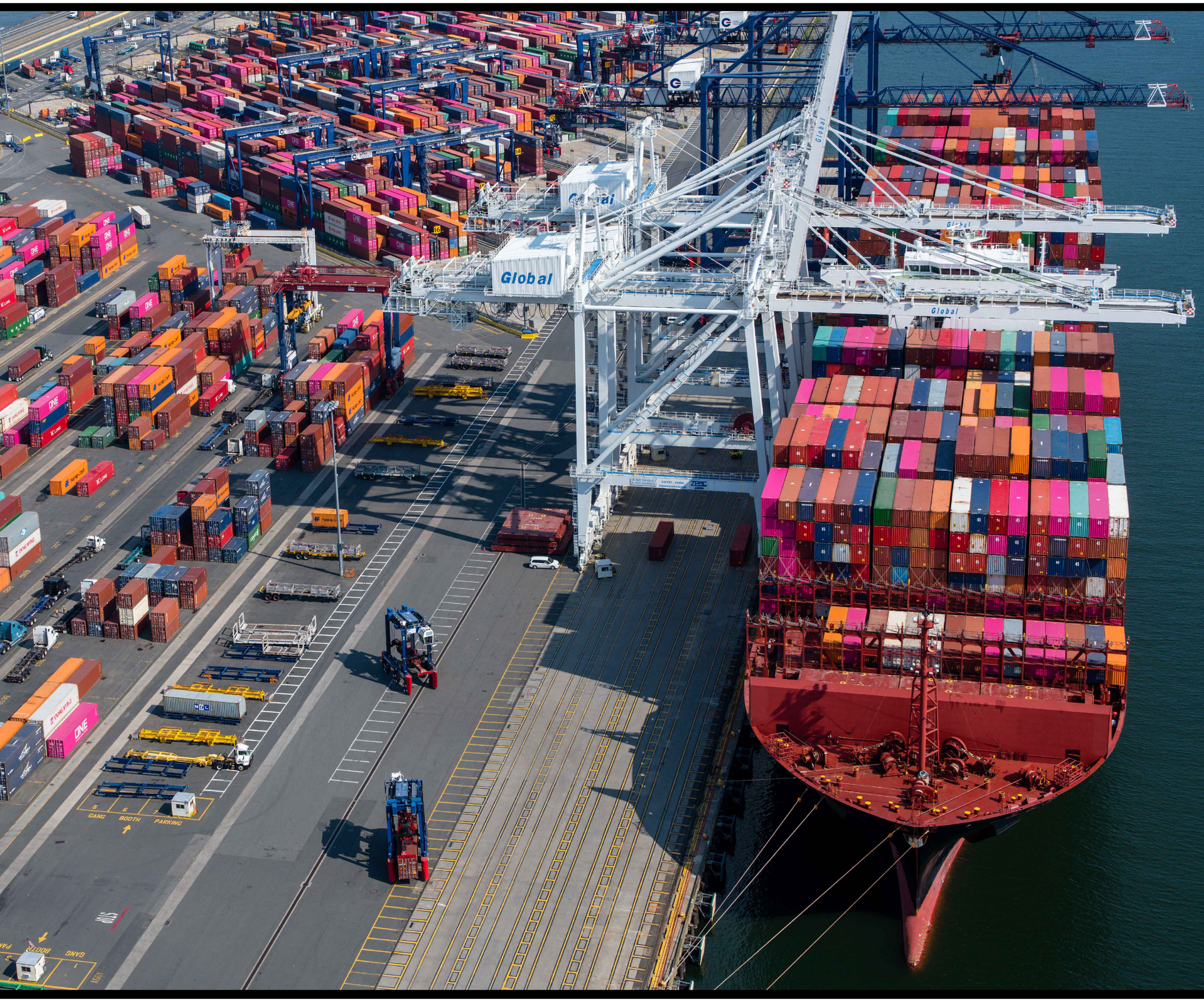
THE PORT AUTHORITY OF NEW YORK AND NEW JERSEY
PORT DEPARTMENT
2023 MULTI-FACILITY MARINE EMISSIONS INVENTORY

PORT AUTHORITY NY NJ
AIR LAND RAIL SEA

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



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ENVIRONMENTAL MANAGEMENT • AIR QUALITY • CLIMATE • SUSTAINABILITY

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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
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 (on-road) vehicle
HFO	heavy fuel oil
hp	horsepower
hp-hr	horsepower hour
IMO	International Maritime Organization
kW	kilowatt
LF	load factor
LPG	liquefied petroleum gas
M	millions
MHE	material handling equipment
MDO	marine diesel oil
MOVES3	EPA's 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
NYCDOT	New York City Department of Transportation
NYNJHS	New York/New Jersey Harbor System

LIST OF ACRONYMS (CONTD)

NYNJLINA	New York/New Jersey Long Island Non-Attainment Area (Ozone)
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
RMG	rail mounted gantry crane
RTG	rubber-tired gantry crane
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

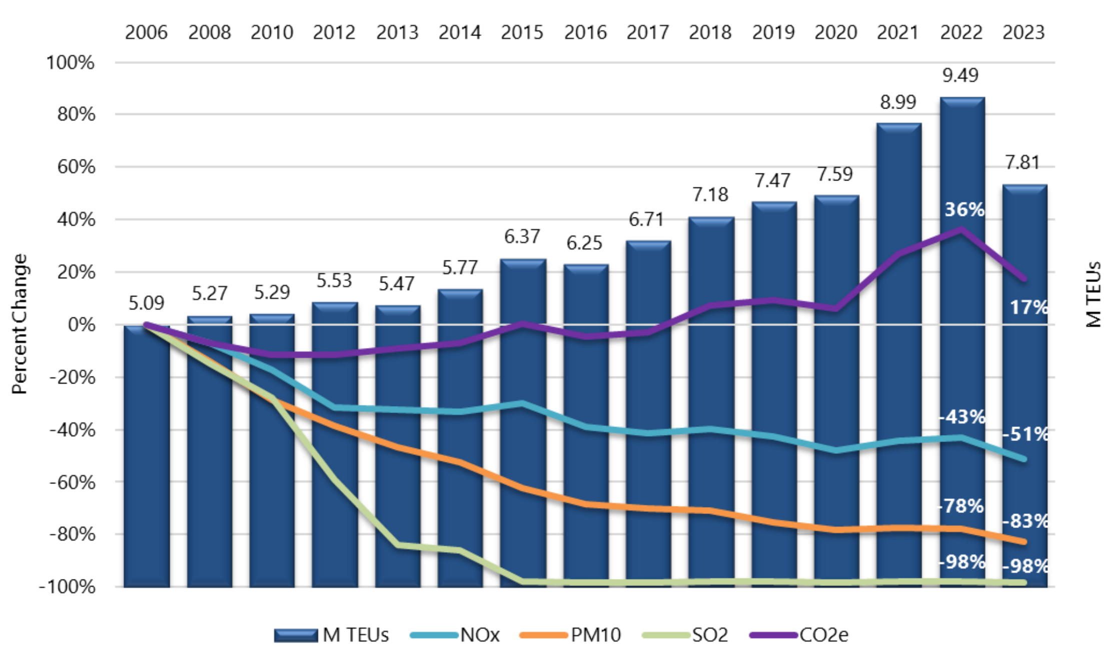
The purpose of this emissions inventory (EI) report is to present the 2023 mobile source air emissions from activities associated with the marine terminal facilities maintained by the Port Authority of New York and New Jersey (the Authority or PANYNJ) and facilities leased to private terminal operators. These mobile emission sources include both land-based mobile sources: material handling equipment (MHE), heavy-duty vehicles (HDV), and locomotives; and commercial marine mobile sources (ocean-going vessels (OGV) and harbor craft). This 2023 EI report is an update of the 2022 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

This report compares 2023 emissions to the previous year (2022) and baseline year (2006) and discusses the findings. The previous years' emissions have been adjusted to account for any current year emission estimating methodology changes, if appropriate. This ensures the prior years' emissions are comparable to the current year's estimates.

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 2023 update, with emission trend lines superimposed over the blue columns illustrating annual TEU throughput in millions (M). NO_x, PM, and SO_2 emissions are significantly lower than the 2006 baseline emissions due to fleet turnover (new engines have lower engine standards) and use of lower sulfur fuels. The increase in GHG emissions (CO_2e) is due to the continued use of conventional fossil fuel, the increased activity over the years due to increased cargo, and fossil fueled equipment.

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



ES.2 Emissions Comparison

Table ES.1 summarizes the emissions comparison which shows lower emissions in 2023 as compared to 2022 and 2006. Container cargo throughput was 7.81 million (M) TEUs in 2023, an 18% drop from 2022.

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	Throughput M TEUs
2023	4,624	119	111	240	1,112	75	760,405	7.81
2022	5,383	151	141	280	1,274	93	880,881	9.49
2006	9,498	690	588	497	1,948	4,019	648,284	5.09
2022-2023, Change (%)	**-14%**	**-21%**	**-21%**	**-14%**	**-13%**	**-20%**	**-14%**	**-18%**
2006-2023, Change (%)	**-51%**	**-83%**	**-81%**	**-52%**	**-43%**	**-98%**	**17%**	**53%**

Compared to previous year, emissions are lower in 2023 due to less throughput and associated activity. Compared to baseline 2006 emissions, emissions are lower in 2023, except for GHG emissions. The cargo TEU throughput is in dark blue, while the emissions changes are in light blue.

Figure ES.2: Emissions Comparison

	2023 vs 2022 Previous Year Change	2023 vs 2006 Baseline Change
Cargo TEU throughput	-18%	53%
NO_x emissions	-14%	-51%
PM_{10} emissions	-21%	-83%
$PM_{2.5}$ emissions	-21%	-81%
VOC emissions	-14%	-52%
CO emissions	-13%	-43%
SO_2 emissions	-20%	-98%
GHG emissions (CO_2e)	-14%	17%

ES.3 Emissions Comparison by Source Category

Key reasons for the lower criteria pollutant emissions in 2023 as compared to 2006 include regulatory requirements, voluntary actions, and measures implemented by the Port Authority to date[1].

- For MHE, under the PANYNJ's introduction of a Material Handling Equipment (MHE, aka CHE) section to the Marine Terminal Tariff FMC Schedule No. PA 10 (Tariff)[2], which sets emission standards for new equipment, phase out requirements for old equipment, as well as zero emission requirements for equipment where commercially available and operationally feasible. The fleet turnover continued introducing new equipment at the terminals. The newer and cleaner fleet, which includes Tier 4 equipment, hybrid, electric cranes, and battery electric equipment, has lowered overall MHE emissions.

- For HDV, the PANYNJ Truck Replacement Program (TRP) provides incentives to replace old trucks with newer, cleaner alternatives which reduces PM and NO_x emissions, mainly. The HDV transition to newer trucks has been significant over the last few years as a result of this Port program. Also, a truck appointment system at container terminals reduced truck turn times and queuing at gates. Some terminals modernized their gate operations which reduces truck idling at the in- and out-gates.

- For locomotives, Tier 4i switchers are used for rail-to-barge cross-harbor service. In addition, the new Intermodal Container Terminal Facility provided near-dock rail access for Port Liberty Bayonne, which reduced truck trips and vehicle miles traveled (VMT) to/from Elizabeth's Millennium Marine Rail.

- For the landside sources, the use of ultra-low sulfur diesel fuel (ULSD) reduced SO_2, NO_x and PM emissions.

- For OGV, the North American Emissions Control Area[3] (ECA) continued to be in effect. The use of fuels with sulfur content of 0.1% or less lowers emissions of SO_2, NO_x and PM emissions from OGVs. In addition, the PANYNJ Clean Vessel Incentive (CVI) Program[4] 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). The CVI Program reduces criteria air pollutants and GHG emissions by incentivizing the use of less fuel and increase of Tier III vessels. One of the cruise terminals supplies shore power to the cruise ships that are shore power capable. In 2022, alternative fueled containerships (LNG) called the Port for the first time and in 2023, the LNG fueled vessel calls increased.

[1] See PANYNJ, *https://www.panynj.gov/port/en/our-port/sustainability.html*
[2] See PANYNJ, *https://www.panynj.gov/port/en/doing-business/tariffs.html*
[3] See EPA, *https://www.epa.gov/regulations-emissions-vehicles-and-engines/designation-north-american-emission-control-area-marine*
[4] See PANYNJ, *https://www.panynj.gov/about/clean-vessel-incentive-program.html*

- For harbor craft, 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 have reduced assist tug emissions.

In general, the increase in GHG reflects the lack of lower emission standards specific to CO_2 as most target NOx and PM. GHG emissions will typically increase with increased activity and fuel consumption if control measures are not implemented. Figure ES.3 presents the 2023 comparison to baseline year 2006 by source category. Most source categories have lower criteria pollutant emissions in 2023 as compared to 2006, except for locomotives.

Figure ES.3: 2006-2023 Emissions Comparison by Source Category

	MHE	Trucks	Locomotives	OGV	Harbor Craft
NO_x emissions	-82% ↓	-56% ↓	-1% ↓	-41% ↓	-47% ↓
PM_{10} emissions	-80% ↓	-75% ↓	-1% ↓	-89% ↓	-78% ↓
$PM_{2.5}$ emissions	-79% ↓	-75% ↓	-0.2% ↓	-87% ↓	-77% ↓
VOC emissions	-83% ↓	-48% ↓	17% ↑	-38% ↓	-68% ↓
CO emissions	-67% ↓	-42% ↓	49% ↑	-32% ↓	-9% ↓
SO_2 emissions	-100% ↓	-88% ↓	-99% ↓	-98% ↓	-99% ↓
GHG emissions	-2% ↓	62% ↑	68% ↑	-18% ↓	15% ↑

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ES.4 Emissions Efficiency

Table ES.2 and Figure ES.4 provide the emissions per M TEUs. Compared to 2006, the 2023 metric is lower across all pollutants which shows efficiency in the emissions emitted per M TEU moved. Compared to 2022, the PM and SO_2 decrease shows efficiency in the emissions emitted per M TEU moved in 2023. More emissions per TEU for NOx and GHG emissions is due to less throughput in 2023 than in 2022 and not enough emission reductions for these pollutants to offset the change in TEU.

Table ES.2: Emissions Efficiency Metric Comparison

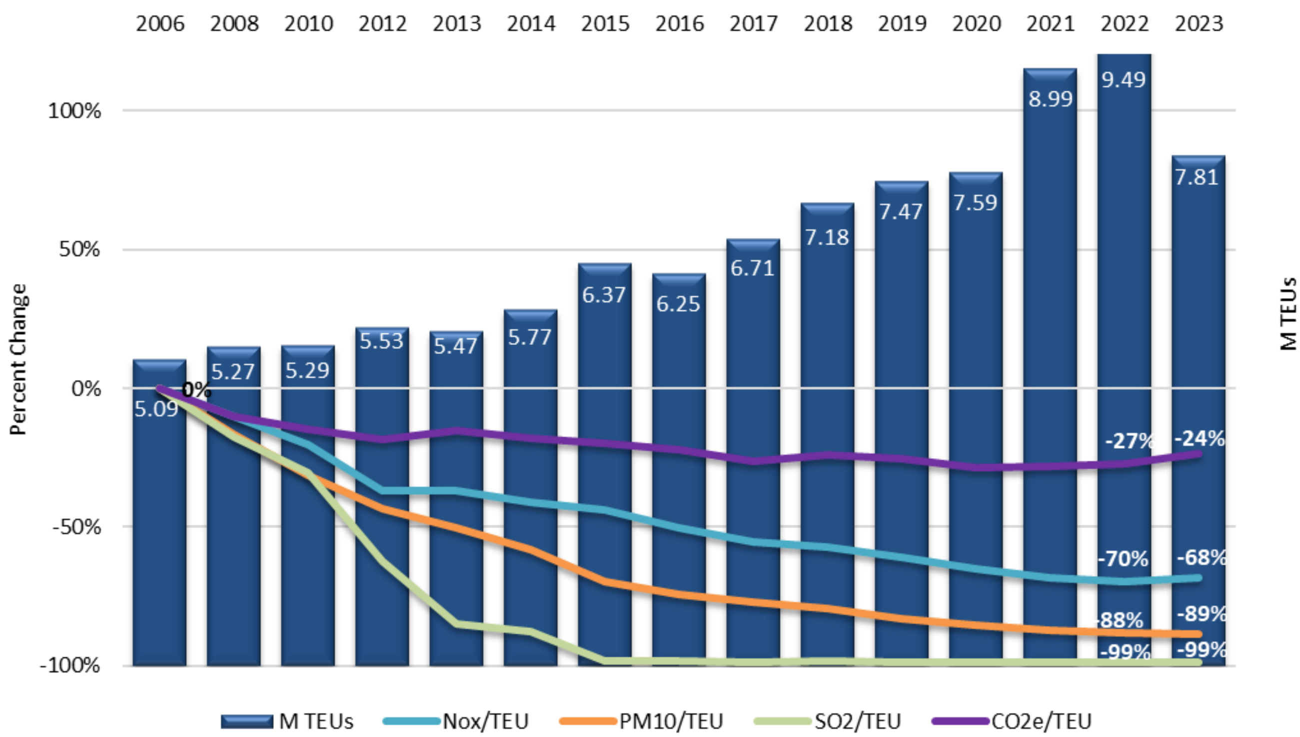
Inventory Year	Emissions / M TEUs						
	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
2023	592	15	14	31	142	10	97,363
2022	567	16	15	29	134	10	92,786
2006	1,865	135	115	98	382	789	127,289
2022-2023, Change (%)	**4%**	**-4%**	**-4%**	**4%**	**6%**	**-2%**	**5%**
2006-2023, Change (%)	**-68%**	**-89%**	**-88%**	**-69%**	**-63%**	**-99%**	**-24%**

Figure ES.4: Emissions Efficiency per M TEUs Comparison

	2023 vs 2022 Previous Year Change	2023 vs 2006 Baseline Change
Cargo TEU throughput	-18% ↓	53% ↑
NO_x emissions/M TEU	4% ↑	↓ -68%
PM_{10} emissions/M TEU	↓ -4%	↓ -89%
$PM_{2.5}$ emissions/M TEU	↓ -4%	↓ -88%
VOC emissions/M TEU	4% ↑	↓ -69%
CO emissions/ M TEU	6% ↑	↓ -63%
SO_2 emissions/ M TEU	↓ -2%	↓ -99%
GHG emissions (CO_2e)/ M TEU	5% ↑	↓ -24%

Figure ES.5 shows the trend for emissions per M TEUs metric. Despite the 53% increase in cargo throughput, the emissions per TEU are lower in 2023 than in 2006. In 2023, less emissions are emitted per TEU as compared to 2006 emissions per TEU for that year.

Figure ES.5: Emissions per M TEUs Trend



ES.5 Emission Estimates and Comparison to Regional Emissions

The 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] The marine terminals are 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). The 2023 National Emissions Inventory (NEI) emissions will not be available until Q1 2026, thus 2020 NYNJLINA emissions were used for the comparison.

Table ES.3 presents the criteria pollutant and GHG (as CO_2e) emissions by emission source category, the total PANYNJ emissions, the total emissions in the NYNJLINA,[6] and the percentage that the PANYNJ emissions made up of the total NYNJLINA emissions. The 2023 and 2022 PANYNJ percent emissions are included to show the year-to-year change.

[5] For example, *https://www3.epa.gov/airquality/greenbook/map8hr_2015.html*

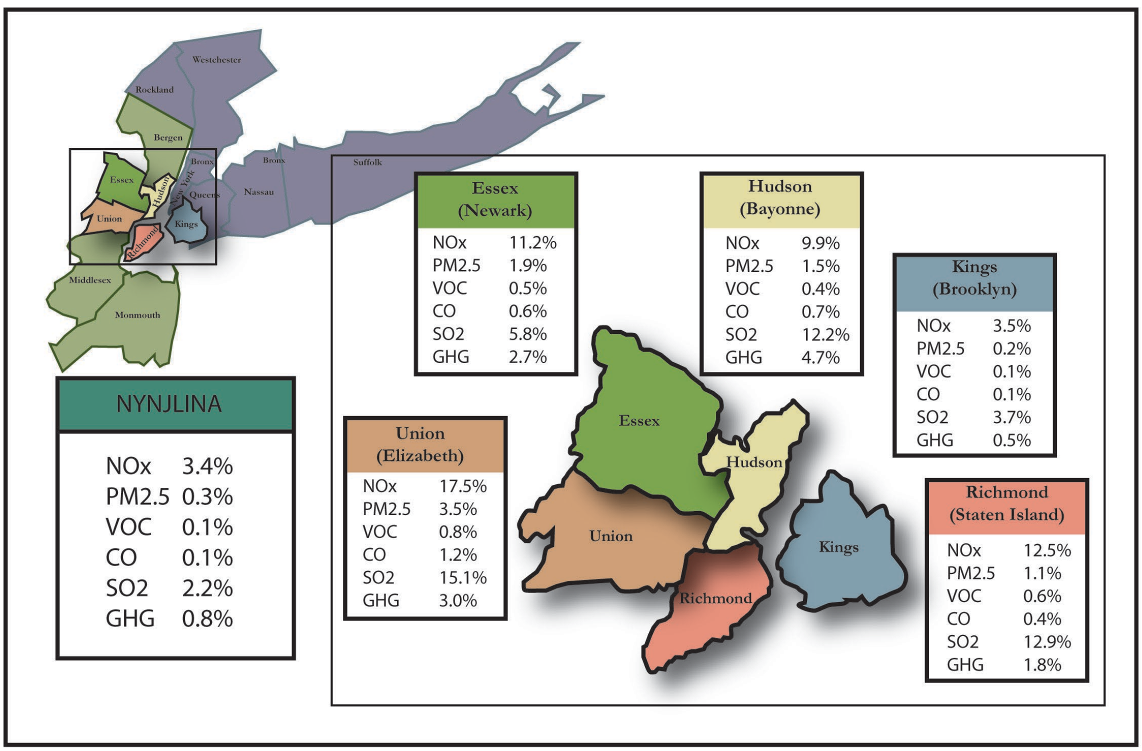
[6] Emissions are primarily from the 2020 National Emissions Inventory, the most recent year's inventory available from EPA. *https://www.epa.gov/air-emissions-inventories/get-air-emissions-data-0*

Table ES.3: Emissions Summary by Source Category, tons per year

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Material handling equipment	264	20	19	23	163	0.4	150,890
Heavy-duty vehicles	1,271	39	36	72	548	1.2	363,988
Locomotives	284	10	9	23	65	0.3	24,689
Ocean-going vessels	2,466	43	40	114	246	72	182,105
Harbor craft	338	7	7	7	90	0.3	38,732
Total PANYNJ emissions	**4,624**	**119**	**111**	**240**	**1,112**	**74.5**	**760,405**
NYNJLINA emissions	**137,049**	**95,410**	**40,985**	**220,174**	**838,105**	**3,327**	**92,488,145**
2023 % of NYNJLINA Emissions	**3.4%**	**0.1%**	**0.3%**	**0.1%**	**0.1%**	**2.2%**	**0.8%**
2022 % of NYNJLINA Emissions	3.9%	0.2%	0.3%	0.1%	0.2%	2.8%	1.0%

Figure ES.6 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 2023 PANYNJ emissions make up of all emissions in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure ES.6: Mobile Source Emissions at PANYNJ Marine Terminals Contribution to NYNJLINA and Local Air Emissions



SECTION 1: INTRODUCTION

Goods from all over the world enter and leave the United States through the largest port complex on the East Coast of North America, the Port of New York and New Jersey (the Port). The Port includes many marine terminals, five of which are under the aegis of the Port Authority of New York and New Jersey (the Authority or PANYNJ).[7]

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 Authority in any way. This inventory also does not include emissions linked to the Authority's non-maritime facilities, such as airports, bridges, and tunnels.

This report furthers ongoing efforts by the Authority's Port Department to assess and evaluate air emissions associated with the Authority's marine terminals, including emissions from material handling equipment (MHE), heavy-duty vehicles (HDV), locomotives, and commercial marine vessels (CMV), which include ocean going vessels (OGV) and harbor craft. The 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 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 ($PM_{2.5}$).[8]

The purpose of this 2023 emissions inventory is to update the emission estimates with a focus on the Authority's marine terminals. This current study has evaluated the MHE, HDV, railroad locomotive, and CMV emission source categories for the year 2023, 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 MHE, HDV, locomotives, and CMV associated with the five Authority marine terminals.
- Illustrate trends over time in emissions associated with the five Authority marine terminals.
- Reflect, to the extent feasible, the effects of voluntary measures initiated by the 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.

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

[8] In December of 2012, New Jersey submitted a request to the EPA for re-designation to attainment of the annual 24-hour $PM_{2.5}$ standard. On August 13, 2013, the USEPA re-designated New Jersey's 13 nonattainment counties to attainment for the annual and the 24-hr $PM_{2.5}$ 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, MHE, HDV, and locomotives with emissions within the NYNJLINA and with regional emissions. It does not include the use of dispersion models to predict ambient concentrations of pollutants or the assessment of health impacts.

The information presented in this report improves the understanding of the nature and magnitude of emission sources associated with the 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. The activity and operational data collected and used to estimate emissions for each of the source categories is consistent with the latest estimating practices.

1.1.1 Pollutants

This inventory estimates and reports the quantity of emissions from mobile emission sources associated with maritime facilities maintained by the Authority and facilities leased to terminal operators. The estimates are based on activities that occurred during calendar year 2023 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[9] (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 GHG Inventory report[10]. The sum of the three GHGs is reported as one CO_2e value using the following GWP values.

- CO_2 – 1 N_2O – 265 CH_4 – 28

[9] *https://www.epa.gov/ghgemissions/understanding-global-warming-potentials*

[10] *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2022 (published 2024)*

1.1.2 Facilities

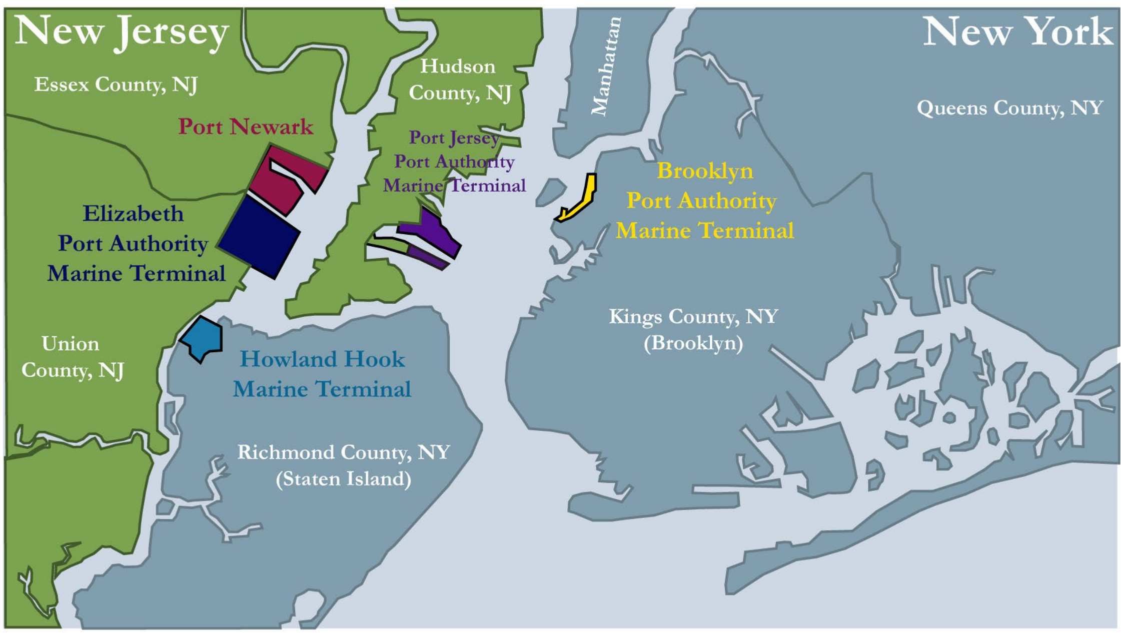
The Authority's New Jersey marine terminals are:

- Port Newark - container, auto, bulk, and on-terminal warehousing operations
- The Elizabeth-Port Authority Marine Terminal - container and on-terminal warehousing operations
- Port Jersey-Port Authority Marine Terminal - container, auto and cruise operations

The Authority's New York marine facilities are:

- The Howland Hook Marine Terminal - container operations
- The Brooklyn-Port Authority Marine Terminal - container and cruise operations

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



1.1.3 Major Changes in 2023

In 2023, there were no major changes to the emissions calculation methodology, except for updating the global warming potential values to be consistent with EPA's latest GWP values. This change impacted GHG emissions only. The OGV emissions were slightly updated with improved activity scripts.

From an activity standpoint, there were fewer vessels at anchorage in 2023 than in the prior year. The trucks engine model year continued to show fleet turnover to cleaner and newer trucks calling the Port.

1.2 Report Organization by Section

The sections that follow summarize emissions results and methodologies for MHE (Section 2), HDV (Section 3), locomotives (Section 4), and CMV (Section 5).

1.3 Summary of Results

Table 1.1 presents the criteria pollutant and CO_2e emissions by source category and compares the Port Authority marine activities covered by this report by source category and compares the totals to total emissions in the NYNJLINA[11]. The NYNJLINA emissions are from the 2020 NEI, the latest available. Comparing 2023 PANYNJ emissions to the 2020 NEI illustrates the relative contribution of the emission sources covered by this inventory to total emissions in the area. EPA will release the 2023 NEI in March 2026, thus the comparison to 2020 NEI, the latest national emissions publicly available.

Table 1.1: Emission Summary by Source Category, tpy

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Material handling equipment	264	20	19	23	163	0.4	150,890
Heavy-duty vehicles	1,271	39	36	72	548	1.2	363,988
Locomotives	284	10	9	23	65	0.3	24,689
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Total PANYNJ emissions	**4,624**	**119**	**111**	**240**	**1,112**	**74.5**	**760,405**
NYNJLINA emissions	**137,049**	**95,410**	**40,985**	**220,174**	**838,105**	**3,327**	**92,488,145**
2023 % of NYNJLINA Emissions	**3.4%**	**0.1%**	**0.3%**	**0.1%**	**0.1%**	**2.2%**	**0.8%**
2022 % of NYNJLINA Emissions	3.9%	0.2%	0.3%	0.1%	0.2%	2.8%	1.0%

Table 1.2 illustrates the percentage contribution of each source category to the total PANYNJ emissions of each pollutant. OGVs and HDVs contribute most emissions (combined over 68-99% depending on pollutant) 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
Material handling equipment	6%	16%	17%	10%	15%	1%	20%
Heavy-duty vehicles	27%	33%	32%	30%	49%	2%	48%
Locomotives	6%	9%	8%	10%	6%	0%	3%
Ocean-going vessels	53%	36%	36%	48%	22%	97%	24%
Harbor craft	7%	6%	6%	3%	8%	0%	5%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

[11] Criteria pollutant and GHG emissions are from the 2020 National Emissions Inventory: *https://www.epa.gov/air-emissions-inventories/get-air-emissions-data-0*

1.4 Overall Comparison of PANYNJ Emissions

This section compares overall Authority marine terminal-related emissions with county level emission totals as reported in the 2020 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

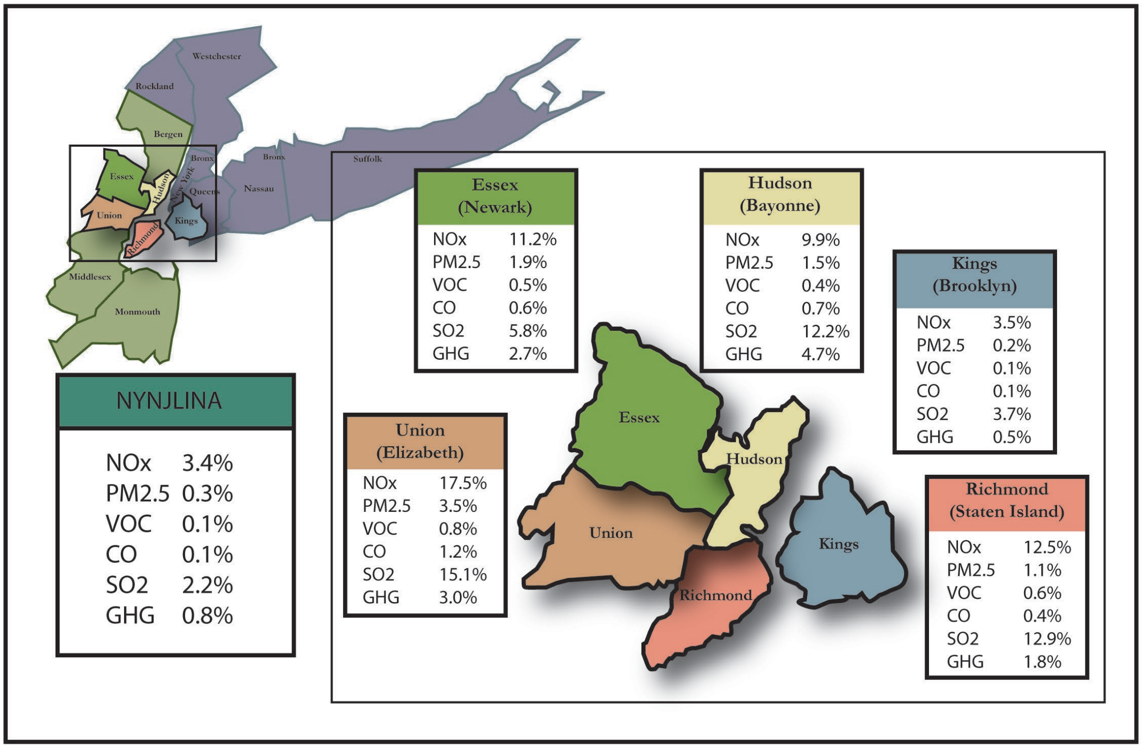


Table 1.3 summarizes by county the estimated emissions from the Authority marine terminal-related activities covered by this report.

Table 1.3: Authority Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	96	3	3	5	39	0	25,762
Essex	NJ	958	26	24	52	233	16	168,642
Hudson	NJ	597	15	14	30	135	11	91,256
Middlesex	NJ	193	6	5	10	80	0	55,432
Monmouth	NJ	283	3	2	10	23	5	12,578
Union	NJ	1,286	46	43	72	388	23	300,521
New Jersey subtotal		**3,412**	**99**	**91**	**180**	**898**	**55**	**654,189**
Bronx	NY	9	0	0	1	4	0	2,925
Kings	NY	395	6	6	20	75	8	26,173
Nassau	NY	5	0	0	0	2	0	1,263
New York	NY	8	0	0	0	2	0	1,073
Orange	NY	52	2	1	3	22	0	15,734
Queens	NY	181	2	2	6	18	3	9,489
Richmond	NY	488	9	9	29	67	8	36,034
Rockland	NY	49	1	1	2	18	0	9,169
Suffolk	NY	12	0	0	0	4	0	1,759
Westchester	NY	11	0	0	0	4	0	2,596
New York subtotal		**1,211**	**21**	**20**	**61**	**215**	**19**	**106,216**
PANYNJ Total		**4,624**	**119**	**111**	**240**	**1,112**	**75**	**760,405**

Table 1.4 lists total emissions of each criteria pollutant by county and state, as reported in the 2020 NEI,[12] which represents the best source of area-wide emissions data and is the most current year available. The overall regional reduction in emissions may be due to stricter regulations for various sources not related to maritime such as point sources, engine standards for vehicles, and regulations in other sectors. The 2023 NEI was not available at the time of this report and thus not included.

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	8,134	2,857	1,770	13,719	65,911	58	4,989,225
Essex County	NJ	8,568	2,133	1,253	10,576	38,019	269	6,214,041
Hudson County	NJ	6,003	1,520	938	7,793	19,634	93	1,928,063
Middlesex County	NJ	8,150	9,560	2,293	15,396	54,142	159	9,194,497
Monmouth County	NJ	5,710	9,297	2,120	14,654	48,392	68	3,481,424
Union County	NJ	7,364	2,001	1,239	8,820	31,784	152	10,024,375
New Jersey subtotal		**43,929**	**27,368**	**9,612**	**70,959**	**257,881**	**799**	**35,831,624**
Bronx County	NY	5,149	2,830	1,644	9,405	26,465	84	2,445,881
Kings County	NY	11,230	5,501	3,499	17,179	53,178	217	4,848,542
Nassau County	NY	11,340	7,434	3,425	15,890	81,479	279	7,413,694
New York County	NY	14,753	17,322	5,865	13,428	79,365	379	5,926,904
Orange County	NY	4,718	5,834	2,544	17,605	31,626	136	4,400,811
Queens County	NY	13,816	7,431	3,810	18,029	61,834	416	10,654,568
Richmond County	NY	3,921	1,506	772	4,851	17,326	63	2,011,953
Rockland County	NY	3,147	2,322	1,098	7,045	21,292	83	1,917,697
Suffolk County	NY	16,210	11,276	5,471	28,583	135,548	598	12,109,830
Westchester County	NY	8,835	6,585	3,245	17,201	72,110	273	4,926,641
New York subtotal		**93,120**	**68,041**	**31,373**	**149,216**	**580,224**	**2,528**	**56,656,521**
TOTAL		**137,049**	**95,410**	**40,985**	**220,174**	**838,105**	**3,327**	**92,488,145**

1.5 Comparison of 2023 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 Authority, the Authority has developed programs aimed at reducing emissions from port operations through various programs developed and implemented initially under the Clean Air Strategy. Authority tenants and other entities involved with the international goods movement also take voluntary actions to reduce their emissions.

[12] 2020 National Emissions Inventory, the most recent year's inventory available from EPA. *https://www.epa.gov/air-emissions-modeling/2022v1-emissions-modeling-platform*

The previous year (2022) and baseline (2006) emissions remain the same in this comparison as those published in the 2022 EI report, except for GHG emissions and OGV emissions. The 2022 OGV emissions changed[13] due to slight change in activity and updated LNG factors.

Table 1.5 presents the annual emissions in 2006, 2022, and 2023. The emissions are expressed in both tons per year and as percentage increases or decreases between 2023 and previous years. The last column includes the cargo throughput in M 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	Throughput M TEUs
2023	4,624	119	111	240	1,112	75	760,405	7.81
2022	5,383	151	141	280	1,274	93	880,881	9.49
2006	9,498	690	588	497	1,948	4,019	648,284	5.09
2022-2023, Change (%)	**-14%**	**-21%**	**-21%**	**-14%**	**-13%**	**-20%**	**-14%**	**-18%**
2006-2023, Change (%)	**-51%**	**-83%**	**-81%**	**-52%**	**-43%**	**-98%**	**17%**	**53%**

Table 1.6 presents the 2023 and 2006 emissions comparison by emission source category. Overall, the 2023 emissions are significantly lower than 2006, except for GHG emissions which are higher by 17% due to increased activity associated with the 53% increase in TEU throughput. In 2023, the GHG emissions increased for locomotives, trucks and harbor craft. There are fewer GHG emissions in 2023 as compared to 2006 for ocean-going vessels (OGV) and material handling equipment (MHE). For OGV, GHG emissions in 2023 are lower despite the 53% increase in TEU throughput. This is due to fewer and larger vessels calling the Port in 2023. For MHE, the increase in hybrid and electric equipment is the reason for the lower GHG emissions in 2023 as compared to 2006.

Since 2006, SO_2 and PM emissions saw the greatest reductions due to continued decreasing levels of sulfur in the fuel used by the various emission source categories. Particulate matter (PM_{10} and $PM_{2.5}$) is lower due to a combination of factors including the Authority's Truck Replacement Program that has helped with the truck fleet (i.e. heavy-duty vehicle) transition to newer trucks serving the Port's terminals and the lower sulfur fuel which also lowers PM emissions. NO_x emissions for trucks and equipment are lower due to the Port tariff which encourages newer equipment and fleet turnover. Lower NO_x emissions for vessels are due to the CVI program which encourages lower speeds for vessels calling the Port terminals. Lower NO_x emissions for harbor craft are due to fleet turnover.

[13] The 2022 OGV emissions due to a correction of the shifts (took out non-berth shifts), updated LNG factors, and update to the MAN engine list to include various listings of same engine (ie. MAN/MAN B&W/B&W).

Table 1.6: Port Related 2023-2006 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
2023							
Material handling equipment	264	20	19	23	163	0.4	150,890
Heavy-duty vehicles	1,271	39	36	72	548	1.2	363,988
Locomotives	284	10	9	23	65	0.3	24,689
Ocean-going vessels	2,466	43	40	114	246	72.2	182,105
Harbor craft	338	7	7	7	90	0.3	38,732
Total	**4,624**	**119**	**111**	**240**	**1,112**	**74.5**	**760,405**
2006							
Material handling equipment	1,503	100	92	132	495	233	154,184
Heavy-duty vehicles	2,911	154	141	139	951	10	224,050
Locomotives	286	10	9	20	44	32	14,710
Ocean-going vessels	4,165	392	314	185	360	3,681	221,638
Harbor craft	633	34	31	21	98	62	33,703
Total	**9,498**	**690**	**588**	**497**	**1,948**	**4,019**	**648,284**
Change between 2006 and 2023 (percent)							
Material handling equipment	-82%	-80%	-79%	-83%	-67%	-100%	-2%
Heavy-duty vehicles	-56%	-75%	-75%	-48%	-42%	-88%	62%
Locomotives	-1%	-1%	0%	17%	49%	-99%	68%
Ocean-going vessels	-41%	-89%	-87%	-38%	-32%	-98%	-18%
Harbor craft	-47%	-78%	-77%	-68%	-9%	-99%	15%
Total	**-51%**	**-83%**	**-81%**	**-52%**	**-43%**	**-98%**	**17%**

Table 1.7 presents the 2023 and 2022 emissions comparison by source category. In 2023, a 18% decrease in TEU throughput resulted in overall lower emissions as compared to 2022 for all pollutants. In 2023, there were less vessels at anchorage than in 2022.

For HDV and MHE, emissions are lower for NO_x and PM due to continued fleet turnover through the implementation of the Truck Replacement Program and newly added section on MHE of the Tariff for equipment. Although, the transition to cleaner trucks and equipment results in lower NO_x and PM emissions, the increased activity due to higher TEU throughput results in higher GHG emissions.

Table 1.7: Port Related 2023-2022 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
2023							
Material handling equipment	264	20	19	23	163	0.4	150,890
Heavy-duty vehicles	1,271	39	36	72	548	1.2	363,988
Locomotives	284	10	9	23	65	0.3	24,689
Ocean-going vessels	2,466	43	40	114	246	72.2	182,105
Harbor craft	338	7	7	7	90	0.3	38,732
Total	**4,624**	**119**	**111**	**240**	**1,112**	**74.5**	**760,405**
2022							
Material handling equipment	362	27	26	32	166	0.5	171,229
Heavy-duty vehicles	1,592	54	50	85	671	1.5	425,950
Locomotives	324	12	11	25	73	0.3	27,616
Ocean-going vessels	2,785	52	48	131	283	90.1	220,370
Harbor craft	321	7	6	7	81	0.3	35,716
Total	**5,383**	**151**	**141**	**280**	**1,274**	**92.7**	**880,881**
Change between 2022 and 2023 (percent)							
Material handling equipment	-27%	-27%	-27%	-27%	-1%	-13%	-12%
Heavy-duty vehicles	-20%	-28%	-27%	-16%	-18%	-19%	-15%
Locomotives	-12%	-12%	-12%	-6%	-10%	6%	-11%
Ocean-going vessels	-11%	-17%	-17%	-13%	-13%	-20%	-17%
Harbor craft	5%	12%	12%	2%	10%	8%	8%
Total	**-14%**	**-21%**	**-21%**	**-14%**	**-13%**	**-20%**	**-14%**

SECTION 2: MATERIAL HANDLING EQUIPMENT

This section presents estimated emissions from the off-road equipment used on Authority marine container terminals to handle marine cargo and to support terminal operations, known collectively as material handling equipment (MHE) in this report or cargo handling equipment. The following subsections present estimated MHE 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 Authority container and cruise terminal tenants have been included in the emission estimates:

- Red Hook Container Terminal at the Brooklyn-Port Authority Marine Terminal
- Red Hook Barge Terminal at Port Newark
- Port Liberty 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
- Port Liberty 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 MHE used at bulk terminals is not included in the MHE inventory, but emissions from CMV calling at bulk terminals are included in Section 5. The following equipment types are included in this inventory:

- Aerial platform
- Crane
- Empty container handler
- Forklift
- Light tower
- Reach stacker
- Rubber Mounted Gantry (RMG) crane
- Rubber Tired Gantry (RTG) crane
- Skid steer loader
- Straddle carrier
- Ship to shore crane
- Sweeper
- Top handler
- Tractor
- Truck (i.e. fuel or water truck)
- Yard tractor

2.1 Emission Estimates

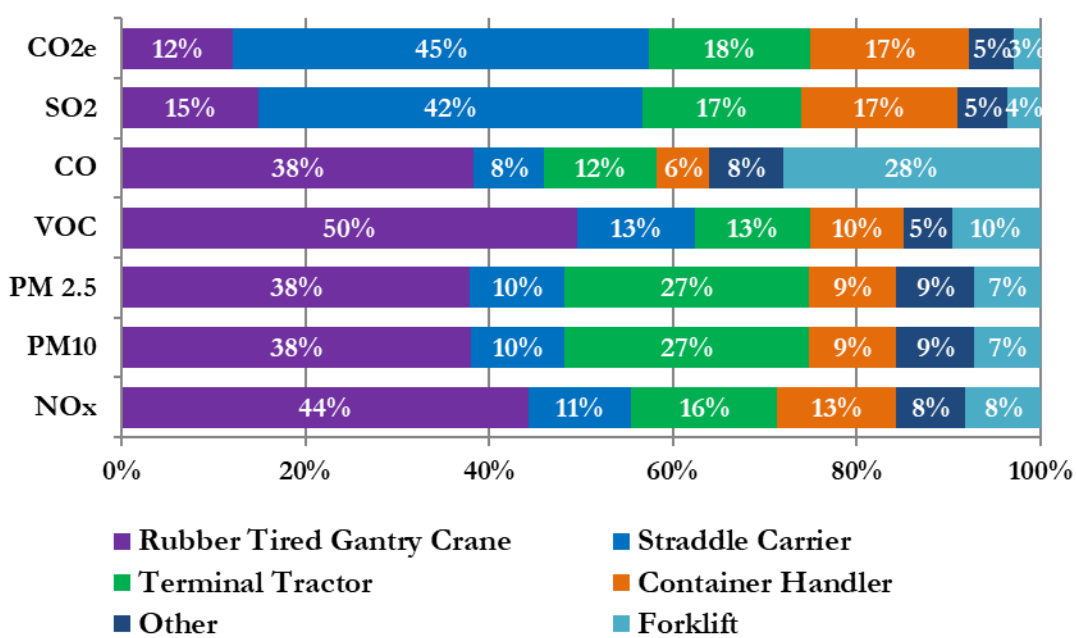
Table 2.1 presents emissions sorted by equipment type for all terminals combined.

Table 2.1: MHE Emissions by Equipment Type, tpy

Equipment Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Terminal Tractor	42	5.2	5.0	2.9	19.9	0.08	26,354
Straddle Carrier	30	2.0	2.0	2.9	12.6	0.18	68,161
Forklift	21	1.4	1.4	2.2	45.7	0.02	4,459
Empty Container Handler	20	1.1	1.1	1.3	5.2	0.03	9,633
Loaded Container Handler	15	0.7	0.7	1.0	4.3	0.05	16,443
Rubber Tired Gantry Crane	117	7.4	7.2	11.4	62.5	0.06	18,273
Reach Stacker	5	0.3	0.3	0.3	1.7	0.01	3,515
Other Equipment	14	1.4	1.4	0.9	11.5	0.01	4,053
Totals	**264**	**20**	**19**	**23**	**163**	**0.43**	**150,890**

Figure 2.1 shows the emissions distribution for various pollutants and types of MHE. Straddle carriers and RTG cranes contribute roughly half of the MHE emissions, respectively followed by terminal tractors, container handlers, and forklifts. Straddle carriers contribute the most to GHG emissions due to the quantity, hours used and engine horsepower. They are relatively new, thus have lower NO_x and PM emissions compared to other equipment type.

Figure 2.1: Distribution of MHE Emissions



2.2 Material Handling Equipment Emission Comparisons

This subsection presents Authority marine terminal MHE emissions by county, comparison to regional emissions and previous years.

2.2.1 Comparisons with County and Regional Emissions

Table 2.2 presents the estimated Port Authority Marine Terminals MHE emissions in the context of overall emissions in the states of New York and New Jersey, and in NYNJLINA based on 2020 NEI, the latest regional emissions as the 2023 NEI won't be available until 2026. The 2022 MHE emissions contribution is included in the table for comparison and to show downward trend in MHE emissions contribution to the region.

Table 2.2: Comparison of PANYNJ Marine Terminals MHE Emissions with State and NYNJLINA, tpy

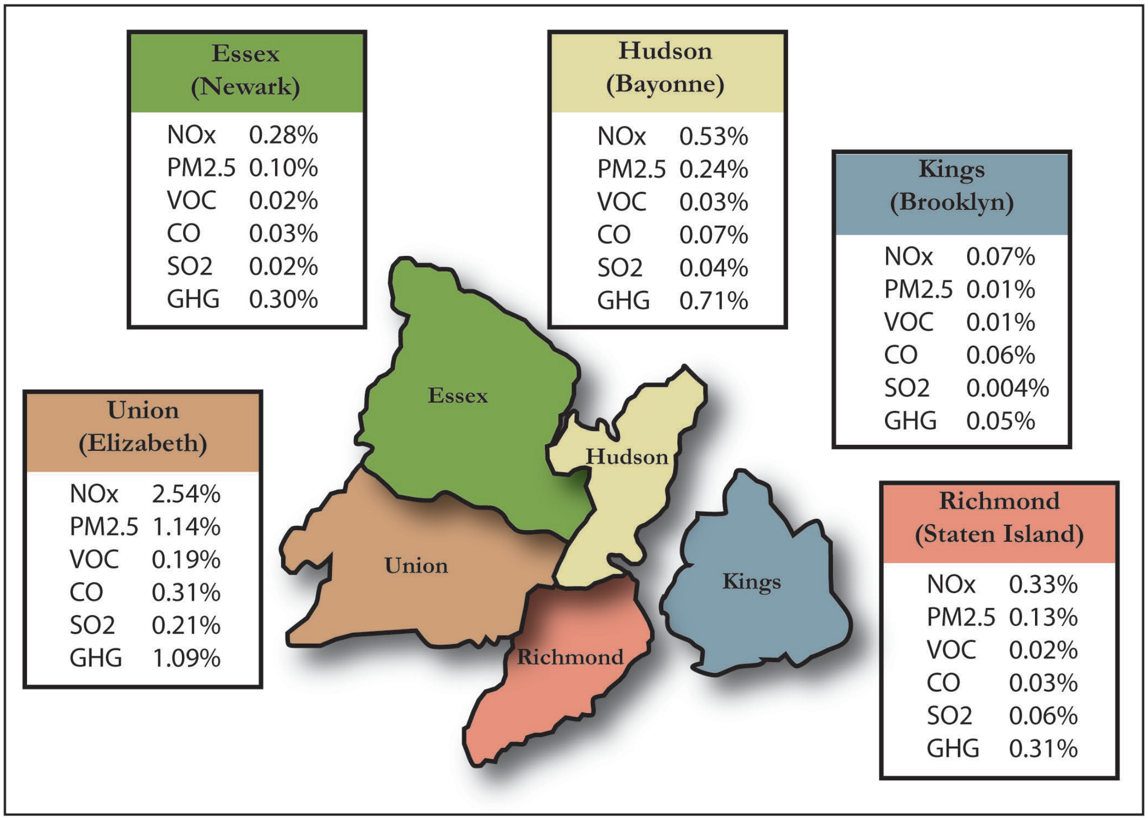
Geographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
NY and NJ	288,737	403,780	130,494	882,141	1,948,186	14,400	178,760,766
NYNJLINA	137,049	95,410	40,985	220,174	838,105	3,327	92,488,145
2023 MHE	264	20	19	23	163	0	150,890
2023 % of NYNJLINA Emissions	**0.19%**	**0.02%**	**0.05%**	**0.01%**	**0.02%**	**0.013%**	**0.16%**
2022 % of NYNJLINA Emissions	**0.26%**	**0.03%**	**0.06%**	**0.01%**	**0.02%**	**0.015%**	**0.19%**

Table 2.3: Summary of MHE 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	24	1	1	2	10	0	18,728
Hudson	NJ	32	2	2	2	14	0	13,710
Middlesex	NJ	0	0	0	0	0	0	0
Monmouth	NJ	0	0	0	0	0	0	0
Union	NJ	187	15	14	17	100	0	109,666
New Jersey subtotal		**243**	**18.3**	**17.7**	**21.0**	**124**	**0.41**	**142,104**
Bronx	NY	0	0	0	0	0	0	0
Kings	NY	8	0	0	1	34	0	2,564
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	13	1	1	1	5	0	6,222
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		**21**	**1.3**	**1.2**	**2.1**	**39**	**0.03**	**8,786**
TOTAL		**264**	**19.5**	**18.9**	**23.1**	**163**	**0.43**	**150,890**

Figure 2.2 illustrates the PANYNJ marine terminals percentage of MHE emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 2.2: PANYNJ Marine Terminals MHE Percent Contribution to Local Air Emissions



2.2.2 Comparisons with Prior Year Emission Estimates

Table 2.4 presents the annual MHE emissions and the percentage difference between 2023, the previous year, and 2006 estimates. In 2023, cargo throughput decreased 18% from the previous year, and emissions decreased 1% to 27% for all pollutants.

Table 2.4: MHE 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
2023	264	20	19	23	163	0.4	150,890
2022	362	27	26	32	166	0.5	171,229
2006	1,503	100	92	132	495	233	154,184
2022-2023, Change (%)	**-27%**	**-27%**	**-27%**	**-27%**	**-1%**	**-13%**	**-12%**
2006-2023, Change (%)	**-82%**	**-80%**	**-79%**	**-83%**	**-67%**	**-100%**	**-2%**

The emissions from MHE were significantly lower in 2023 as compared to 2006 despite the 53% TEU throughput increase. Lower emissions are due to fleet turnover to cleaner, newer equipment including equipment with Tier 4 engines and hybrid technology. GHG emissions (CO_2 equivalents) were 2% lower in 2023 than in 2006 potentially due to an increase in hybrid and electric equipment which consume less diesel fuel as compared to the fuel consumed in the baseline year.

The following figure graphically illustrates the changes in MHE emissions between the 2006 baseline emissions inventory and 2023, with emission trend lines superimposed over the annual M TEU throughput. The percent changes for 2022 and 2023 are included to see the difference between the two years.

Figure 2.3: MHE Emissions Relative to TEU Throughput

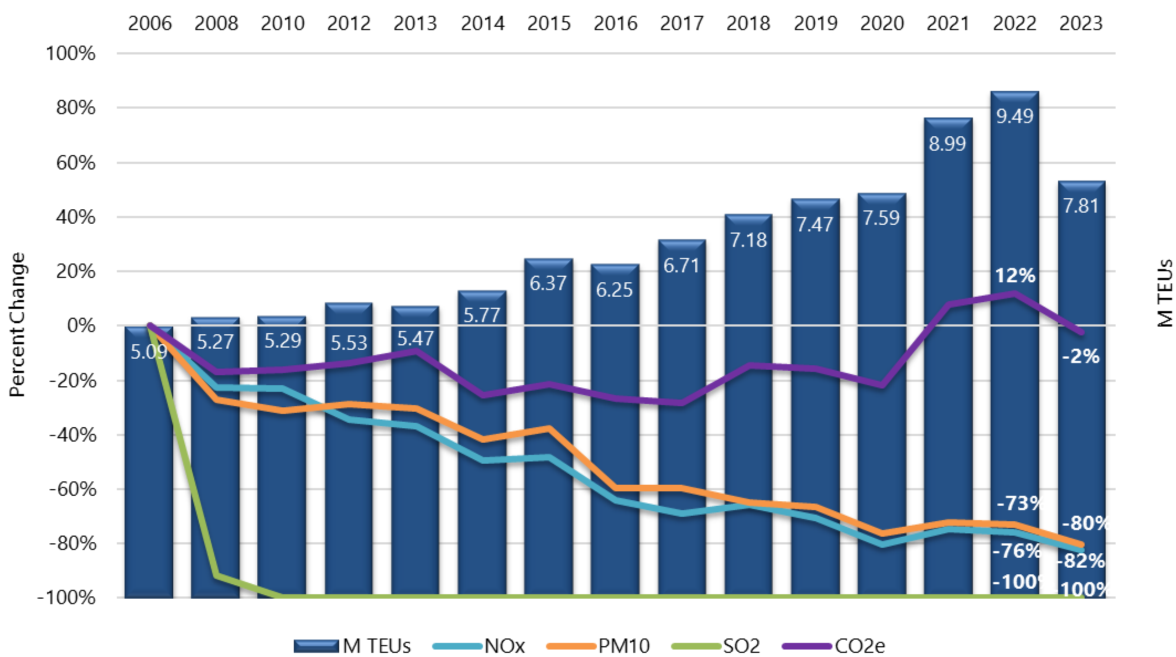


Table 2.5 compares emissions efficiency per M TEUs. The lower the value, the higher the efficiency from an emissions per TEU cargo throughput.

Table 2.5: MHE Emission Efficiency per M TEUs Comparison

Inventory Year	Emissions / M TEUs						
	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
2023	34	3	2	3	21	0.056	19,320
2022	38	3	3	3	17	0.053	18,036
2006	295	20	18	26	97	46	30,274
2022-2023, Change (%)	**-11%**	**-12%**	**-12%**	**-11%**	**20%**	**5%**	**7%**
2006-2023, Change (%)	**-89%**	**-87%**	**-87%**	**-89%**	**-78%**	**-100%**	**-36%**

2.3 MHE Emission Calculation Methodology

This subsection describes the methods used to collect information and estimate emissions from MHE.

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.

2.3.2 Emission Estimating Methodology

The general form of the equation for estimating MHE 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.

Emission factors were developed using the equipment specific emission factors output of EPA's MOVES3 emission estimating model.[14] The MHE identified by survey was categorized into the most closely corresponding MOVES3.0.2 equipment type. Table 2.6 presents equipment types by Source Classification Code (SCC), load factor, and MOVES3.0.2 category name.

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

Table 2.6: 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

Table 2.7 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 (122 in 2023) as it is not used in MOVES to estimate the tail pipe emissions of fossil fueled equipment only.

Table 2.7: MOVES/NONROAD Equipment Category Population List

NONROAD Category	Source Category Code	2006 Count	2022 Count	2023 Count
Aerial lift	2270003010	11	22	25
Crane	2270002045	13	4	6
Diesel forklift	2270003020	0	163	189
Propane forklift	2267003020	87	90	102
Other industrial equipment	2270003040	143	217	221
Other material handling equipment	2270003050	260	457	480
Offroad truck	2270002051	9	13	22
Signal board / light tower	2270002027	12	12	12
Skid-steer loader	2270002072	0	18	18
Sweeper / scrubber	2270003030	2	4	5
Diesel terminal tractor	2270003070	350	435	405
Propane terminal tractor	2267003070	0	0	20
Totals		**887**	**1,435**	**1,505**

For each calendar year, the MOVES3 model was run to output emission factors in grams/hp-hr for each of the MOVES3.0.2 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 MHE 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.

A control factor was applied to equipment identified as being equipped with on-road engines. Ambient temperatures do not significantly affect diesel exhaust emissions; therefore, they were estimated as ranging from approximately 24 to 86 degrees Fahrenheit.

2.4 Description of Material 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 (85%) of equipment is diesel powered, as illustrated in Figure 2.4. The inventory also includes 124 propane powered forklifts and 122 pieces of electric equipment. The electric equipment includes 10 yard tractors, 25 forklifts, 24 RMG cranes, and 63 ship to shore cranes. For 2023, the percentage of diesel equipment is lower than previous year (85% vs 87%) due to increase in electric and propane equipment.

Figure 2.4: Material Handling Equipment Count by Fuel Type

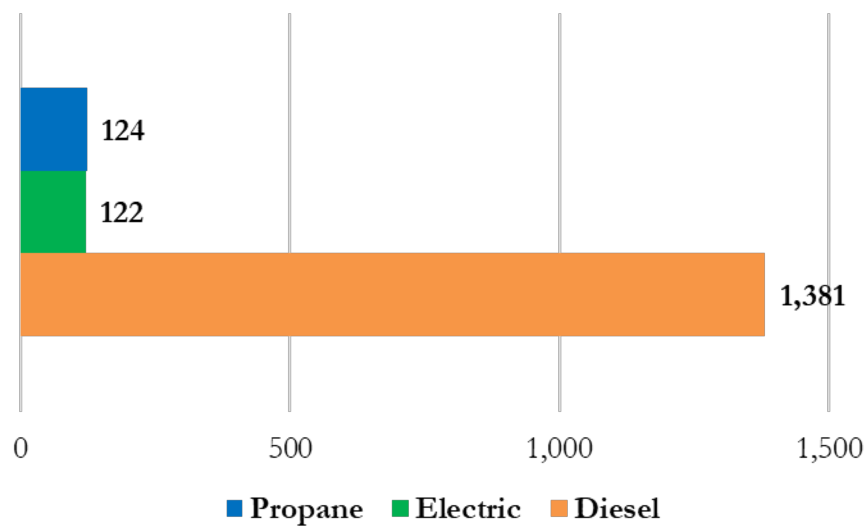


Table 2.8 summarizes the 2023 fleet characteristics of the MHE, including electric equipment, in terms of equipment count, model year, horsepower, and annual operating hours. As noted above, emissions were estimated using equipment-specific values for each piece of equipment. When the model year, horsepower or hours of use was unknown for a specific piece of equipment, the averages shown below were used as defaults.

Table 2.8: Material Handling Equipment Characteristics

	Count	Power (hp)			Model Year			Annual Activity Hours		
Equipment Type		**Min**	**Max**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**
Aerial platform	25	49	200	64	2004	2022	2015	0	500	185
Crane	6	450	810	570	1973	2023	1995	0	1,500	617
Empty Container Handler	88	160	252	213	1995	2023	2015	0	4,880	2,024
Forklift	291	42	388	101	1987	2023	2012	0	5,296	484
Forklift (electric)	25									
Straddle Carrier (hybrid)	2	148	148	148	2021	2021	2021	2,836	2,836	2,836
Light Tower	12	50	50	50	2001	2001	2001	0	640	202
Reach Stacker	42	330	382	349	1999	2023	2013	0	2,605	944
RMG Crane (electric)	24							609	4,825	3,656
RTG Crane	64	450	1,000	591	2001	2022	2006	0	8,187	3,602
Skid Steer Loader	18	38	49	47	2004	2019	2017	0	341	171
Straddle Carrier	414	320	429	365	2010	2023	2018	0	6,177	3,023
STS Crane (electric)	63									
Sweeper	5	24	320	111	2005	2023	2016	0	922	270
Top Handler	91	284	388	358	2004	2023	2016	331	5,382	1,993
Tractor	4	38	38	38	2014	2014	2014	0	0	0
Truck	22	240	450	300	2003	2018	2009	0	2,600	1,329
Yard tractor	421	145	265	175	1999	2023	2016	0	4,835	1,619
Yard Tractor (electric)	10									
Total	**1,627**									

Figure 2.5 illustrates the total population distribution of the MHE by equipment type and separating the electric equipment into its own equipment category.

Figure 2.5: Population Distribution of MHE

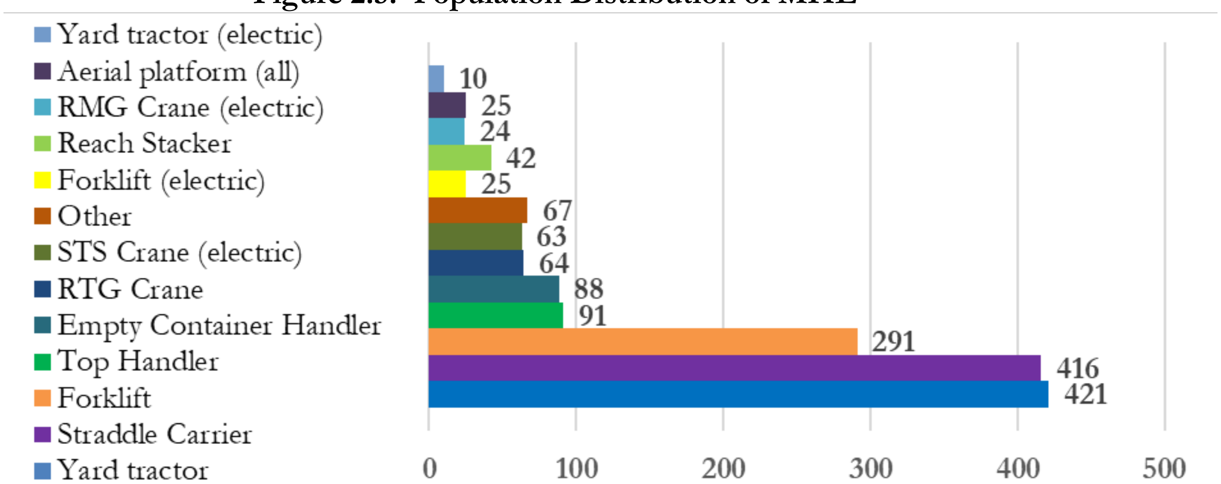


Table 2.9 presents the diesel engines by Tier in the 2023 inventory for 1,381 diesel engines. In 2023, equipment turnover to Tier 4 engines continued. The previous year's percentages were included for comparison. The table includes diesel equipment count only and does not match the overall equipment count since electric and propane equipment is not included in the diesel tier count table. The unknown column is for equipment with unknown horsepower and/or engine model year that determines the engine Tier level. Figure 2.6 shows the engine Tier distribution from 2016 to present showing the increase in Tier 4f engines over time.

Table 2.9: MHE Diesel Equipment Tier Count

Equipment Type	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4i	Tier 4f	Unknown	Total
Empty Container Handler	1	0	1	20	15	51	0	88
Forklift	10	24	18	6	69	62	0	189
Loaded Container Handler	0	0	2	14	7	68	0	91
Reach Stacker	0	4	9	4	4	21	0	42
RTG Crane	0	7	30	18	3	6	0	64
Straddle Carrier	0	0	0	7	40	369	0	416
Terminal Tractor	0	6	15	48	41	271	24	405
Other	4	12	11	14	4	39	2	86
2023 Total	**15**	**53**	**86**	**131**	**183**	**887**	**26**	**1,381**
2023 Percent	**1%**	**4%**	**6%**	**9%**	**13%**	**64%**	**1.9%**	
2022 Percent	1%	3%	6%	13%	13%	62%	1.3%	

Figure 2.6: MHE Diesel Engine Tier Count Distribution by Calendar Year

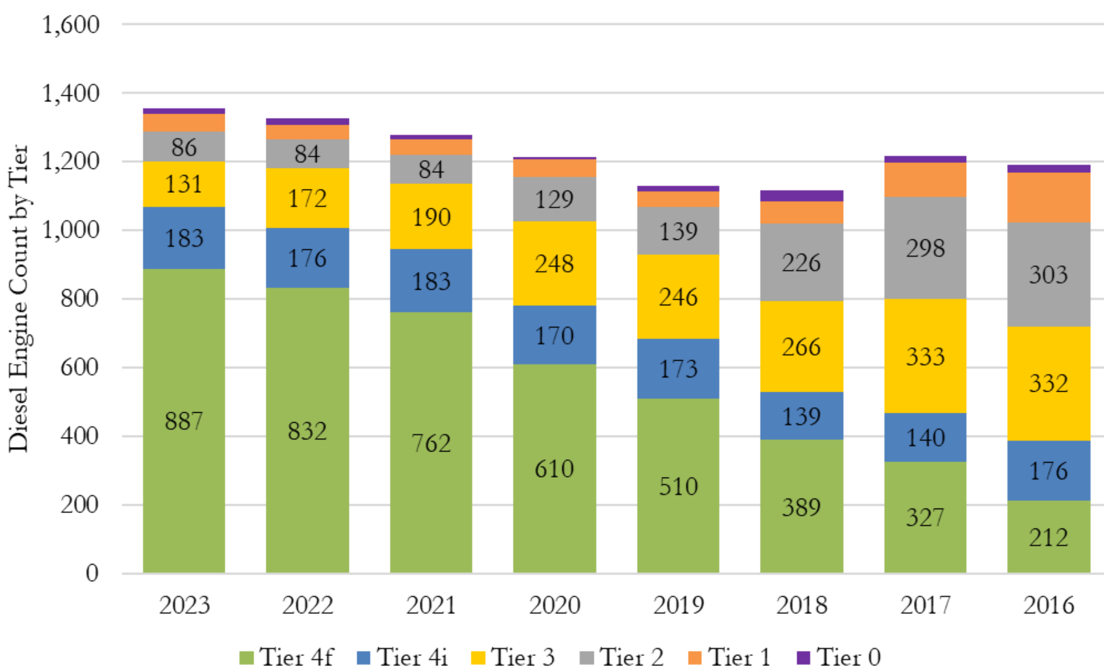


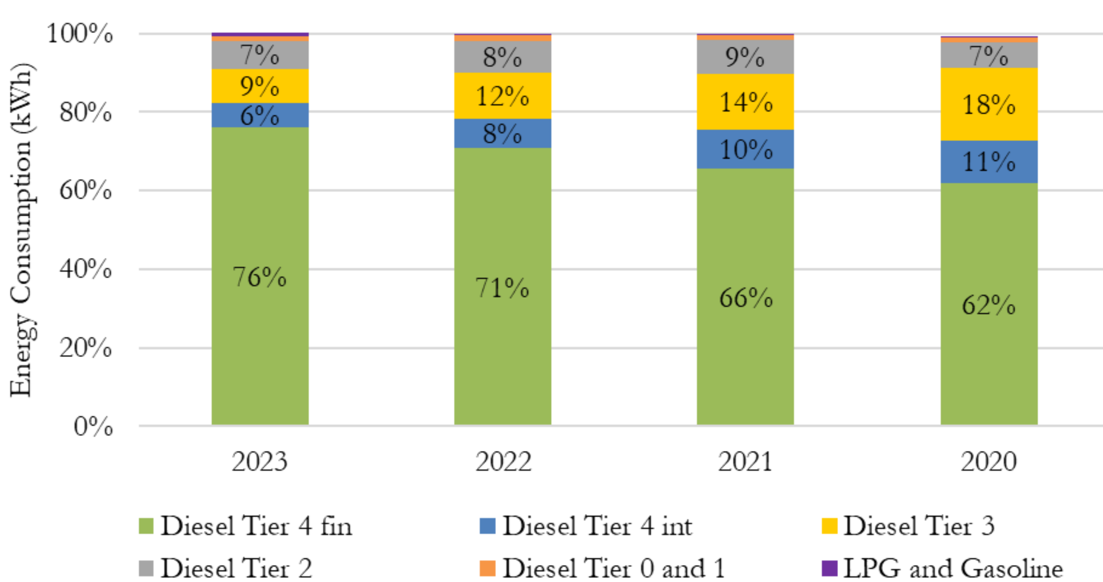
Table 2.10 shows the 2023 MHE energy consumption for propane and diesel equipment by Tier level. About 91% of total equipment energy usage in terms of kWh is from diesel Tier 3 and Tier 4 equipment. The newer pieces of equipment are being used more, especially Tier 4 equipment, and produce lower emissions.

Table 2.10: MHE Energy Consumption

Engine Type and Tier	Energy Consumption kWh	Percent Total 2023	Percent Total 2022
Gasoline	344,400	0.2%	0.0%
Propane	1,497,810	0.9%	0.2%
Diesel Tier 0	208,408	0.1%	0.6%
Diesel Tier 1	1,203,131	0.7%	1.2%
Diesel Tier 2	12,559,540	7%	8%
Diesel Tier 3	15,096,196	9%	12%
Diesel Tier 4 int	10,570,461	6%	8%
Diesel Tier 4 fin	131,908,504	76%	71%
Total	**173,388,450**	**100%**	

Figure 2.7 shows the comparison in energy consumption (kWh) distribution since 2020 when data became readily available. The transition to Tier 4 final is more pronounced in 2022 as the equipment of choice to move cargo is the newer, cleaner Tier 4 MHE as compared to Tier 3 and older equipment. The increased usage, not just count of cleaner, newer MHE has resulted in lower NO_x and PM emissions despite the increased activity.

Figure 2.7: MHE Energy Consumption Distribution



The following Figures 2.8 through 2.12 show examples of the most common types of MHE: terminal tractor, straddle carrier, loaded container handler, empty container handler, and forklift.

Figure 2.8: Example Terminal Tractor

Figure 2.9: Example Straddle Carrier

Figure 2.10: Example Loaded Container Handler

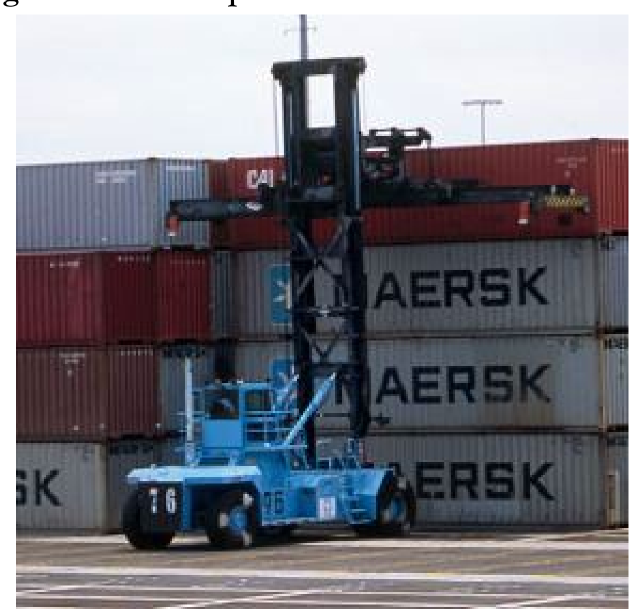


Figure 2.11: Example Empty Container Handler

Figure 2.12: Example Forklift

SECTION 3: HEAVY-DUTY VEHICLES

This section presents estimated emissions from HDVs that visit the container terminals, warehouses, and automobile handling facilities within the 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 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 vehicle types.

3.1 Heavy-Duty Vehicle Emission Estimates

Emissions have been estimated for HDVs traveling within the marine terminals associated with the 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 both driving emissions and idling emissions from trucks waiting to enter the terminal to pick up or drop off cargo. 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 lates EPA on-road emissions model MOVES4 emission estimating model. 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	78	2.4	2.2	3.9	37	0.06	17,845
On-Terminal Idling	146	5	5	11	57	0.07	22,315
On-Road Driving	1,047	32	29	58	454	1.07	323,829
Totals	**1,271**	**39**	**36**	**72**	**548**	**1.20**	**363,988**

A portion of the emissions presented above originate from trucks owned by Authority tenants. The remaining emissions are from trucks that are owned by companies that are not directly associated with the Authority. Trucks owned by tenants of the Authority made up approximately 3% of all trucks that are tagged to enter Authority-leased (tenant) facilities. The remaining trucks that service Authority tenant facilities are owned or managed by companies that are not associated with the Authority. The emissions attributed to trucks owned or managed by tenant and non-tenant companies is presented in Table 3.2. Emissions have been allocated between tenants and non-tenants using 3% tenant truck percentage, assuming all trucks tagged to enter Authority facilities operate an equivalent number of miles in accomplishing their business.

Table 3.2 shows that most HDV emissions associated with the Authority arise from trucks owned or managed by companies that are not associated with the Authority.

Table 3.2: HDV Emissions from Tenant and Non-Tenant Trucks, tpy

Truck Owner Status	Percent of Tags	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Tenant trucks	3%	38	1.2	1.1	2.2	16	0.04	10,822
Non-tenant trucks	97%	1,234	38	35	70	532	1.17	353,166
All Trucks	**100%**	**1,271**	**39**	**36**	**72**	**548**	**1.20**	**363,988**

3.1.1 On-Terminal Emissions

Summaries of HDV driving and idling emissions by state and mode are presented in Table 3.3.

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

Activity Component	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
New Jersey							
On-Terminal Driving	77	2.4	2.2	3.8	37	0.06	17,690
On-Terminal Idling	140	5	5	11	55	0.07	21,349
New Jersey subtotal	**217**	**7**	**7**	**14**	**91**	**0.13**	**39,038**
New York							
On-Terminal Driving	0.7	0.02	0.02	0.03	0.3	0.001	155
On-Terminal Idling	6	0.2	0.2	0.5	2.4	0.00	966
New York subtotal	**7**	**0.3**	**0.2**	**0.5**	**2.7**	**0.00**	**1,121**
Total NJ & NY	**224**	**8**	**7**	**15**	**94**	**0.13**	**40,159**

3.1.2 On-Road Emissions

Table 3.4 presents estimates of on-road emissions in tons per year by state from container terminal trucks.

Table 3.4: 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	144,403,288	941	28.4	26.2	51.7	408	0.96	290,888
New York	16,352,486	107	3.2	3.0	5.9	46	0.11	32,941
Total	**160,755,774**	**1,047**	**31.7**	**29.1**	**57.5**	**454**	**1.07**	**323,829**

3.2 HDV Emission Comparisons by County and Region

In this section, Authority marine terminal-related truck emissions are compared with all emissions in the NYNJLINA on a county-by-county basis. This section also presents a comparison of 2023 HDV emission estimates with the results of the previous year (2022) and baseline (2006) emissions inventories.

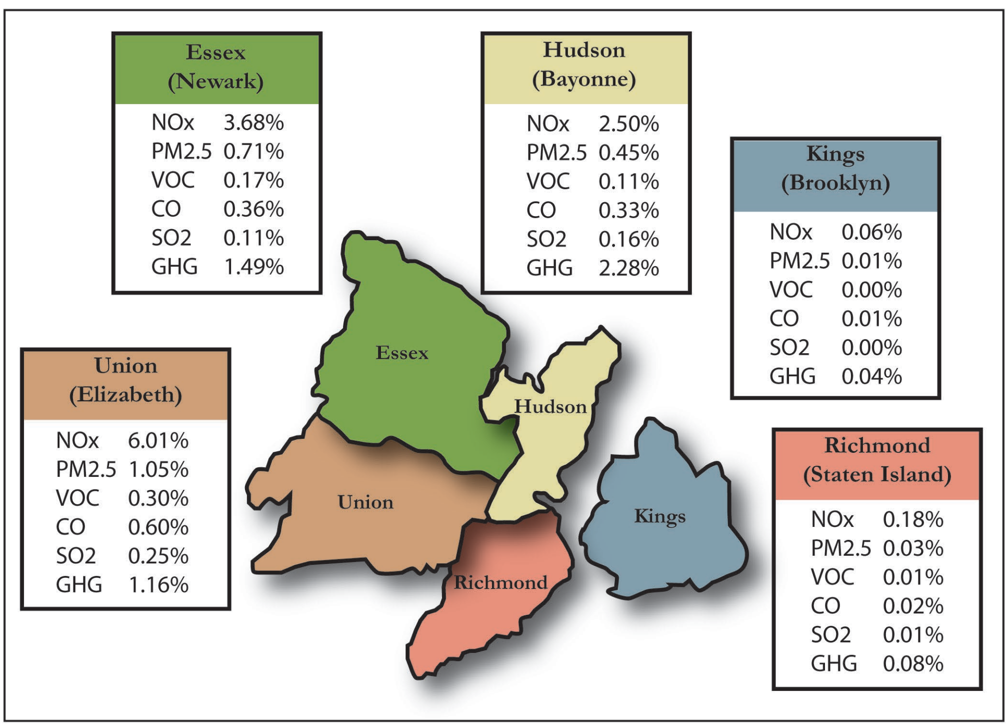
3.2.1 Comparisons with County and Regional Emissions

Overall county-level emissions were excerpted from the most recent 2020 NEI[15]. Table 3.5 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 provides the percentage that Port Authority Marine HDV emissions make up of overall NYNJLINA emissions. The percentage of Port Marine HDV emissions are lower in 2023.

Table 3.5: 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
NY and NJ	288,737	403,780	130,494	882,141	1,948,186	14,400	178,760,766
NYNJLINA	137,049	95,410	40,985	220,174	838,105	3,327	92,488,145
HDV	1,271	39	36	72	548	1	363,988
2023 % of NYNJLINA Emissions	**0.93%**	**0.04%**	**0.09%**	**0.03%**	**0.07%**	**0.04%**	**0.39%**
2022 % of NYNJLINA Emissions	1.16%	0.06%	0.12%	0.04%	0.08%	0.04%	0.46%

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



[15] Accessed at: *https://www.epa.gov/air-emissions-inventories/get-air-emissions-data-0*

Table 3.6 summarizes estimated criteria pollutant emissions from the Authority marine terminal HDV related activities reported in this current inventory, at the county level.

Table 3.6: Summary of Heavy-duty Vehicle Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	76	2	2	4	33	0.08	23,430
Essex	NJ	315	10	9	18	137	0.31	92,760
Hudson	NJ	150	5	4	8	65	0.14	43,872
Middlesex	NJ	174	5	5	10	75	0.18	53,680
Monmouth	NJ	1	0	0	0	0	0.00	228
Union	NJ	442	14	13	26	189	0.38	115,956
New Jersey subtotal		**1,158**	**36**	**33**	**66**	**499**	**1.09**	**329,926**
Bronx	NY	9	0	0	1	4	0.01	2,898
Kings	NY	7	0	0	0	3	0.01	1,791
Nassau	NY	3	0	0	0	1	0.00	1,066
New York	NY	1	0	0	0	1	0.00	445
Orange	NY	50	2	1	3	22	0.05	15,565
Queens	NY	6	0	0	0	3	0.01	1,884
Richmond	NY	7	0	0	0	3	0.01	1,524
Rockland	NY	18	1	1	1	8	0.02	5,464
Suffolk	NY	4	0	0	0	2	0.00	1,087
Westchester	NY	8	0	0	0	3	0.01	2,339
New York subtotal		**113**	**3**	**3**	**6**	**49**	**0.11**	**34,062**
Total		**1,271**	**39**	**36**	**72**	**548**	**1.20**	**363,988**

3.2.2 Comparisons with Prior Year Emission Estimates

Table 3.7 presents annual HDV emissions in 2023, the previous year, and 2006. The effects of the progressively newer fleet, documented since 2008 and discussed later in this section, show up in the significant decreases of NO_x and PM emissions since 2006. The continued renewal of the drayage truck fleet results in newer, lower-emitting trucks which replaced older, higher-emitting trucks, in part resulting from the Authority's Truck Replacement Program. Trucks newer than model year 2007 emit substantially less PM than older model year trucks, and trucks newer than model year 2010 emit substantially less NO_x. The CO_2e emissions increase is in line with the TEU throughput changes as the newer diesel engines do not reduce greenhouse gases since GHG emissions are affected by amount of fuel consumed.

Table 3.7: 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	Throughput M TEUs
2023	1,271	39	36	72	548	1.2	363,988	7.81
2022	1,592	54	50	85	671	1.5	425,950	9.49
2006	2,911	154	141	139	951	10	224,050	5.09
2022-2023, Change (%)	**-20%**	**-28%**	**-27%**	**-16%**	**-18.3%**	**-19%**	**-15%**	**-18%**
2006-2023, Change (%)	**-56%**	**-75%**	**-75%**	**-48%**	**-42%**	**-88%**	**62%**	**53%**

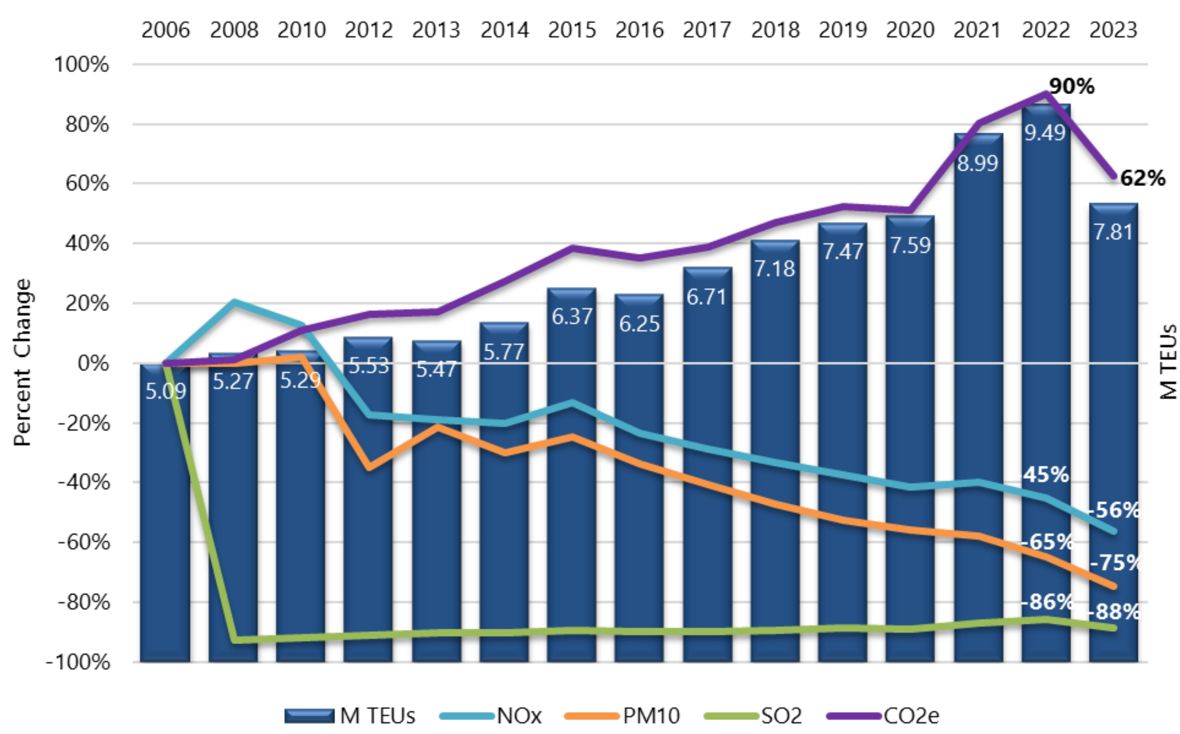
Table 3.8 compares emissions per M TEUs. A negative number is an improvement in efficiency as less emissions are emitted per million TEU cargo throughput.

Table 3.8: HDV Emission per M TEUs Comparison

	Emissions / M TEUs						
Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
2023	163	5	5	9	70	0.15	46,605
2022	168	6	5	9	71	0.16	44,867
2006	572	30	28	27	187	2.05	43,992
2022-2023, Change (%)	**-3%**	**-12%**	**-12%**	**2%**	**-1%**	**-1%**	**4%**
2006-2023, Change (%)	**-72%**	**-83%**	**-83%**	**-66%**	**-62%**	**-92%**	**6%**

The following figure graphically illustrates the changes in NO_x, PM_{10}, SO_2, and CO_2e emissions from HDVs between the 2006 baseline emissions inventory and the latest update (2023), with emission trend lines superimposed over the annual M TEU throughput.

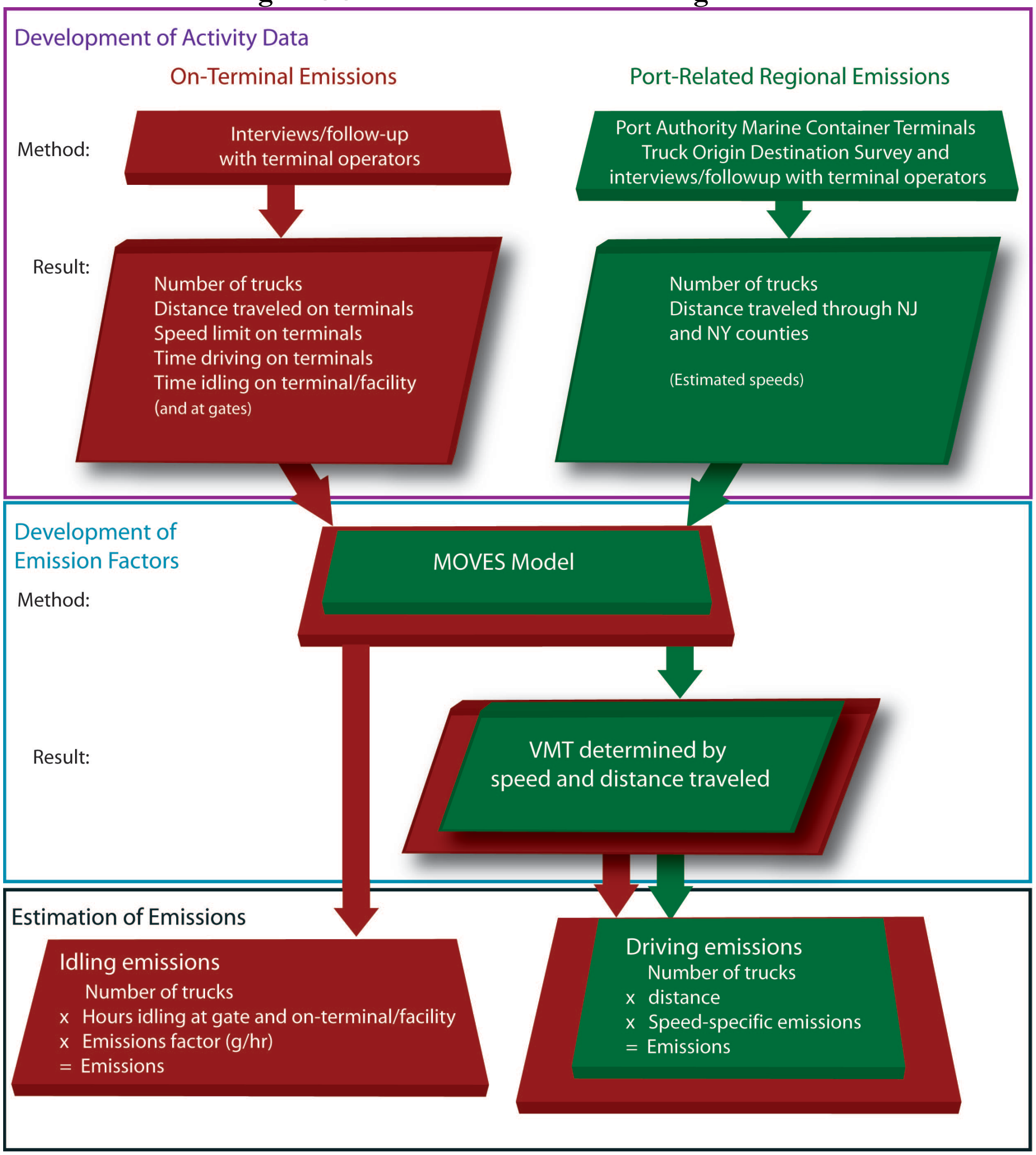
Figure 3.2: HDV Emissions Relative to M TEU Throughput



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 PortTruckPass (PTP) system[16], 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 Authority container terminals leased to private operators, are listed in Table 3.9.

Table 3.9: Reported Container Terminal Operating Characteristics

Terminal	Number Truck Calls (annual)	Total Distance (miles)	Total Idle Time (hours)
Container A	2,151,512	3,227,269	1,000,453
Container B	1,352,764	1,352,764	723,729
Container C	783,342	1,253,347	305,503
Container D	612,756	612,756	202,209
Container E	153,583	15,358	69,880
Container F	83,488	41,744	36,735

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 above table.

[16] *https://www.porttruckpass.com/*

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 HDV emissions 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[17] in 2017. Starting with the 2017 emissions inventory, these survey results replaced the previous O&D information used for the past several emissions inventories.

Model Year Distribution

Model year is an important characteristic of HDV because emission standards are applicable on a model year basis. Since newer trucks are subject to stricter (lower) emission standards for certain pollutants 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 Authority marine terminals have implemented gate systems that make use of radio frequency identification (RFID) technology to identify and record HDV 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.

Figures 3.4 through 3.6 illustrate the changes in model year distributions of the trucks serving the Authority terminals in calendar years 2008, 2010, and annually 2012 through 2023. 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 NO_x requirements in addition to maintaining the particulate standards.

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[17] 2017 Origin & Destination Study. Hatch, draft report 2017.

Figure 3.4 shows the increase of newer model year trucks and the reduction of older trucks from among the vehicles calling at the terminals. In 2023, 76% of the trucks that called the Port have the cleanest engines available, model year 2010 and newer. 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

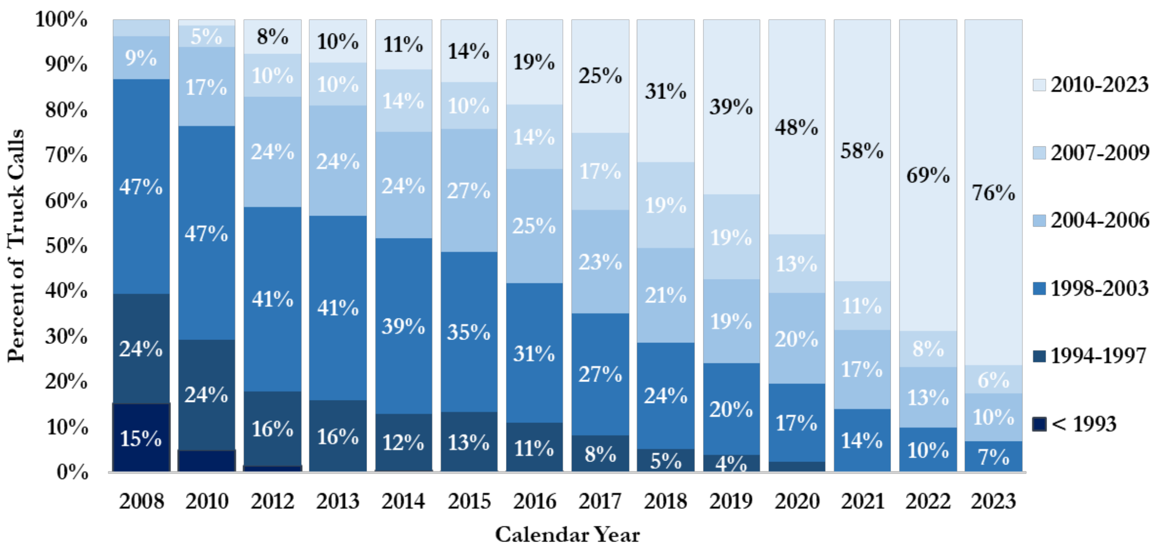
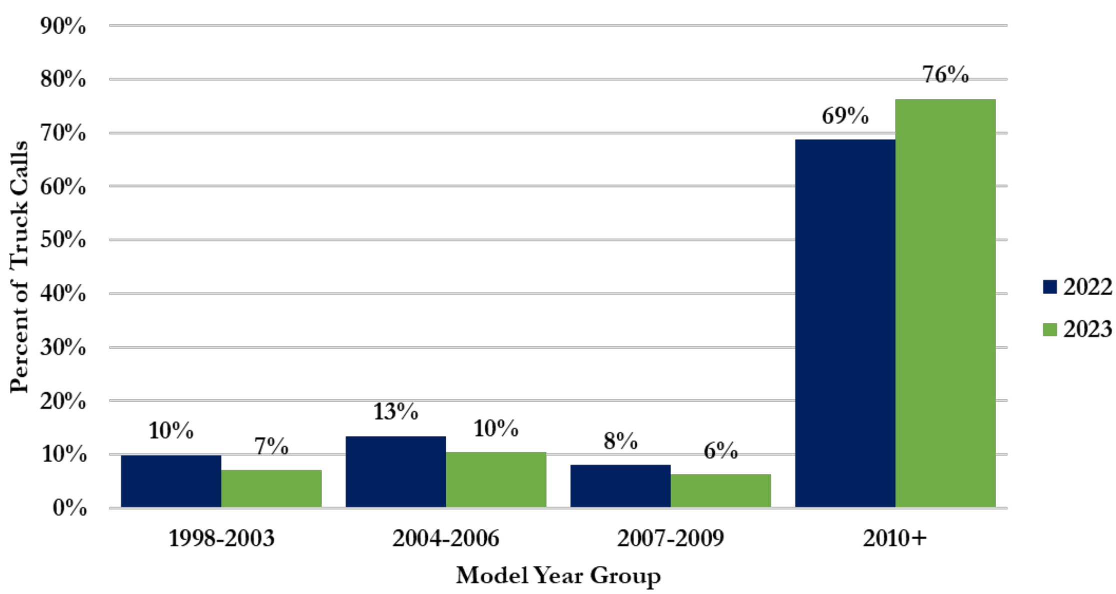


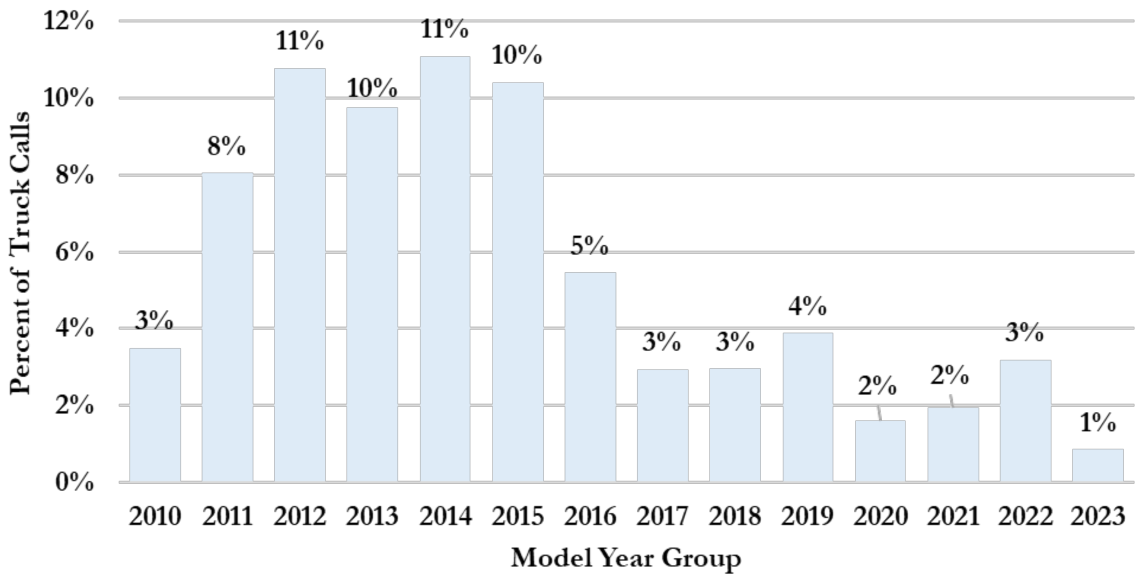
Figure 3.5 illustrates the model year distribution of HDV during 2023 as compared to the prior year in more detail. This figure shows that the 2023 distribution of HDV continues to add new trucks while the older model years are taken out of service. The transition to cleaner trucks is evident year over year and thus, the emissions continue to be lower for the HDV that call the Port as compared to prior years.

Figure 3.5: 2023 and 2022 Distribution of Model Year Groups



Providing yet more detail, Figure 3.6 breaks out the 2023 distribution of the newest model year group, those that are in the lowest and cleanest emissions group subject to the 2010+ emission standards. This figure shows that the predominant model years were 2012 through 2015, with newer model year trucks (2016 – 2023) making up 23% of this cleanest group.

Figure 3.6: 2023 Distribution of 2010+ Model Years



3.3.2 Emission Estimating Methodology

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

$$\boldsymbol{E = EF \times Act}$$

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 MOVES4, 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 selected by the user. MOVES4 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 and combination long-haul trucks of each model year. Combination short-haul truck is the vehicle type in MOVES4 most closely associated with the trucks serving the container terminals, defined in the model as combination tractor/trailer trucks with more than four tires with a range of operation up to 200 miles. Combination long-haul truck is the vehicle associated with the trucks serving the auto terminals, defined in the model as double/triple semitrailers, with six or more axes and range of operation beyond 200 miles. The emission factors developed by model year were used to develop composite emission factors that reflect the actual vehicle age distribution for trucks used at the Authority marine terminals.

The road types in MOVES4 most closely associated with port HDV 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 MOVES4 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 short-term idling of trucks in normal operation on the container terminals, and the extended idling by automobile transport trucks to load vehicles at the auto terminals. MOVES4 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 MOVES4 model run are specified in a dataset known as a "runspec" that is produced during the setup of the model run.

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, where the other numbers are to represent the final emissions in tons/year):

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

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 MOVES4-derived driving and idling emission factors for the 2023 EI model year distribution of combination short-haul and long-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 MOVES4 highway/local average speeds.

Table 3.10: 2023 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)	53.234	2.002	1.842	3.948	20.377	0.027	7,988	0.845	0.349
Extended Idle (g/hr)	72.174	0.915	0.842	7.837	43.908	0.027	7,935	0.000	0.871
On-Terminal (g/mi)	10.779	0.329	0.303	0.533	5.130	0.008	2,394	0.245	0.058
On-Road (g/mi)	5.911	0.179	0.164	0.325	2.563	0.006	1,780	0.174	0.027

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 HDV 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[18] 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	➢ Best Transportation, Inc. ➢ East Coast Warehouse ➢ Eastern Warehouse ➢ International Motor Freight ➢ Harbor Freight ➢ MTC Transportation ➢ Mecca & Sons Trucking ➢ Accem Warehouse ➢ Courier Systems ➢ DiPinto ➢ TEV Trucking ➢ TRT International

[18] *https://www.panynj.gov/port/en/publications.html*

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.

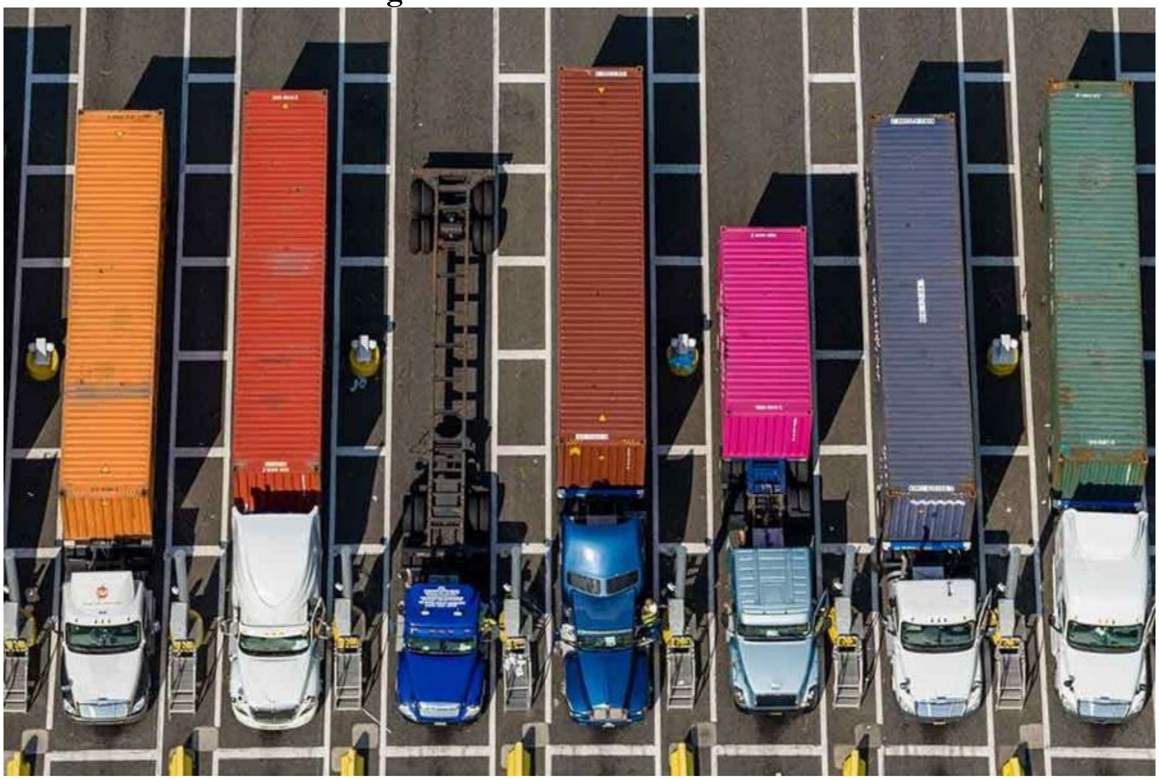
The "first point of rest" is the location at which import cargo (received from ships) is transferred from the first means of transport out of the arrival terminal to the ground or to another mode of transportation (such as truck-to-rail transfer). This occurs, for example, at the warehouse facilities 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 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 gross vehicle weight rating (GVWR). The emission estimates developed by the current regulatory model MOVES 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 3.7 is an illustration of container trucks at a Port Authority marine terminal.

Figure 3.7: HDV with Container



SECTION 4: LOCOMOTIVES

This section presents estimated emissions from the locomotives that visit and serve the Authority's marine container terminals and discusses the methodologies used in developing the estimates. Locomotive activity from two general categories, line haul and switching, was considered in developing the emission estimates. Line haul activity refers to the movement of import and export cargo within the NYNJLINA boundary that originates or culminates at the Authority marine terminals. Switching locomotive activity includes activity related to movement of cargo within the boundaries of the following Authority marine terminals:

- Port Newark
- Elizabeth - Port Authority Marine Terminal
- Port Jersey - Port Authority Marine Terminal
- Howland Hook 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. Also, the Authority-owned New York New Jersey Rail, LLC (NYNJR) operates a cross-harbor car float service that uses switching locomotives to move rail cars off and onto a barge with rail track on its deck 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.

4.1 Locomotive Emission Estimates

This subsection presents the estimated emissions from line haul and switching activities associated with the Authority marine terminals. Table 4.1 summarizes the line haul and switching emissions. The relationships between these emissions and overall county and state emissions are presented and discussed in subsection 4.2.

Table 4.1: Locomotive Emission Estimates, tpy

Locomotive Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
				tons per year			
Line Haul	95	2.1	1.9	3.4	30.0	0.1	11,564
Switching	190	8.0	7.5	20.1	35.4	0.2	13,125
Totals	**284**	**10.1**	**9.4**	**23**	**65**	**0.3**	**24,689**

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 2023 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.[19]

Table 4.2: Comparison of PANYNJ Marine Terminals Locomotive Emissions with State and NYNJLINA Emissions, tpy

ographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
NY and NJ	288,737	403,780	130,494	882,141	1,948,186	14,400	178,760,766
NYNJLINA	137,049	95,410	40,985	220,174	838,105	3,327	92,488,145
Locomotives	284	10	9	23	65	0.3	24,689
2023 % of NYNJLINA Emissions	**0.21%**	**0.01%**	**0.02%**	**0.01%**	**0.01%**	**0.01%**	**0.03%**
2022 % of NYNJLINA Emissions	0.24%	0.01%	0.03%	0.01%	0.01%	0.01%	0.03%

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.[20] 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.

[19] 2020 National Emission Inventory Databases, US EPA, as cited above.

[20] Accessed at*: https://www.epa.gov/air-emissions-inventories/get-air-emissions-data-0*

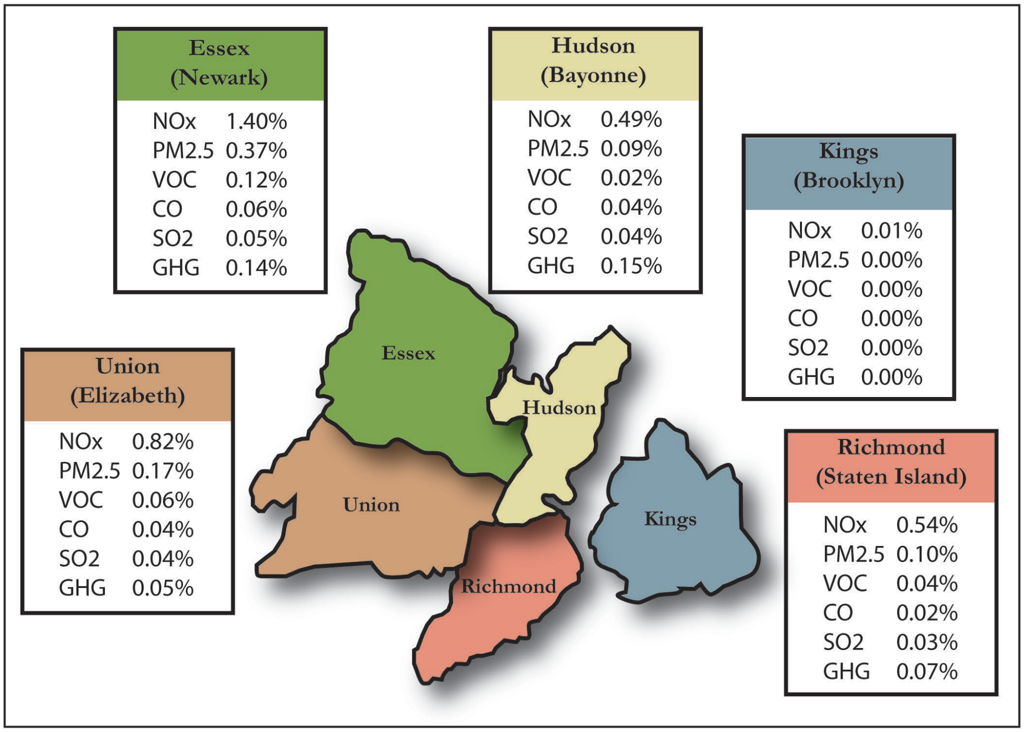
Table 4.3 presents estimated criteria pollutant emissions from the Authority marine terminal-related locomotive activity reported in this current inventory, at the county level.

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	18	0.4	0.4	0.6	5.7	0.02	2,184
Essex	NJ	120	5.0	4.7	12.2	23.4	0.13	8,715
Hudson	NJ	29	0.9	0.8	1.9	7.7	0.03	2,956
Middlesex	NJ	6	0.1	0.1	0.2	1.8	0.01	711
Monmouth	NJ	0	0.0	0.0	0.0	0.0	0.00	0
Union	NJ	61	2.3	2.1	5.3	13.5	0.07	5,086
New Jersey subtotal		**233**	**8.7**	**8.0**	**20.2**	**52.1**	**0.26**	**19,653**
Bronx	NY	0	0.0	0.0	0.0	0.0	0.00	0
Kings	NY	1	0.0	0.0	0.0	0.4	0.00	148
Nassau	NY	0	0.0	0.0	0.0	0.0	0.00	0
New York	NY	0	0.0	0.0	0.0	0.0	0.00	0
Orange	NY	0	0.0	0.0	0.0	0.0	0.00	0
Queens	NY	0	0.0	0.0	0.0	0.0	0.00	0
Richmond	NY	21	0.8	0.8	2.2	3.8	0.02	1,392
Rockland	NY	29	0.6	0.6	1.0	9.1	0.03	3,497
Suffolk	NY	0	0.0	0.0	0.0	0.0	0.00	0
Westchester	NY	0	0.0	0.0	0.0	0.0	0.00	0
New York subtotal		**51**	**1.5**	**1.4**	**3.2**	**13.3**	**0.05**	**5,037**
Total		**284**	**10.1**	**9.4**	**23.4**	**65.4**	**0.32**	**24,689**

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

Emissions are lower in 2023 as compared to 2022 due less on-dock lifts in 2023. Between 2006 and 2023, the locomotive emissions increased for VOC, CO and CO_2e, but at a lower rate than the increase in cargo moved by rail into and out of the Port. The on-dock rail throughput increased by 86% between 2006 and 2023 but the increases in CO and CO_2 were 49% and 68%, respectively, likely due to incremental efficiency improvements implemented by the railroads and the Authority. The pollutants NO_x, PM and SO_2 emissions are lower in 2023 as compared to 2006 mainly due to the use of lower sulfur fuel.

Table 4.4 presents the 2023 locomotive emissions, along with the 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
2023	284	10	9	23	65	0.32	24,689	629,193
2022	324	12	11	25	73	0.30	27,616	706,774
2006	286	10	9	20	44	32	14,710	338,884
2022-2023, Change (%)	**-12%**	**-12%**	**-12%**	**-6%**	**-10%**	**6%**	**-11%**	**-11%**
2006-2023, Change (%)	**-1%**	**-1%**	**0%**	**17%**	**49%**	**-99%**	**68%**	**86%**

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 2023 update, with emission trend lines superimposed over the annual on-dock lift throughput (in thousands of lifts). The NO_x and PM_{10} emission changes track closely together and may be hard to distinguish from one another in the figure. The NO_x and PM_{10} emissions are 1% lower in 2023 than in 2006.

Figure 4.2: Locomotive Emissions Relative to On-dock Lifts

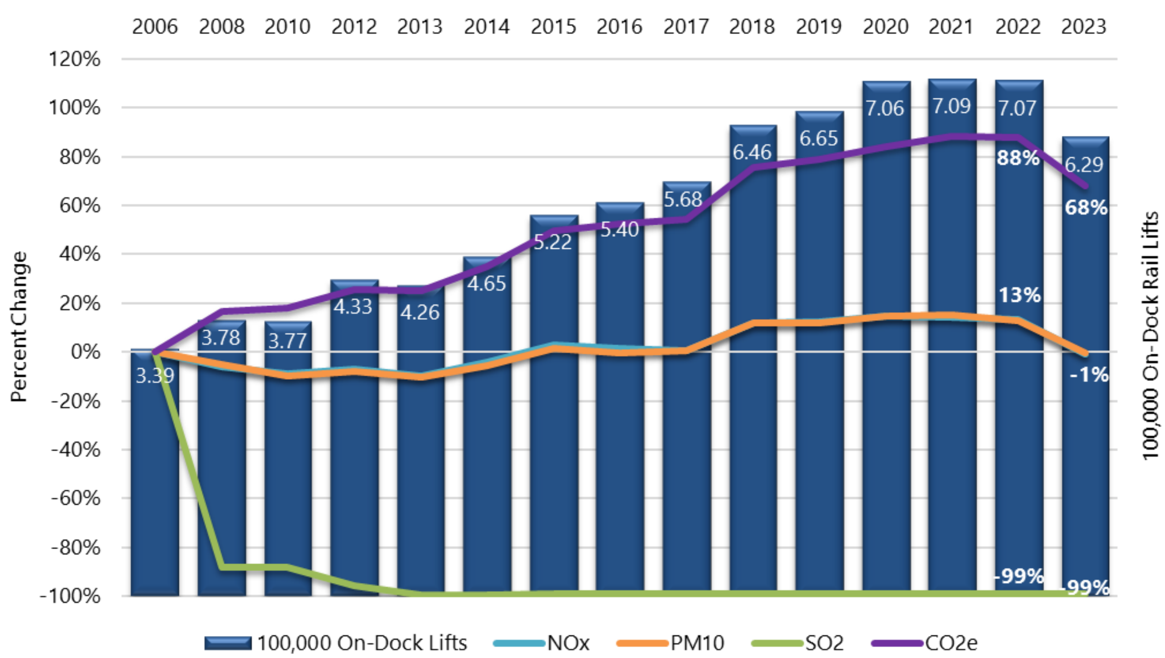


Table 4.5 compares emissions per 100,000 lifts which is a better metric for locomotives. A lower emissions per 100,000 lifts means it is more efficient; thus, the negative percent change is moving in the right direction.

Table 4.5: Locomotive Emission per 100,000 Lifts Comparison

	Emissions / 100,000 Lifts						
Inventory Year	**NO_x**	**PM_{10}**	**$PM_{2.5}$**	**VOC**	**CO**	**SO_2**	**CO_2e**
2023	45.2	1.6	1.5	3.7	10.4	0.05	3,924
2022	45.8	1.6	1.5	3.5	10.3	0.04	3,907
2006	84.4	3.0	2.8	5.9	13.0	9.44	4,341
2022-2023, Change (%)	**-2%**	**-1%**	**-1%**	**5%**	**1%**	**19%**	**0.4%**
2006-2023, Change (%)	**-46%**	**-46%**	**-46%**	**-37%**	**-20%**	**-99%**	**-10%**

4.3 Locomotive Emission Calculation Methodology

There is no regulatory model available for estimating locomotive emissions, such as the MOVES4 model used for MHE 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 Authority's marine terminals via rail,[21] 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 estimated amount of fuel used in the transport of cargo to and from the Authority marine terminals, which has been estimated using several parameters including the number of train trips, estimated train weights, and distance. Step one in this process estimates the number and average lengths and container capacities of trains used to transport this cargo. Step two estimates the average weight of each of these trains (gross tons, the weight of cargo and rail cars); 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 gallon of fuel (g/gal). The process is explained in detail below.

[21] Information provided by PANYNJ by email.

The emission factors for most pollutants (NO_x, PM, VOCs, CO) come from an EPA publication[22] issued in support of locomotive rulemaking. The emission factors are published for each engine tier level and also, with the exception of CO, 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 2022 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 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 2023. The emission factors for N_2O and CH_4 were obtained from an EPA publication on greenhouse gases.[23]

The emission factors for line haul locomotives are presented in Table 4.6. The published g/gal emission factors for 2023 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 4.6: 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	84	1.9	1.7	3.0	26.7	0.10	10,186	0.25	0.79
g/hp-hr	4.0	0.09	0.08	0.14	1.28	0.005	489	0.012	0.038

The starting point of the calculations is the average length and schedule of trains servicing each marine terminal, as reported in the 2005 Authority rail utilization study.[24] Each of the two railroads serving the marine terminals operates one inbound and two outbound trains 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 the additional outbound train. The estimating 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.

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

[23] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2022; April 2024; Table A- 86: Emission Factors for N_2O Emissions from Non-Highway Mobile Combustion (g gas/kg fuel) and Table A- 87: Emission Factors for CH_4 Emissions from Non-Highway Mobile Combustion (g gas/kg fuel).

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

The first step is to estimate the average lengths of the trains based on how many rail cars they are made up of, using the following equation.

$$\boldsymbol{Train\ length = Number\ of\ cars \times Car\ length \times Number\ of\ locomotives \times Locomotive\ length}$$

Where:

Train length = Estimated length of intermodal train, feet
Number of cars = Number of multi-platform rail cars per train
Car length = Length of each 5-platform car, feet
Number of locomotives = Average number of locomotives per train
Locomotive length = Length of each locomotive, feet

Table 4.7 presents the parameters and estimated average lengths of the inbound and outbound trains of both railroads, with three columns representing each railroad.

Table 4.7: Line-Haul Train Length Assumptions

	Trains - Railroad "A"			Trains - Railroad "B"		
Parameters	**Outbound**	**Outbound**	**Inbound**	**Outbound**	**Outbound**	**Inbound**
# of 5-platform cars per train	25	27	27	27	27	23
Length of 5-platform car, feet	300	300	300	300	300	300
Length of cargo, feet	7,500	8,100	8,100	8,100	8,100	6,900
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	**7,640**	**8,240**	**8,240**	**8,240**	**8,240**	**7,040**

In addition to train length, the average number of containers each train can carry is estimated using the following equation.

$$\boldsymbol{Train\ capacity = Number\ of\ cars \times Number\ of\ platforms/car \times TEUs/platform \times Density \times TEUs/container}$$

Where:

Train capacity = Estimated number of containers per train
Number of cars = Number of multi-platform rail cars per train
Number of platforms/cars = Number of platforms per rail car
TEUs/platform = Maximum number of TEUs per platform
Density = average percentage utilization of platforms
TEUs/container = Average number of TEUs per container

Table 4.8 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 filled. The density assumptions in Table 4.8 show 100% density which assumes all container slots are to be filled. 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 4.8: Line-Haul Train Container Capacities

	Trains - Railroad "A"			Trains - Railroad "B"		
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)	500	540	540	540	540	460
Average "density"	100%	100%	100%	100%	100%	100%
TEUs per train (adjusted)	500	540	540	540	540	460
Average TEUs per container:	1.80	1.80	1.80	1.80	1.80	1.80
Containers per train (average)	**277**	**299**	**299**	**299**	**299**	**255**

The total number of containers moved by rail during the year is estimated using the following equation.

$$\boldsymbol{Total\ containers = Trains/day \times Days/week \times Containers/train}$$

Where:

Total containers = Estimated number of containers moved by train
Trains/day = Average number of trains each day
Days/week = Average number of days each week in which a train arrives or departs
Containers/train = Estimated train capacity, average number of containers per train

Table 4.9 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 4.8). The total estimated number of containers moved by the train configurations described above (and shown below in Table 4.9) corresponds to the reported actual 2023 on-dock rail throughput to within approximately four hundredths of a percent (estimated total of 318,500 + 310,492 = 628,992, versus actual 629,193). 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 4.9: Line-Haul Train Schedules and Throughput

Parameters	Trains - Railroad "A"			Trains - Railroad "B"		
	Outbound	**Outbound**	**Inbound**	**Outbound**	**Outbound**	**Inbound**
Trains/day	1	1	1	1	1	1
Days/week	7	7	7	7	7	7
Trains per year	364	364	364	364	364	364
Containers/year	100,828	108,836	108,836	108,836	108,836	92,820
Total estimated containers:	**318,500**			**310,492**		

The next step in estimating fuel consumption is estimating the gross weight of each of the train sizes described by the previous tables using the following equations.

$$\textit{Train weight} = \textit{Number of cars} \times \textit{Number of platforms/car} \times \textit{Gross tons/platform}$$

Where:

Train weight = Estimated weight of average train, tons
Number of cars = Number of multi-platform rail cars per train
Number of platforms/cars = Number of platforms per rail car
Gross tons/platform = Average weight of platform with cargo, tons

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 2023 submittals of an annual report known as the "R-1."[25] 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 4.10. The table also 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 4.10.

Table 4.10: Line-Haul Train Gross Weight

Parameters	Trains - Railroad "A"			Trains - Railroad "B"		
	Outbound	**Outbound**	**Inbound**	**Outbound**	**Outbound**	**Inbound**
Platforms per train (average)	125	135	135	135	135	115
Gross tons per platform	89	89	89	89	89	89
Gross weight of train	**11,070**	**11,955**	**11,955**	**11,955**	**11,955**	**10,184**

[25] *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2023* (Norfolk Southern Railroad) and *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2023* (CSX Transportation, Inc.). https://www.stb.gov/uploads/R1-NS-2023

Overall annual gross tonnage for each railroad is the gross weight of each train multiplied by the number of trains per year. These figures total approximately 12.73 million gross tons for the railroad whose trains are represented by the left three columns in the previous tables, and approximately 12.41 million gross tons for the railroad whose trains are represented by the three columns to the right.

Since fuel use and emissions depend not only on the weight of the trains but also on the distance the trains travel, the primary routes taken by the two railroads were evaluated for distance within each county included in this inventory, and the annual number of gross tons for each railroad was multiplied by the distance. The result of this calculation is an estimate of the number of gross ton-miles associated with each county, as shown in Table 4.11. Fuel consumption in each county was estimated by multiplying the ton-miles by the factor of 0.99 gallons of fuel per thousand gross ton-miles, derived from information in the 2023 R-1 reports on fuel consumption and gross ton-miles. The result of this calculation step is also shown in the table below.

Table 4.11: Line Haul Locomotive Ton-Mile and Fuel Use Estimates

County	Track Mileage	Thousand Gross Ton-Miles	Gallons Fuel
North Route			
Essex	3	38,198,368	38,580
Hudson	13	165,526,263	167,182
Bergen	15	190,991,842	192,902
Rockland	24	305,586,947	308,643
South Route			
Essex	5	62,052,202	62,673
Union	15	186,156,606	188,018
Middlesex	5	62,052,202	62,673
Total	**80**	**1,010,564,431**	**1,020,670**

The last step is to apply the emission factors (Table 4.12) in grams per gallon to the fuel use estimate (in gallons) presented above to calculate the total line haul locomotive emissions.

4.3.2 Switching Emissions

Switching emission estimates have been based primarily on the activity information developed for the previous Authority inventories of MHE and rail emissions, and the change in on-rail cargo throughputs at Port Newark, Elizabeth PA Marine Terminal, Staten Island, and Bayonne between 2022 and 2023. The scaling of activity with growth in container throughput by rail should provide a reasonable estimate of activity growth. The 2003 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, 629,193 containers moved by rail in 2023 divided by 706,744 containers moved by rail in 2022 results in a growth factor of 0.8902 or an 11 % decrease in throughput; this was multiplied by the 2022 operating hours estimate of 71,411 for a 2023 estimate of 63,570 hours.

A variety of switchers operate in ExpressRail service, a network of dedicated rail facilities including support track and rail yards for each of the port's major container terminals. These include 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.[26] 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. The emission factors are listed in Table 4.12. The switching locomotives operated by the rail-to-barge cross-harbor service are new Tier 4i units. A single container terminal operated a pair of rented Tier 0 switchers on terminal, so the Tier 0 emission factors have been used for those locomotives' emissions.

Table 4.12: Switching Locomotive Emission Factors

Units	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
Tier 0 emission factors									
g/gal	191	6.7	6.1	16.1	27.7	0.15	10,182	0.303	0.76
g/hp-hr	12.6	0.44	0.40	1.06	1.83	0.01	672	0.020	0.05
Tier 1 emission factors									
g/gal	150	6.5	6.1	16.1	27.7	0.10	10,182	0.258	0.76
g/hp-hr	9.9	0.43	0.40	1.06	1.83	0.01	672	0.017	0.05
Tier 4i emission factors									
g/gal	68	0.2	0.2	1.3	27.7	0.10	10,182	0.26	0.76
g/hp-hr	4.5	0.015	0.014	0.084	1.83	0.01	672	0.017	0.05
Tier 4 emission factors									
g/gal	15	0.2	0.2	1.3	27.7	0.15	10,182	0.26	0.76
g/hp-hr	1.0	0.015	0.014	0.084	1.83	0.01	672	0.017	0.05

[26] 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.

Emission factors for most pollutants are from the 2009 EPA publication. 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 expressed in units of grams per horsepower-hour. An estimate of annual horsepower-hours for ExpressRail 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 63,570 hours by the average in-use horsepower of 264 results in an estimate of approximately 16.8 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 Authority marine terminals 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 Authority marine terminals covered by this 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 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 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 Authority facilities specifically.

Beyond the 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 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

Photo courtesy of PANYNJ

SECTION 5: COMMERCIAL MARINE VESSELS

This section presents estimated emissions from ocean-going vessels (OGVs) and harbor craft, collectively known as commercial marine vessels (CMVs), calling at the following 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 containers, cruise passengers, automobiles, bulk liquids, and break bulk. Thus, this category includes a wide variety of OGV types along with assist tugs and barges. The following OGV are included in this inventory:

- Auto carrier
- Bulk vessel
- Containership
- Cruise ship
- General cargo
- RoRo
- Tanker

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 Authority, 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 NYNJLINA in which 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 Authority marine terminal related CMV activities or emissions occur within the county.

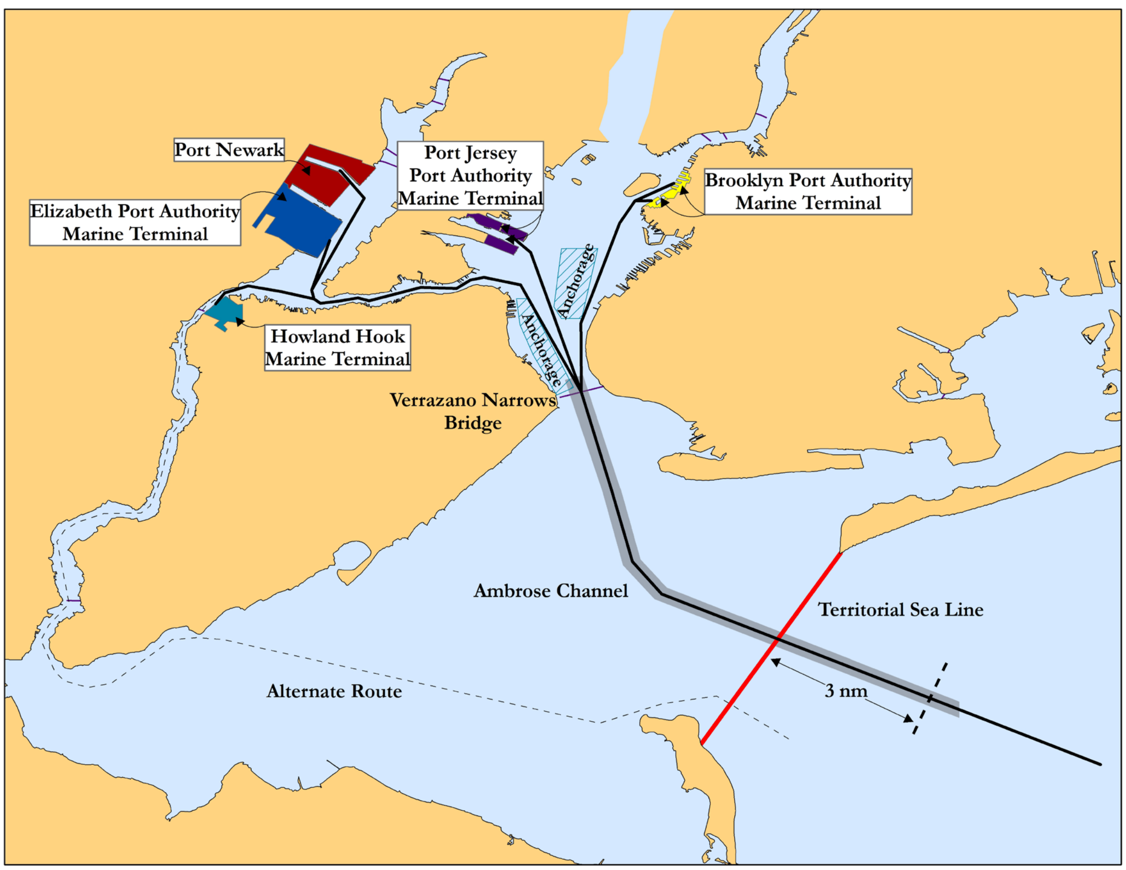
In many cases, vessel travel lanes do not fall neatly within one or another county. Best efforts have been made to reasonably allocate emissions to the relevant counties (and states).

5.1 CMV Emission Estimates

Emission estimates have been developed for CMV on the basis of vessel type, engine type and relative activity. The following OGV types are included: containerships, cruise ships, automobile and other vehicle carriers, tankers, and bulk carriers. The harbor craft category includes vessels that assist ocean-going vessels in maneuvering and docking (assist tugs) and the vessels that move cargo barges within the NYNJHS (towboats). Emissions from barges are not included because the inventory is limited to mobile source combustion emissions. Emissions have been estimated for OGV and harbor craft 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 in OGV. Harbor craft are not equipped with boilers.

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



Vessels occasionally wait for berth space while anchored in one of two designated anchorage areas located in the harbor within the Verrazano Narrows Bridge. Emissions from vessels that are at anchorage in one of these areas are included in the total emissions presented in this report. In 2023, there were fewer vessels at anchorage than in 2022 and vessels also spent less time at berth. These are the main reasons for the decrease in OGV emissions in 2023 as compared to 2022.

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 emissions are shown by subcategories. The numbers associated with the containership subcategories refer to size ranges in TEU capacity.

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	126	2.1	1.9	5.6	12.5	3.5	8,706
Bulk Carrier	64	1.2	1.1	2.2	5.9	2.9	4,993
Container - 1000	64	1.3	1.2	2.3	6.4	3.0	5,709
Container - 2000	125	2.0	1.9	4.7	11.3	4.2	8,671
Container - 3000	43	0.7	0.6	1.7	3.7	1.2	3,055
Container - 4000	237	3.6	3.3	10.0	20.0	6.2	15,272
Container - 5000	108	1.6	1.5	5.6	10.4	2.0	6,939
Container - 6000	220	3.8	3.5	14.9	24.5	6.1	14,284
Container - 7000	18	0.3	0.3	1.1	1.9	0.6	1,318
Container - 8000	425	6.8	6.3	19.1	39.8	10.6	29,267
Container - 9000	132	2.2	2.1	5.9	12.4	3.5	9,868
Container - 10000	51	0.8	0.8	2.2	4.6	1.4	3,755
Container - 11000	82	1.4	1.3	4.5	8.7	1.9	5,893
Container - 12000	15	0.5	0.4	1.7	3.2	0.3	1,863
Container - 13000	223	4.4	4.0	9.0	21.9	6.4	20,251
Container - 14000	107	2.3	2.1	5.5	13.8	3.9	10,280
Container - 15000	16	0.6	0.5	2.0	3.9	1.0	2,193
Container - 16000	4	0.1	0.1	0.4	0.6	0.2	253
Cruise Ship	272	4.7	4.3	9.9	26.3	9.0	18,815
General Cargo	13	0.3	0.2	0.5	1.3	0.6	983
RoRo	56	1.0	0.9	3.2	6.9	0.6	4,225
Tanker	64	1.4	1.2	2.3	6.0	3.3	5,512
Total	**2,466**	**43**	**40**	**114**	**246**	**72**	**182,105**

Table 5.2 presents the OGV emissions by engine type. Table 5.3 differentiates emissions according to transit and dwelling (hoteling) 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	898	8	8	53	78	12	30,542
Auxiliary Engines	1,465	25	23	57	157	40	100,101
Boilers	104	10	9	5	11	20	51,462
Total	**2,466**	**43**	**40**	**114**	**246**	**72**	**182,105**

Table 5.3: OGV Emissions by Operating Mode, tpy

Operating Mode	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Transit	1,211	14	13	65	111	22	55,047
Dwelling	1,255	29	27	50	135	50	127,057
Total	**2,466**	**43**	**40**	**114**	**246**	**72**	**182,105**

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 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	192	4	4	4	40	0.1	15,268
Assist Tugs	146	3	3	3	49	0.2	23,464
Totals	**338**	**7**	**7**	**7**	**90**	**0.3**	**38,732**

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 current year emission estimates with the previous years' inventories. First, 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 (2020 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 2023 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	288,737	403,780	130,494	882,141	1,948,186	14,400	178,760,766
NYNJLINA	137,049	95,410	40,985	220,174	838,105	3,327	92,488,145
OGV	2,466	43	40	114	246	72	182,105
Harbor Craft	338	7	7	7	90	0.3	38,732
Total Commercial Marine Vessels	2,804	50	47	121	335	73	220,837
2023 % of NYNJLINA Emissions	**2.0%**	**0.05%**	**0.11%**	**0.06%**	**0.04%**	**2.2%**	**0.2%**
2022 % of NYNJLINA Emissions	**2.3%**	**0.06%**	**0.13%**	**0.07%**	**0.05%**	**2.7%**	**0.3%**

5.2.1 OGV Emission Comparisons with County and Regional Emissions

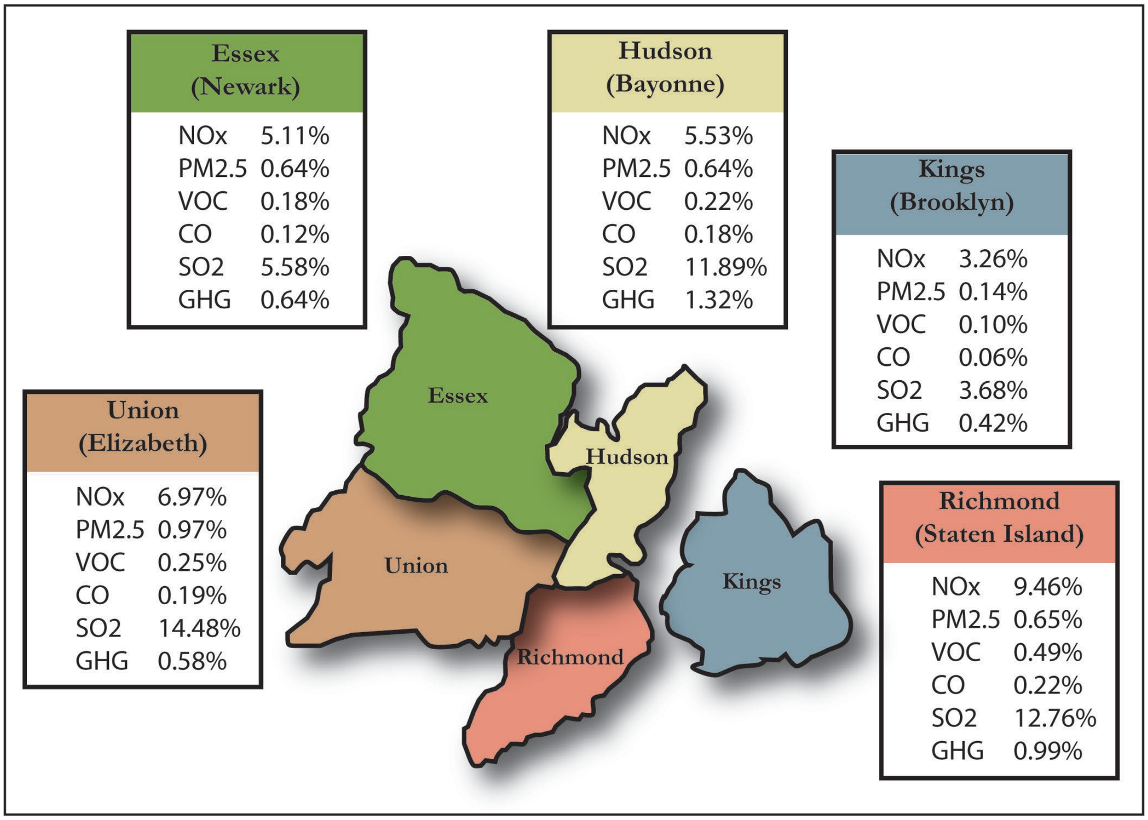
Table 5.6 summarizes estimated criteria pollutant and GHG emissions from OGVs at the county level. All counties within the inventory area are listed, so counties without associated OGV emissions are shown with zero emissions. The percentage allocation of emissions per county are based on the geographical location of Automatic Identification System (AIS) data points provided by the U.S. Coast Guard, so the allocation percentages may change from year to year along with the activity.

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

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	0	0	0	0	0	0	0
Essex	NJ	438	9	8	19	44	15	39,549
Hudson	NJ	332	6	6	17	35	11	25,543
Middlesex	NJ	0	0	0	0	0	0	2
Monmouth	NJ	272	3	2	10	21	5	11,584
Union	NJ	513	13	12	22	60	22	57,868
New Jersey subtotal		**1,555**	**31**	**28**	**68**	**160**	**53**	**134,546**
Bronx	NY	0	0	0	0	0	0	0
Kings	NY	366	5	5	18	34	8	20,222
Nassau	NY	0	0	0	0	0	0	0
New York	NY	3	0	0	0	0	0	196
Orange	NY	0	0	0	0	0	0	0
Queens	NY	171	2	2	6	14	3	7,304
Richmond	NY	371	5	5	24	38	8	19,836
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		**911**	**12**	**12**	**48**	**86**	**19**	**47,558**
Total		**2,466**	**43**	**40**	**116**	**246**	**72**	**182,105**

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

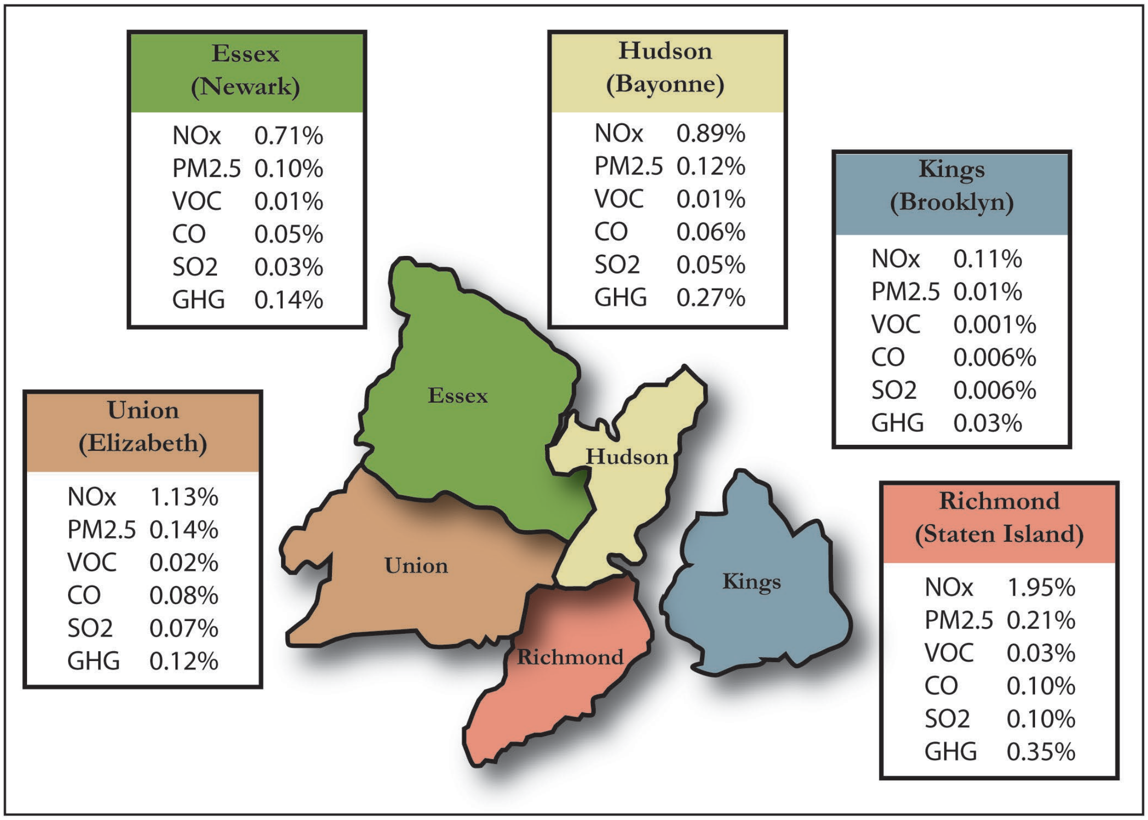
Table 5.7 summarizes estimated emissions from assist tugs and tow boats at the county level.

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	0.04	0.04	0.04	0.39	0.00	148
Essex	NJ	61	1.30	1.29	1.18	19.18	0.08	8,889
Hudson	NJ	53	1.18	1.15	1.09	12.66	0.05	5,175
Middlesex	NJ	13	0.29	0.28	0.27	2.73	0.01	1,039
Monmouth	NJ	10	0.21	0.21	0.20	2.01	0.01	765
Union	NJ	83	1.77	1.76	1.62	25.87	0.10	11,944
New Jersey subtotal		**222**	**4.8**	**4.7**	**4.4**	**62.8**	**0.25**	**27,960**
Bronx	NY	0	0.01	0.01	0.01	0.07	0.00	27
Kings	NY	12	0.27	0.27	0.25	3.33	0.01	1,448
Nassau	NY	2	0.06	0.05	0.05	0.52	0.00	197
New York	NY	4	0.08	0.08	0.08	1.01	0.00	433
Orange	NY	2	0.05	0.05	0.04	0.45	0.00	169
Queens	NY	4	0.08	0.08	0.08	0.79	0.00	301
Richmond	NY	76	1.69	1.65	1.57	17.56	0.06	7,060
Rockland	NY	3	0.06	0.06	0.05	0.55	0.00	208
Suffolk	NY	8	0.19	0.18	0.18	1.77	0.01	672
Westchester	NY	3	0.07	0.07	0.07	0.68	0.00	257
New York subtotal		**116**	**2.6**	**2.5**	**2.4**	**26.7**	**0.10**	**10,772**
TOTAL		**338**	**7.4**	**7.2**	**6.8**	**89.6**	**0.34**	**38,732**

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 2023 OGV emissions and prior years' emissions can be attributed to changing levels of cargo throughput, different vessel types calling the terminals during different years, updated average auxiliary engine and auxiliary boiler loads, use of shore power, programs carried out by the 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. Specifically for 2023 compared to the previous year (2022), the lower emissions are due to lower TEU cargo throughput which resulted in less vessels at anchorage, less shifts, and less time at berth. The lower emissions are also due to an increase in vessels calling with Tier III engines and more LNG fueled containerships calling the Port.

For 2023 emissions, the GWP values were updated, and the previous year's GHG emissions were updated to be consistent with this change. The 2022 OGV emissions also changed slightly due to a correction of the shifts (took out non-berth shifts), updated LNG factors, and update to the MAN engine list to include various listings of same engine (ie. MAN/MAN B&W/B&W).

Programs that had an impact on OGV emissions in calendar year 2023 are listed below.

- In 2023, there were less vessel calls for most vessel types, except for cruise ship calls that increased in 2023. This resulted in overall lower emissions, but slightly higher emissions for cruise ships.
- In 2023, there were fewer vessels at anchorage than in 2022. This resulted in lower emissions.
- Larger vessels continued to make calls to the terminals in 2023.
- This was the second year that LNG fueled containerships called the Port.
- All vessels used 0.1% or less sulfur content fuel per the ECA requirement.
- The Port Authority of New York and New Jersey CVI Program continued to be in effect in 2023. In 2023, there were 1,822 calls to the Authority marine terminals by vessels enrolled in the program, with 599 individual vessels making 883 calls that earned incentive payments.
- Newer vessels with Tier III engines are calling the Authority terminals. These vessels comply with IMO Tier III NO_x limits while in US waters which achieve significant NO_x reductions as compared to older engines. However, the full impact of Tier III NO_x standards is not achieved if the main engine load is equal or less than 25% because at these loads the exhaust gas temperature does not reach the level required for selective catalytic reduction (SCR) or exhaust gas recirculation (EGR) systems to effectively reduce emissions.

Table 5.8 presents a comparison of 2023 OGV emissions out to the three nautical mile boundary, with emissions in the same area for the previous year and the 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 2023 were lower by 11% to 20% (depending on pollutant) compared to 2022, in line with the TEU throughput which was 18% less in 2023. The lower OGV emissions in 2023 were mainly due to less time spent at berth, less shifts, and less anchorage calls.

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	Throughput M TEUs
2023	2,466	43	40	114	246	72	182,105	7.81
2022	2,785	52	48	131	283	90	220,370	9.49
2006	4,165	392	314	185	360	3,681	221,638	5.09
2022-2023, Change (%)	**-11%**	**-17%**	**-17%**	**-13%**	**-13%**	**-20%**	**-17%**	**-18%**
2006-2023, Change (%)	**-41%**	**-89%**	**-87%**	**-38%**	**-32%**	**-98%**	**-18%**	**53%**

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 latest update (2023), with emission trend lines superimposed over the annual M TEU throughput.

Figure 5.4: OGV Emissions Relative to TEU Throughput

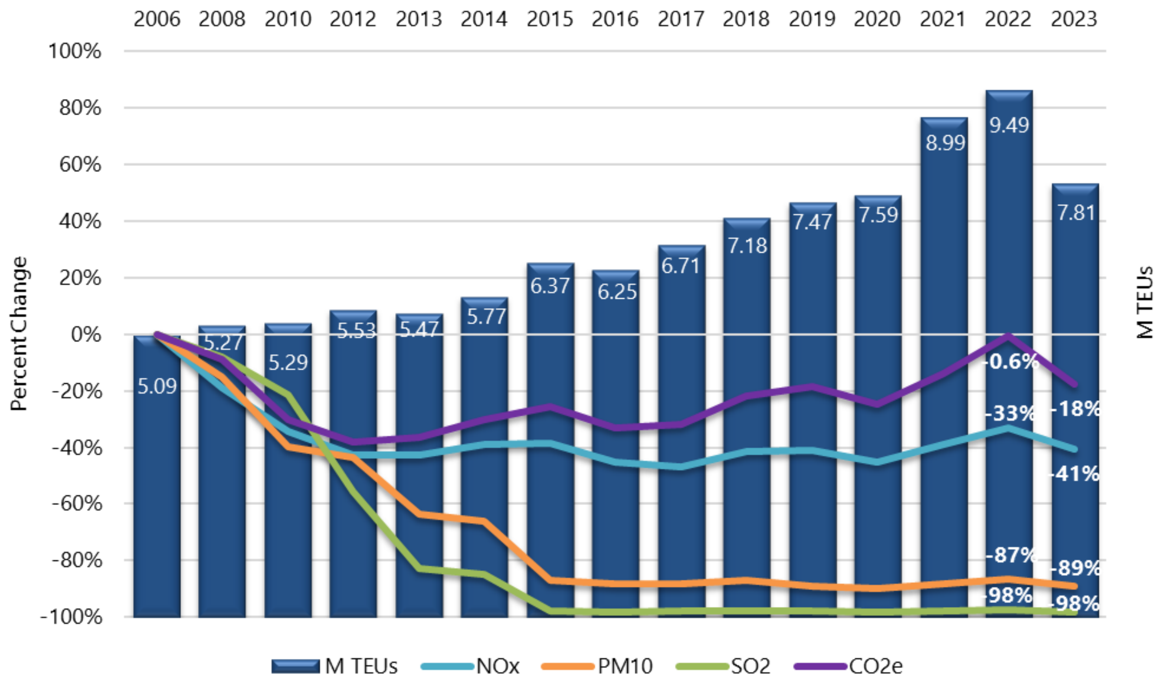


Table 5.9 compares emissions per M TEUs. Emissions per TEU are similar in 2023 and 2022 for OGV. An increase with the efficiency metric (emissions per M TEUs) means inefficiency.

Table 5.9: OGV Emission per M TEUs Comparison

	Emissions / M TEUs						
Inventory Year	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
2023	316	6	5	15	31	9	23,317
2022	293	5	5	14	30	9	23,212
2006	818	77	62	36	71	723	43,518
2022-2023, Change (%)	**8%**	**0%**	**0%**	**6%**	**6%**	**-3%**	**0%**
2006-2023, Change (%)	**-61%**	**-93%**	**-92%**	**-60%**	**-55%**	**-99%**	**-46%**

5.2.4 Comparison of Harbor Craft Emissions with Prior Year Emission Estimates

Table 5.10 presents the harbor craft emissions comparison to prior years' emissions. Compared to the previous year, overall harbor craft emissions increased slightly by 2-12% due to the towboat fleet composition and activity. Compared to 2006, the emission reductions are due to fleet turnover to newer vessels. CO_2e emissions are higher in 2023 compared to 2006 due to increased activity and lack of engine emission standards for CO_2.

Table 5.10: 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
2023	338	7	7	7	90	0	38,732
2022	321	7	6	7	81	0	35,716
2006	633	34	31	21	98	62	33,703
2022-2023, Change (%)	**5%**	**12%**	**12%**	**2%**	**10%**	**8%**	**8%**
2006-2023, Change (%)	**-47%**	**-78%**	**-77%**	**-68%**	**-9%**	**-99%**	**15%**

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 for vessel movements to and from the Authority marine terminals based on AIS information provided by the U.S. Coast Guard. Information from IHS Markit (previously known as "Lloyd's data" due to previous company ownership) has been used to develop profiles of the physical and operational parameters of OGVs along with the information from Starcrest's Vessel Boarding Program (VBP) data system. The VBP program collects engine load and boiler data for hoteling, maneuvering and transit modes.

5.3.1 Data Sources

Data sources are the sources of information used in developing the emission estimates for commercial marine vessels associated with the 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 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 Authority marine terminals was used in conjunction with other data sources, such as IHS Markit and 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 over the water boundary and the terminal berth, including the area where vessels are maneuvering at a reduced speed within the harbor. Dwelling (also known as hoteling) refers to the vessel's operation while at berth or at anchorage.

Activity levels are evaluated based on the number of calls the vessels made to Authority marine terminals, duration of dwelling, distance traveled, and speed profiles within the channel. These parameters are 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 engine rating, onboard auxiliary load, IMO tier level of the vessel, and nation of registry.

The emission estimates developed for this report are based exclusively on the OGV calls to Authority-owned marine terminals, a subset of all NYNJHS calls. Operating hours (activity) are based on the AIS distance/speed over ground calculation for periods that the vessels are in motion. Dwell times are calculated for each vessel call to a terminal or anchorage area from AIS data where the speed indicates the vessel was not in motion.

Table 5.11 lists the vessel movements. Larger container vessels with a carrying capacity above 10,000 TEUs were 20% of total containership movements. In 2023, 5 dual-fueled LNG vessels, using LNG fuel, made 14 calls to the Port.

Table 5.11: Vessel Movements for the Authority Marine Terminals

Vessel Type	Arrivals	Departures	Shifts	Total
Auto Carrier	258	259	46	563
Bulk Carrier	86	87	37	210
Container - 1000	192	194	5	391
Container - 2000	275	275	6	556
Container - 3000	78	79	4	161
Container - 4000	326	326	12	664
Container - 5000	129	128	5	262
Container - 6000	229	229	10	468
Container - 7000	18	18	0	36
Container - 8000	374	372	13	759
Container - 9000	120	120	5	245
Container - 10000	36	36	2	74
Container - 11000	78	80	0	158
Container - 12000	22	22	0	44
Container - 13000	181	180	4	365
Container - 14000	96	95	0	191
Container - 15000	26	26	0	52
Container - 16000	3	3	0	6
Cruise Ship	161	161	3	325
General Cargo	23	23	11	57
RoRo	83	83	59	225
Tanker	70	68	40	178
Total	**2,864**	**2,864**	**262**	**5,990**

Table 5.12 lists the minimum, maximum, and average dwell times at berth (hours) for the different vessel types and sizes that called at Authority terminals.

Table 5.12: Average Dwell Times at Berth, hours

Vessel Type	Min	Max	Average
Auto Carrier	3	65	18
Bulk Carrier	14	363	119
Container - 1000	5	51	20
Container - 2000	4	540	21
Container - 3000	2	78	20
Container - 4000	1	269	22
Container - 5000	6	70	23
Container - 6000	9	226	24
Container - 7000	13	54	32
Container - 8000	2	84	32
Container - 9000	12	67	37
Container - 10000	12	71	46
Container - 11000	7	67	40
Container - 12000	30	74	43
Container - 13000	7	330	57
Container - 14000	27	117	59
Container - 15000	28	81	52
Container - 16000	35	48	41
Cruise Ship	1	62	11
General Cargo	7	87	45
RoRo	1	63	18
Tanker	10	319	51

Table 5.13 shows the average dwell time per vessel type and number of vessels at anchorage for 2023. There were less vessels at anchorage in 2023 as compared to 2022.

Table 5.13: Average Dwell Times at Anchorage, hours

Vessel Type	Min	Max	Average	Vessel Count
Auto Carrier	1	21	8	5
Bulk	2	206	33	18
Containership	1	32	11	32
Cruise	9	19	13	3
General Cargo	6	36	22	4
Tanker	1	47	12	25
2023	**1**	**206**	**17**	**87**
2022	**0**	**144**	**16**	**119**

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). The emission factors (see section 5.3.2) were updated to reflect the Tier level of the assist tug fleet operating in the harbor in 2021 and remained the same for 2023.

Table 5.14 lists the number of vessel assists for the various vessel types during the calendar year of the study. In 2023, there were 17% more vessel assists than in 2022.

Table 5.14: Assist Tug Operating Data and Assumptions

Vessel Type	Total Assists
Auto Carrier	1,122
Bulk Carrier	390
Containership	8,830
Cruise Ship	325
General Cargo	100
RoRo	450
Tanker	324
Total	**11,541**

5.3.1.3 Towboats (Harbor Craft)

This category of vessels is made up of the tugboats used for the barge movements associated with PANYNJ berths. The public berths at Port Newark see 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, and these commodities are often moved by barge. There are also two container terminals with known barge calls that provide barge trips each year that are included in the barge activity for calculation of 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 yards, also to reduce truck trips.

A list of discrete harbor craft, including towboats, identified with AIS data analysis was used to update vessel characteristic assumptions. The harbor craft (i.e., vessels not included in the OGV source category) that transited through the New York/New Jersey harbor area were studied and the engine characteristics updated for this inventory. The average towboats have larger engines than in prior inventories, potentially due to the larger ocean-going vessels and liquid bulk barges.

5.3.2 Emission Estimating Methodology

Emissions are estimated for the three combustion emission source types associated with marine vessels: main (or propulsion) engines, auxiliary engines, and, for OGVs, auxiliary boilers, and for the operational modes transit (arrival/departure) and dwelling (at-berth and anchorage). Operating data and the methods of estimating emissions are discussed below. 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, for ships using LNG as a primary fuel, 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 turned off while the vessel is tied up at berth or at anchorage. The emissions calculation can be described using the following equation:

$$\boldsymbol{E_i = EF \times Energy_i \times FCF}$$

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 engines 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:

$$\boldsymbol{Energy_i = Load \times Act}$$

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 Emission Factors

OGVs using diesel fuel and operating in the study area used 0.1% fuel oil sulfur content limit per the ECA fuel requirement. In addition, several vessels under the CVI program used cleaner fuel with lower sulfur content than what is required under the ECA and some vessels also used LNG. Emission factors for all engine types used in this study were obtained either from equations or values included in EPA's document entitled "Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions," dated September 2020 (EPA's EI Guidance Document)[27].

The PM_{10} emission factors are based on the following equation:

$$PM\ EF = PM_{base} + (S_{act} \times BSFC \times 0.02247 \times 7)$$

Where:

PM EF = PM_{10} emission factors adjusted for the fuel type and S content of the fuel (g/kW-hr)
PM_{base} = Base emission factor assuming zero fuel sulfur (g/kWhr)
= 0.1545 g/kW-hr for distillate fuel (MGO and MDO)
= 0.5761 g/kW-hr for residual fuel (HFO)
S_{act} = actual fuel sulfur level (weight ratio)
BSFC = brake specific fuel consumption in g/kW-hr
0.02247 is fraction of sulfur in fuel that is converted to direct sulfate
7 is molecular weight ratio of sulfate PM to sulfur = 224/32 = 7

The $PM_{2.5}$ emission factor is based on the following equation:

$$PM_{2.5}\ EF = PM\ EF \times Fraction$$

Where:

PM EF = PM_{10} emission factor in g/kW-hr
Fraction = $PM_{2.5}$ to PM_{10} ratio dependent on fuel type
= 0.8 for HFO
= 0.92 for MGO and MDO

[27] *https//www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance*

The SO_x emission factor is based on the following equation:

$$SO_2\ EF = S_{act} \times BSFC \times 2 \times 0.97753$$

Where:

SO_2 EF = SO_x emission factor (g/kW-hr)
S_{act} = actual fuel sulfur level (weight ratio)
BSFC = brake specific fuel consumption in g/kW-hr
0.97753 is the fraction of fuel sulfur converted to SO_2 and
2 is the ratio of molecular weights of SO_2 and S.=64/32 = 2

The CO_2 emission factor is based on the following equation:

$$CO_2\ EF = BSFC \times CCF$$

Where:

CO_2 EF = CO_2 emission factor (g/kW-hr)
BSFC = brake specific fuel consumption in g/kW-hr
CCF= carbon content factor as a function of fuel type (CO_2/g fuel)
= 3.206 for MGO/MDO
= 3.114 for HFO
= 2.750 for LNG

Table 5.15 shows BSFC by engine type used in equations for PM, SO_x and CO_2 emission factors.

Table 5.15: BSFC by Engine Type and Fuel Type for Ocean Going Vessels, g/kW-hr

Engine Category	IMO Tier	Model Year Range	BSFC
Using HFO Fuel			
Slow speed propulsion	All	All	195
Medium speed propulsion	All	All	215
Medium speed auxiliary	All	All	227
High speed auxiliary	All	All	227
Steam propulsions and boiler	All	All	305
Gas turbine	All	All	305
Using HFO Fuel			
Slow speed propulsion	All	All	185
Medium speed propulsion	All	All	205
Medium speed auxiliary	All	All	217
High speed auxiliary	All	All	217
Steam propulsions and boiler	All	All	300
Gas turbine	All	All	300

NO_x emission factors are based on the IMO Tier of the vessel engines, which is based on the keel laid date provided in the IHS Markit data. Table 5.16 compares 2023, 2022, and 2021 OGV calls by engine Tiers. For 2023, 4% of the vessel calls were vessels with Tier III engines. For these Tier III vessels, 42% of the time, the main engine load was high enough for the main engines to operate at the Tier III NO_x level.

Table 5.16: Vessel Propulsion Engine Tier Calls Comparison

Year	Tier 0	Tier I	Tier II	Tier III	No Tier
2023	5%	61%	30%	4%	1%
2022	6%	62%	28%	3%	1%
2021	4%	67%	26%	3%	0%

Tables 5.17 and 5.18 list the emission factors for propulsion and auxiliary engines using 0.1% sulfur which is the fuel that is used to be compliant with the IMO North American ECA requirement. When available, vessel specific ESI NO_x emission factors, which represent actual EIAPP NO_x values, are used instead of the default values for propulsion and auxiliary engines.

Table 5.17: OGV Emission Factors for Diesel Propulsion, Steam Propulsion and Gas Turbine Engines, g/kW-hr

Engine Category	Tier	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Slow speed propulsion	0	1999 and older	17.0	0.184	0.169	0.6	1.4	0.362	593	0.029	0.012
Slow speed propulsion	I	2000 to 2011	16.0	0.184	0.169	0.6	1.4	0.362	593	0.029	0.012
Slow speed propulsion	II	2011 to 2016	14.4	0.184	0.169	0.6	1.4	0.362	593	0.029	0.012
Slow speed propulsion	III	2016 and newer	3.4	0.184	0.169	0.6	1.4	0.362	593	0.029	0.012
Medium speed propulsion	0	1999 and older	13.2	0.187	0.172	0.5	1.1	0.401	657	0.029	0.010
Medium speed propulsion	I	2000 to 2011	12.2	0.187	0.172	0.5	1.1	0.401	657	0.029	0.010
Medium speed propulsion	II	2011 to 2016	10.5	0.187	0.172	0.5	1.1	0.401	657	0.029	0.010
Medium speed propulsion	III	2016 and newer	2.6	0.187	0.172	0.5	1.1	0.401	657	0.029	0.010
Gas turbine	na	All	5.7	0.010	0.009	0.1	0.2	0.587	962	0.075	0.002
Steam propulsion	na	All	2.0	0.160	0.147	0.1	0.2	0.587	962	0.075	0.002

Table 5.18: OGV Emission Factors for Auxiliary Engines using 0.1% S, g/kW-hr

Engine Category	Tier	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Medium Auxiliary	0	1999 and older	13.8	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
Medium Auxiliary	I	2000 to 2010	12.2	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
Medium Auxiliary	II	2011 to 2015	10.5	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
Medium Auxiliary	III	2016 and newer	2.6	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
High Auxiliary	0	1999 and older	10.9	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008
High Auxiliary	I	2000 to 2010	9.8	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008
High Auxiliary	II	2011 to 2015	7.7	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008
High Auxiliary	III	2016 and newer	2.0	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008

Information from engine manufacturers[28] and classification societies[29] suggest that Tier III propulsion engines will not meet Tier III emission standards when operating at or below 25% load because the exhaust heat does not reach the necessary temperature for selective catalytic reduction (SCR) or exhaust gas recirculation (EGR) systems to effectively reduce emissions. As such, when Tier III main engines operated below 25% within the emissions inventory domain, the default Tier II NO_x emission factor or, if available, Tier II EIAPP NO_x factors were used in emission calculations. In 2023, 58% of movements for the vessels with Tier III main engines, were at loads below 25% and therefore the Tier II NO_x emission rates were used to estimate emissions.

In addition to the auxiliary engines that are used to generate electricity for on-board uses, most OGVs have one or more boilers used for fuel heating and for producing hot water and steam. Table 5.19 shows the emission factors used for the auxiliary boilers.

Table 5.19: Emission Factors for OGV Auxiliary Boilers using 0.1% S, g/kW-hr

Engine Category	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Auxiliary Boiler	All	2.0	0.20	0.19	0.10	0.20	0.59	962	0.075	0.002

[28] See: MAN Diesel & Turbo, "Tier III Two-Stroke Technology"
[29] DNV-GL, "NOx Tier III Update: Choices and challenges for on-time compliance," November 2017.

In 2023, 5 vessels used LNG fuel for 14 calls. Table 5.20 shows the emission factors used for auxiliary engines and boilers using LNG fuel per EPA's Ports EI Guidance for most pollutants, except for the SO_x EF which is from the IMO 4th GHG Study[30] and 6.8% MGO as pilot fuel. The brake specific fuel consumption (BSFC) used for LNG fuel in this report is 166 g/kWh.

Table 5.20: Emission Factors for Auxiliary Engines and Boilers using LNG fuel and 6.8% MGO as Pilot Fuel, g/kW-hr

Engine Category	IMO Tier	Range Year	NO_x	PM_{10}	$PM_{2.5}$	DPM	HC	CO	SOx	CO_2	N_2O	CH_4
Medium speed Auxiliary	Tier 0	1999 and older	2.15	0.408	0.038	0.013	0.03	1.29	0.03	472.8	0.029	0.001
Medium speed Auxiliary	Tier I	2000 to 2011	2.04	0.408	0.038	0.013	0.03	1.29	0.03	472.8	0.029	0.001
Medium speed Auxiliary	Tier II	2011 to 2016	1.93	0.408	0.038	0.013	0.03	1.29	0.03	472.8	0.029	0.001
Medium speed Auxiliary	Tier III	2016 and newer	1.39	0.408	0.038	0.013	0.03	1.29	0.03	472.8	0.029	0.001
High speed Auxiliary	Tier 0	1999 and older	1.95	0.408	0.038	0.013	0.03	1.27	0.03	472.8	0.029	0.001
High speed Auxiliary	Tier I	2000 to 2011	1.88	0.408	0.038	0.013	0.03	1.27	0.03	472.8	0.029	0.001
High speed Auxiliary	Tier II	2011 to 2016	1.74	0.408	0.038	0.013	0.03	1.27	0.03	472.8	0.029	0.001
High speed Auxiliary	Tier III	2016 and newer	1.35	0.408	0.038	0.013	0.03	1.27	0.03	472.8	0.029	0.001
Auxiliary boilers	na	na	1.35	0.417	0.038	0.000	0.01	1.23	0.01	490.9	0.075	0.000

[30] IMO, https://www.imo.org/en/ourwork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx

5.3.2.3 OGV Low Load Adjustment

In general terms, diesel-cycle engines are not as efficient when operated at low loads compared with higher load operation. A low engine load condition may occur when a vessel is traveling at slower speeds such as maneuvering within a harbor or transiting the vessel speed reduction participation zone. During emission estimation, low load adjustment (LLA) factors are multiplied by the latest emission factors for 2-stroke (slow speed) diesel propulsion engines, adjusted for fuel differences between the actual fuel and the fuel used when the emission factors were developed. A detailed discussion and presentation of LLA used during emission estimation can be found in the latest San Pedro Bay Ports Emission Inventory Methodology Report[31].

5.3.2.4 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 65% 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, vessel specific auxiliary engine and auxiliary boiler loads are not readily available for specific vessels. The information used for these estimates has been collected by Starcrest, as part of the VBP. Through the VBP, auxiliary engine and boiler data is collected from ship engineers at various ports to determine actual engine load information for the various operational modes.

Starcrest has developed a hierarchy for establishing auxiliary engine and boiler load assumptions that uses VBP data as a starting point, since that data is the most ship specific.

- If a vessel that calls has corresponding data in the VBP dataset, that data is used for the vessel's characteristics.
- If the vessel has no directly applicable data in the VBP dataset, a default is used that is based on an average by vessel type and size range for all of the VBP data collected between 2005 through 2023. The average is made up of vessels within the vessel type and size range that called the Authority in previous years.
- If the vessel has no directly applicable data in the VBP dataset and is in a vessel type and size range that has not called previously, a default is used that is the average of the higher and lower vessel size or, if not available, recently published defaults used for other port EIs.[32]

[31] Starcrest Consulting Group, LLC, 2021, San Pedro Bay Ports Emissions Inventory Methodology Report (Version 2, pp 15-25)

[32] See: Port of Los Angeles 2021 Air Emissions Inventory, 2022 and Port of Long Beach 2021 Air Emissions Inventory, 2022

Table 5.21 lists the OGV auxiliary engine load assumptions by vessel type and mode used in this inventory. Transit refers to the mode of operation when a vessel is traveling within the study area but outside of the harbor, while maneuvering refers to when a vessel is operating at slower speeds within the harbor.

Table 5.21: OGV Auxiliary Engine Load by Mode, kW

Vessel Type	Transit (kW)	Manuevering (kW)	Berth Dwelling (kW)	Anchorage Dwelling (kW)
Auto Carrier	590	1,187	1,048	565
Bulk	259	377	369	253
Container - 1000	960	1,280	658	1,000
Container - 2000	1,181	1,823	652	525
Container - 3000	1,015	1,663	790	850
Container - 4000	1,342	2,463	970	954
Container - 5000	1,367	2,420	989	957
Container - 6000	1,609	2,566	1,086	1,229
Container - 7000	1,573	2,575	1,005	880
Container - 8000	1,703	2,654	1,262	1,229
Container - 9000	1,618	2,853	1,116	1,183
Container - 10000	1,569	1,950	1,066	1,083
Container - 11000	1,941	2,529	1,111	1,398
Container - 12000	1,925	2,346	1,371	1,334
Container - 13000	1,616	2,260	1,215	1,225
Container - 14000	1,738	2,276	1,228	1,141
Container - 15000	2,189	2,525	917	1,133
Container - 16000	1,839	2,607	1,004	1,167
General Cargo	471	1,098	778	180
RoRo	590	1,187	1,048	565
Tanker - Chemical	427	510	1048	384

House load defaults for cruise ships (diesel electric and non-diesel electric) are listed in Table 5.22. Most of the cruise ships that called the cruise terminal were diesel electric.

Table 5.22: Cruise Ship Auxiliary Engine Load, kW

Vessel Type	Passenger Count	Transit (kW)	Maneuvering (kW)	Berth Dwelling (kW)
Cruise	0-199	332	585	293
Cruise	200-1,499	2,768	3,833	2,965
Cruise	1,500-1,999	6,883	8,100	5,624
Cruise	2,000-2,499	8,033	9,000	7,680
Cruise	2,500-2,999	8,052	8,577	6,410
Cruise	3,000-3,499	7,867	9,511	7,069
Cruise	3,500-3,999	8,615	9,230	7,201
Cruise	4,000-4,499	8,552	9,086	7,851
Cruise	4,500-4,999	8,980	9,359	8,479
Cruise	5,000-5,499	9,429	9,733	9,157
Cruise	5,500-5,999	9,900	10,122	9,890
Cruise	6,000-6,499	10,395	10,527	10,681

5.3.2.5 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 5.23 presents auxiliary boiler energy defaults in kilowatts for each vessel type by mode.

Table 5.23: Auxiliary Boiler Load Defaults by Mode, kW

Vessel Type	Transit (kW)	Maneuvering (kW)	Berth Dwelling (kW)	Anchorage Dwelling (kW)
Auto Carrier	91	186	313	303
Bulk	39	92	123	123
Container - 1000	104	209	455	265
Container - 2000	133	261	363	328
Container - 3000	183	342	522	476
Container - 4000	188	370	485	481
Container - 5000	238	467	565	559
Container - 6000	256	480	610	606
Container - 7000	328	568	660	656
Container - 8000	238	472	598	621
Container - 9000	355	521	653	633
Container - 10000	303	393	540	540
Container - 11000	198	320	456	460
Container - 12000	135	292	490	490
Container - 13000	271	366	594	590
Container - 14000	332	490	584	621
Container - 15000	237	369	407	407
Container - 16000	212	359	407	407
Cruise Ship	832	874	1,210	812
General Cargo	72	161	207	207
RoRo	91	186	313	303
Tanker - Chemical	85	134	446	250

Table 5.24 presents the load defaults for the auxiliary boilers for diesel electric cruise ships.

Table 5.24: Auxiliary Boiler Load Defaults by Mode for Diesel Electric Vessels, kW

Vessel Type	Passenger Count	Transit (kW)	Maneuvering (kW)	Berth Dwelling (kW)
Cruise	0-199			
Cruise	200-1,499	692	766	850
Cruise	1,500-1,999	1,070	1,145	1,951
Cruise	2,000-2,499	1,382	1,773	3,005
Cruise	2,500-2,999	671	736	1,363
Cruise	3,000-3,499	568	748	1,276
Cruise	3,500-3,999	555	506	859
Cruise	4,000-4,499	335	29	551
Cruise	4,500-4,999	281	21	468
Cruise	5,000-5,499	236	16	398
Cruise	5,500-5,999	198	12	338
Cruise	6,000-6,499	166	9	287

5.3.2.6 Assist Tugs, Towboats (Harbor Craft)

The emission estimating methodology is the same for assist tugs and towboats (as a group, termed harbor craft), based on an estimate of operating time of the vessels in service related to the 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

Consistent with EPA's latest Port EI Guidance document,[33] the load factor used for assist tug main engines is 50% and for auxiliary engines it is 43%. The main engine load factor for towboats is 68% and for auxiliary engines it is 43%.

[33] *https://www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance*

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 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 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. After the partial first year of operation, 2015, the number of barge calls has remained similar each year. 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 British Petroleum (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 2021, the fleet composite emission factors were updated based on the latest assist tug fleet mix and used for the 2022 and 2023 EI. 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. 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. Towboat emission factors are updated based on towboats from AIS data. Table 5.25 lists the assist tug emission factors and Table 5.26 lists the towboat emission factors. The latest emission factors from EPA's Port Emissions Inventory Guidance were used to calculate the composite emission factors.

Table 5.25: 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	4.28	0.09	0.09	0.08	1.46	0.01	679.5	0.03	0.001
Auxiliary Engines	4.87	0.10	0.09	0.16	0.93	0.01	679.5	0.03	0.003

Table 5.26: 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	8.65	0.19	0.19	0.18	1.82	0.01	679	0.03	0.003
Auxiliary Engines	7.95	0.22	0.21	0.26	1.28	0.01	679	0.03	0.005

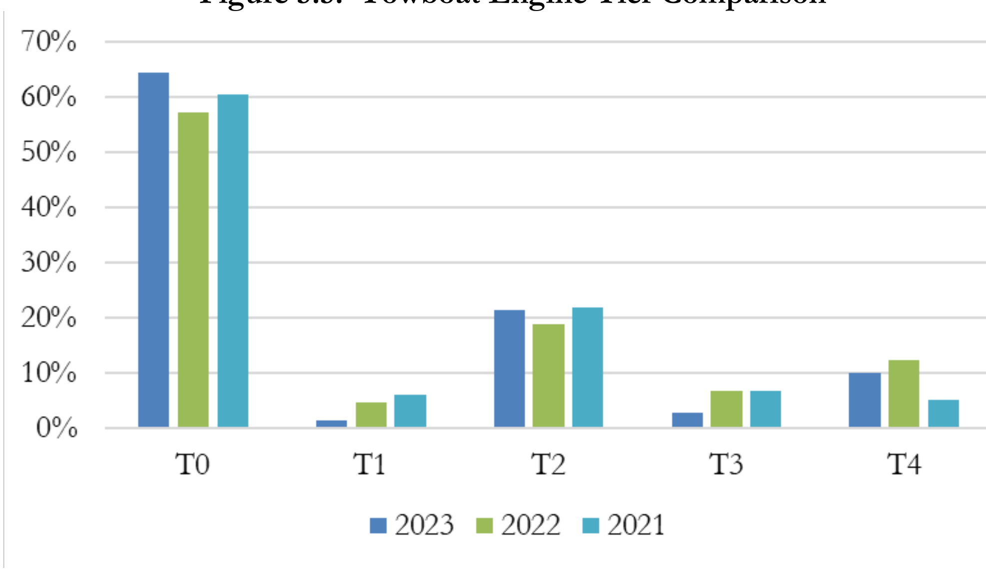
The engine emission factors are based on marine engine standards (i.e., Tier 1, Tier 2, Tier 3, and Tier 4). For the emissions inventory, the weighted assist tug emission factors were based on current tugboat fleet data. For 2023, the assist and escort services fleet were the same as what was used in 2022.

For towboats that transited the NYNJ harbor, the engine activity and engine Tier was updated based on 2023 information. The towboat emission factors were updated in 2023 accordingly. It should be noted that not all of these towboats called a Port Authority terminal, but the group as a whole is assumed to represent an average fleet of towboats operating in the EI domain in 2023. Table 5.27 presents the tier distribution of the harbor craft fleet in 2023. The assist tug engine tiers remained the same, but the towboat engine tiers were updated and show the engine fleet in 2023 is older than 2022 and 2021.

Table 5.27: Distribution of Harbor Craft Engines by Tier

Vessel Type	Engine Type	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
Assist Tug	Main	0%	0%	33%	33%	33%
Assist Tug	Auxiliary	0%	0%	22%	78%	0%
Towboat	Main	64%	1%	21%	2%	10%
Towboat	Auxiliary	60%	6%	20%	14%	0%

Figure 5.5: Towboat Engine Tier Comparison



5.4 Description of Marine Vessels and Vessel Activity

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

5.4.1 Ocean-Going Vessels

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

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

Figure 5.6: Bulk Carrier

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 5.7: 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 5.8: 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 5.9: Car Carrier

Tankers carry liquid bulk cargos such as crude oil, finished liquid petroleum products, and many 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 5.10: Tanker

5.4.2 Harbor Craft

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. Tugboats 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 5.11: Tugboat