time the tug spends assisting on an OGV call, the average number of assist tugs per OGV call, and the total number of OGV calls by vessel type to the Port Authority owned marine terminals. The average assist and escort time of 1.25 hours per vessel is based on the time a vessel travels to or from a berth which is confirmed by AIS data and also from conversations with pilots. The number of OGV calls changes each year.

The operating time of towboats and pushboats has been estimated from the 2006 towboat detailed activity data in which time was estimated by dividing trip length by speed in mode. Since 2006, detailed origination-destination data has not been available. For this inventory, the average 2006 trip time of 2.7 hours was used. The number of barge calls are updated each year for the dedicated Cross Harbor Barge service. With the exception of the first year which was not a full year, the barge calls have remained fairly constant. The barge calls at public berths at Port Newark are also reviewed each year, but the level of activity has not changed for several years. It is acknowledged that BP is no longer a tenant of Port Newark. However, due to the similar throughput of metric tons of cargo, the public berth barge trips have been kept same.

Emission factors for all pollutants were updated based on latest detailed engine information. In 2019, the fleet composite emission factors were updated for assist tugs and for towboats. This update was based on specific data such as engine model year and kilowatts, published (on their websites) by the two companies that provide assist and escort tugs. and based on the 2019 towboats/pushboats that transited the. First, the emission factors were determined for the individual vessel engine(s) by looking up vessel/engine specifications from various websites, then the kilowatt weighted fleet composite emission factors were calculated separately for assist tugs and towboats. Table 5.20 lists the assist tug emission factors and Table 5.21 lists the towboat/pushboats emission factors.

Table 5.20: Assist Tug 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	9.63	0.38	0.35	0.37	3.05	0.01	690	0.03	0.01
Auxiliary Engines	8.68	0.28	0.25	0.25	2.54	0.01	690	0.03	0.01

Table 5.21: Towboat 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	9.75	0.37	0.34	0.35	2.79	0.01	690	0.03	0.01
Auxiliary Engines	8.44	0.29	0.27	0.24	3.01	0.01	690	0.03	0.01

The engine emission factors are based on marine engine standards (i.e., Tier 1, Tier 2, Tier 3, and Tier 4) and the EPA engine category (1 or 2).[29] EPA identifies the engine category in terms of cylinder displacement. Category 1 engines have displacement of 1 to 5 liters per cylinder, while category 2 engines have a cylinder displacement between 5 to 30 liters.

For the emissions inventory, the weighted assist tug emission factors were based on current tugboat fleet data. A list of 31 specific tugboats for the two main companies that provide assist and escort services were updated for 2019 and used for the assist tugs. For towboats that transited the NYNJ harbor, about 195 discrete towboats/pushboats from 60 operators were used to update the towboat emission factors. It should be noted that not all of the discrete towboats called on a Port Authority berth but assumed to represent an average fleet of towboats operating in the EI domain in 2019. Table 5.22 presents the tier distribution of the harbor craft fleet in 2019.

Table 5.22: Distribution of Harbor Craft Engines by Tier

Vessel Type	Engine Type	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
Assist Tug	Main	58%	3%	29%	3%	6%
Assist Tug	Auxiliary	68%	3%	6%	23%	0%
Towboat	Main	57%	8%	22%	8%	5%
Towboat	Auxiliary	57%	2%	20%	16%	5%

5.4 Description of Marine Vessels and Vessel Activity

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

5.4.1 Ocean-Going Vessels

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

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

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

Figure 5.5: Bulk Carrier

M/S «Vinstra» – 63.429 t.dw. Bulkskip av Panmax-typen. Bygget 6/75 ved Mitsubishi Heavy Industries, Kobe – O. Ditlev-Simonsen Jr.

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

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

Figure 5.6: Containership at Berth

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

Figure 5.7: Cruise Ship

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

Figure 5.8: Car Carrier

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

Figure 5.9: Tanker

5.4.2 Assist Tugs, Towboats, Pushboats

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

Figure 5.10: Tugboat