

THE PORT AUTHORITY OF NEW YORK AND NEW JERSEY PORT DEPARTMENT 2022 MULTI-FACILITY EMISSIONS INVENTORY



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



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Prepared by:
 **STARCREST CONSULTING GROUP, LLC**
ENVIRONMENTAL MANAGEMENT • AIR QUALITY • CLIMATE • SUSTAINABILITY

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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 ₂ e	carbon dioxide equivalents
CSX	CSX Transportation, a US railroad
CVI	Clean Vessel Incentive Program
E	emissions
ECA	North American Emissions Control Area
EF	emission factor
EI	emissions inventory
EPA	United States Environmental Protection Agency
EPAMT	Elizabeth Port Authority Marine Terminal
ESI	Environmental Ship Index
FCF	fuel correction factor
GCT Bayonne	Global Container Terminal at the Port Jersey Port Authority Marine Terminal
GCT New York	Global Container Terminal at Howland Hook Marine Terminal on Staten Island
GHGs	greenhouse gases
g/hp-hr	grams per horsepower hour
g/mi	grams per mile
g/hr	grams per hour
g/MMGTM	grams of emissions per million gross ton-miles
GTM	gross ton-miles
GVWR	gross vehicle weight rating
GWP	global warming potential
HDV	heavy-duty (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
MHE	material handling equipment
MDO	marine diesel oil
MOVES3	EPA's motor vehicle emission estimating model
NO _x	oxides of nitrogen
N ₂ O	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

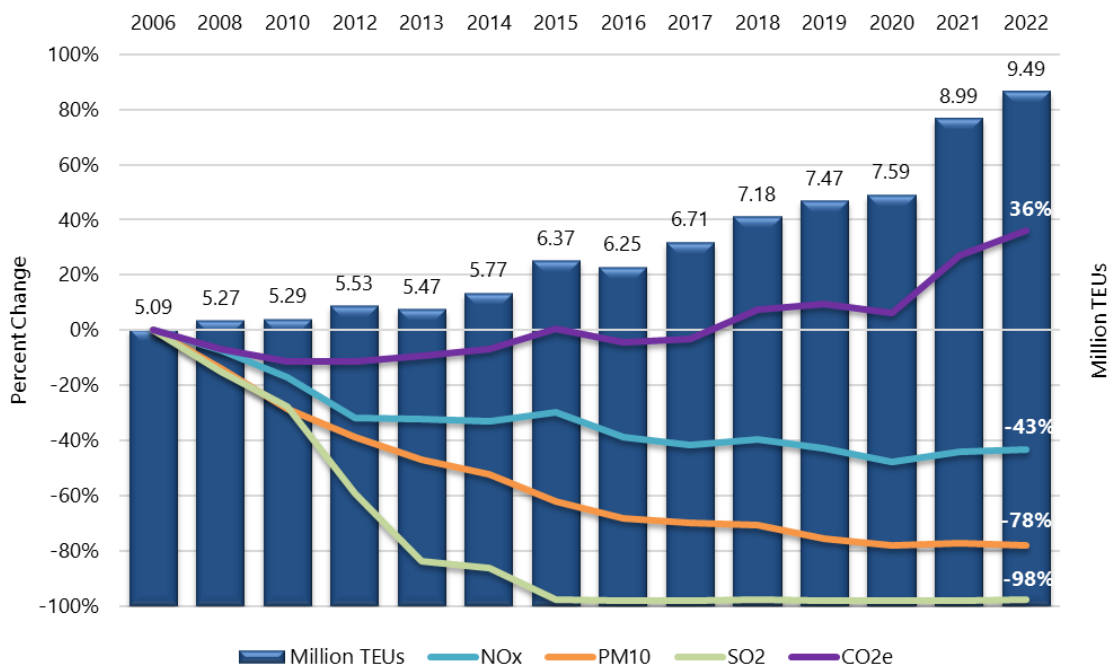
The purpose of this emissions inventory (EI) report is to present the 2022 mobile source air emissions from activities associated with the marine terminal facilities maintained by the Port Authority of New York and New Jersey (the Authority) and facilities leased to private terminal operators. These 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 2022 EI report is an update of the 2021 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 2022 emissions to the previous year (2021) 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, PM₁₀, PM_{2.5}, SO₂ and CO_{2e} between the 2006 baseline emissions inventory and the 2022 update, with emission trend lines superimposed over the blue columns illustrating annual TEU throughput in millions (M). NO_x, PM, and SO₂ emissions are significantly lower than the 2006 baseline emissions despite TEU cargo growth. The increase in GHG emissions (CO_{2e}) reflects the lack of lower emission standards or emission control measures for CO₂.

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



Emissions Comparison

Table ES.1 summarizes the emissions comparison. Calendar year 2022 was another record year for containerized cargo throughput at the Authority, reaching 9.5 million (M) TEUs.

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
2022	5,397	152	142	288	1,287	93	882,964	9.49
2021	5,294	157	146	296	1,264	79	824,072	8.99
2006	9,498	690	588	497	1,948	4,019	648,284	5.09
2021-2022, Change (%)	2%	-3%	-3%	-3%	2%	17%	7%	6%
2006-2022, Change (%)	-43%	-78%	-76%	-42%	-34%	-98%	36%	86%

Compared to previous year, emissions are higher in 2022, except for PM and VOC emissions. Compared to baseline 2006 emissions, emissions are lower in 2022, 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

	2022 vs 2021 Previous Year Change	2022 vs 2006 Baseline Change
Cargo TEU throughput	6% ↑	86% ↑
NO _x emissions	2% ↑	↓ -43%
PM ₁₀ emissions	↓ -3%	↓ -78%
PM _{2.5} emissions	↓ -3%	↓ -76%
VOC emissions	↓ -3%	↓ -42%
CO emissions	2% ↑	↓ -34%
SO ₂ emissions	17% ↑	↓ -98%
GHG emissions (CO _{2e})	7% ↑	36% ↑

ES.2 Emissions Comparison by Source Category

Key reasons for the lower criteria pollutant emissions in 2022 as compared to 2006 include regulatory requirements, voluntary actions, and measures implemented by the Port Authority to date¹.

- For MHE, under the Port Authority of New York and New Jersey (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 commercial 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 criteria pollutant emissions.
- For HDV, the PANYNJ Truck Replacement Program provides incentives to replace old trucks with newer, cleaner alternatives which reduces PM and NO_x emissions, mainly. 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 GCT 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 SO₂, NO_x and PM emissions.
- For OGV, the North American Emissions Control Area³ (ECA) continued to be in effect. The use of fuels with sulfur content of 0.1% or less lowers emissions of SO₂, NO_x and PM emissions from OGVs. In addition, the PANYNJ Clean Vessel Incentive (CVI) Program⁴ 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). CVI reduces criteria pollutants and GHG emissions by using less fuel and it has also increased the Tier III vessel calls. One of the cruise terminals supplies shore power to the cruise ships that are shore power capable. In 2022, alternative fueled containerships (LNG fuel) called the Port for the first time.
- 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.

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>

In general, the increase in GHG reflects the lack of lower emission standards or emission control measures for CO₂. GHG emissions will typically increase with increased activity and fuel consumption. Figure ES.3 presents the 2022 comparison to baseline year 2006 by source category. Most source categories have lower criteria pollutant emissions in 2022 as compared to 2006, except for locomotives.

Figure ES.3: 2006-2022 Emissions Comparison by Source Category

	MHE	Trucks	Locomotives	OGV	Harbor Craft
NO_x emissions	-76% ↓	-45% ↓	13% ↑	-33% ↓	-49% ↓
PM₁₀ emissions	-73% ↓	-65% ↓	13% ↑	-86% ↓	-81% ↓
PM_{2.5} emissions	-72% ↓	-65% ↓	14% ↑	-84% ↓	-79% ↓
VOC emissions	-76% ↓	-38% ↓	25% ↑	-25% ↓	-69% ↓
CO emissions	-67% ↓	-29% ↓	66% ↑	-18% ↓	-17% ↓
SO₂ emissions	-100% ↓	-86% ↓	-99% ↓	-98% ↓	-99% ↓
GHG emissions	12% ↑	90% ↑	88% ↑	-0.3% ↓	6% ↑

ES.3 Emissions Efficiency

Table ES.2 and Figure ES.4 provide the emissions per M TEUs. Compared to 2006, the 2022 metric is lower across all pollutants which shows efficiency in the emissions emitted per M TEU moved. The SO₂ and CO_{2e} emissions per M TEU are higher in 2022 than 2021 mainly due to the increased number of vessels at anchorage and more OGV activity, such as cruise vessels.

Table ES.2: Emissions Efficiency Metric Comparison

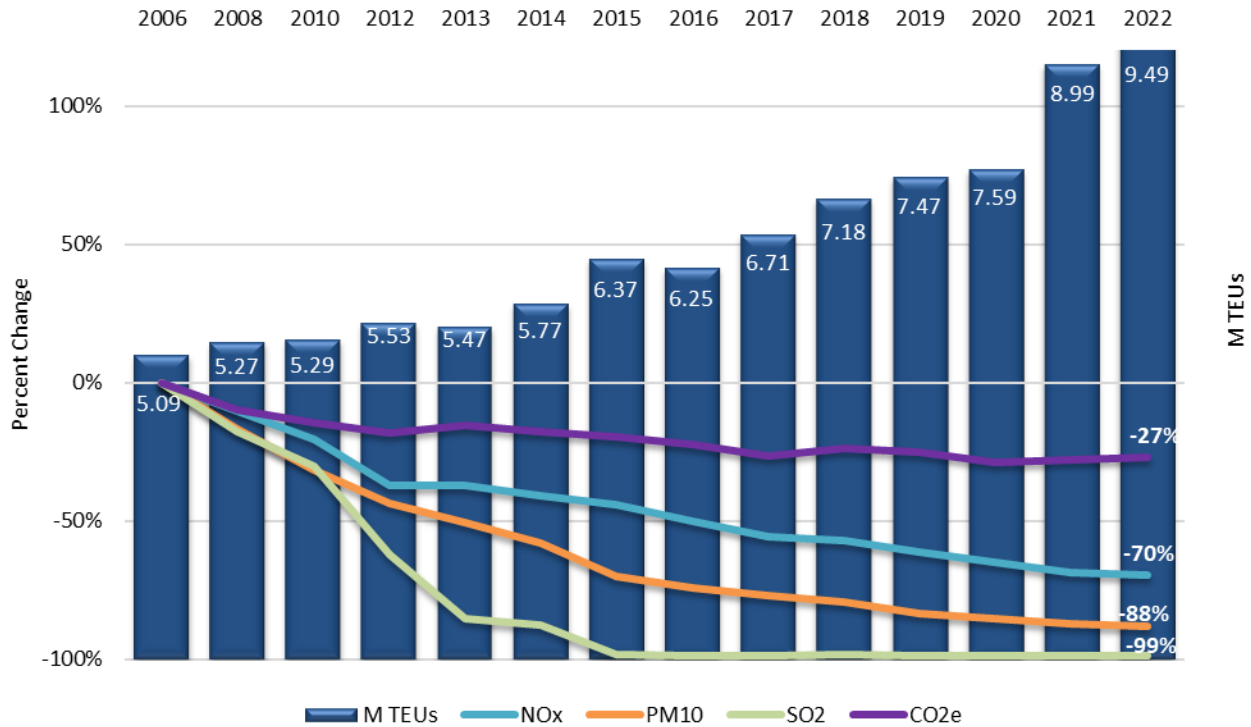
Inventory Year	Emissions / M TEUs						
	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
2022	568	16	15	30	136	10	93,006
2021	589	17	16	33	141	9	91,707
2006	1,865	135	115	98	382	789	127,289
2021-2022, Change (%)	-4%	-9%	-9%	-8%	-4%	11%	1%
2006-2022, Change (%)	-70%	-88%	-87%	-69%	-65%	-99%	-27%

Figure ES.4: Emissions Efficiency per M TEUs Comparison

	2022 vs 2021	2022 vs 2006
	Previous Year Change	Baseline Change
Cargo TEU throughput	6%	86%
NO _x emissions/M TEU	-4%	-70%
PM ₁₀ emissions/M TEU	-9%	-88%
PM _{2.5} emissions/M TEU	-9%	-87%
VOC emissions/M TEU	-8%	-69%
CO emissions/ M TEU	-4%	-65%
SO ₂ emissions/ M TEU	11%	-99%
GHG emissions (CO _{2e})/ M TEU	1%	-27%

Figure ES.5 shows the trend for emissions per M TEUs metric. Despite the 86% increase in cargo throughput, the emissions per M TEU are lower in 2022 than in 2006.

Figure ES.5: Emissions per M TEUs Trend



ES.4 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).

Table ES.3 presents the criteria pollutant and GHG (as CO₂e) 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 in 2022. The 2021 PANYNJ emissions were re-estimated to compare with the latest regional emissions show the year-to-year change.

⁵ For example, https://www.epa.gov/airquality/greenbook/map8br_2015.html

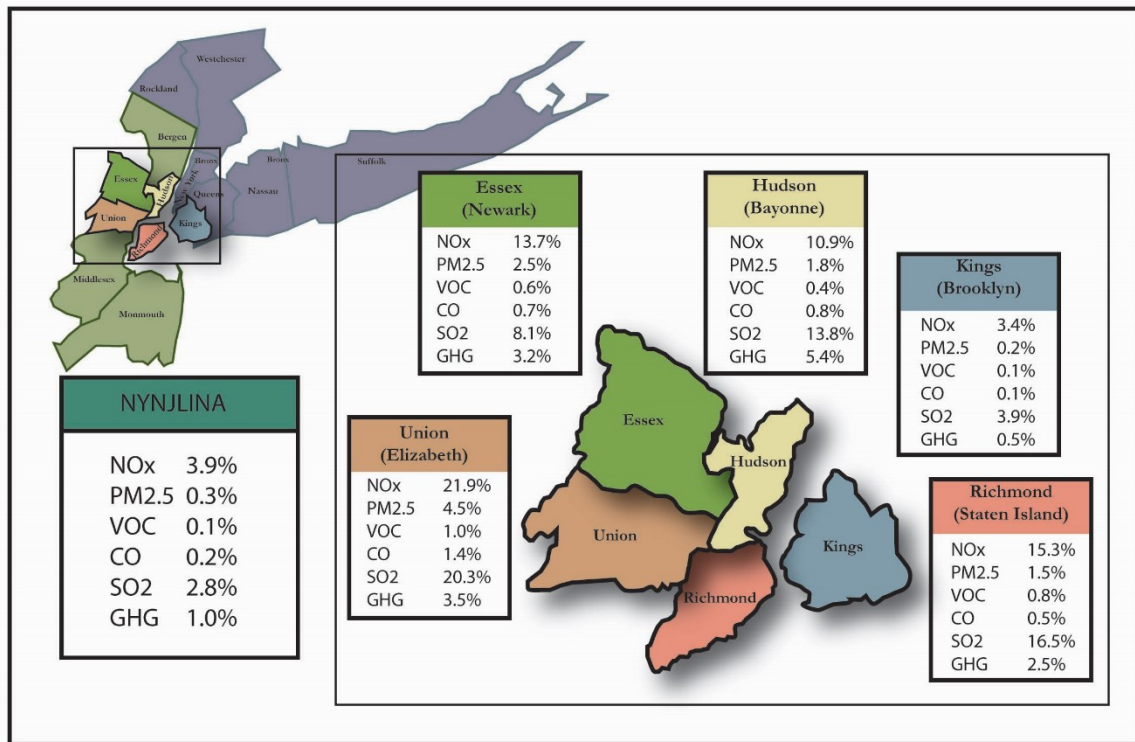
⁶ Emissions are primarily from the 2020 National Emissions Inventory, the most recent year’s inventory available from EPA. <https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data>

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}
Cargo handling equipment	362	27	26	32	166	0.5	172,640
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	2,799	53	49	140	296	90	220,987
Harbor craft	321	7	6	7	81	0.3	35,772
Total PANYNJ emissions	5,397	152	142	289	1,287	92.8	882,964
NYNJLINA emissions	137,049	95,410	40,985	220,174	838,105	3,327	92,488,145
2022 % of NYNJLINA Emissions	3.9%	0.2%	0.3%	0.1%	0.2%	2.8%	1.0%
2021 % of NYNJLINA Emissions	3.9%	0.2%	0.4%	0.1%	0.2%	2.4%	0.9%

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 2022 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).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 2022 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 2022, 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 2021 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 (PM₁₀),
- 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 (SO₂).

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

- Carbon dioxide (CO₂)
- Nitrous oxide (N₂O)
- Methane (CH₄)

GHG emissions are presented in terms of CO₂ equivalents (CO₂e), a measure that weights each gas by its global warming potential (GWP) value relative to CO₂. The CO₂e emissions include CO₂, methane (CH₄) and nitrous oxide (N₂O). The CO₂e value is calculated by multiplying each GHG's total emissions by its corresponding GWP value from EPA's latest GHG Inventory report⁹. The sum of the three GHGs is reported as one CO₂e value using the following GWP values.

- CO₂ – 1 N₂O – 298 CH₄ – 25

⁹ <https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks:1990-2019>

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 2022

In 2022, there were no changes to the emissions calculation methodology for any of the source categories. From an activity standpoint, there were more vessels at anchorage in 2022 due to supply chain congestion. Cruise vessel activity returned to normal post-COVID after low vessel calls in 2020 and 2021. The towboat engine characteristics were updated using the latest vessel information which showed larger engines and fleet turnover. 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 PANYNJ totals to the total emissions in the NYNJLINA¹⁰. The NYNJLINA emissions are from the 2020 NEI, the latest available. Comparing 2022 PANYNJ emissions to the latest 2020 NEI illustrates the relative contribution of the emission sources covered by this inventory to total emissions in the area.

Table 1.1: Emission Summary by Source Category, tpy

Source Category	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
Cargo handling equipment	362	27	26	32	166	0.5	172,640
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	2,799	53	49	140	296	90	220,987
Harbor craft	321	7	6	7	81	0.3	35,772
Total PANYNJ emissions	5,397	152	142	289	1,287	92.8	882,964
NYNJLINA emissions	137,049	95,410	40,985	220,174	838,105	3,327	92,488,145
2022 % of NYNJLINA Emissions	3.9%	0.2%	0.3%	0.1%	0.2%	2.8%	1.0%
2021 % of NYNJLINA Emissions	3.9%	0.2%	0.4%	0.1%	0.2%	2.4%	0.9%

Table 1.2 illustrates the percentage contribution of each source category to the total PANYNJ emissions of each pollutant. The OGV and HDV contribute most emissions (over 70-99% 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}
Cargo handling equipment	7%	18%	18%	11%	13%	1%	20%
Heavy-duty vehicles	29%	35%	35%	30%	52%	2%	48%
Locomotives	6%	8%	8%	9%	6%	0%	3%
Ocean-going vessels	52%	35%	34%	48%	23%	97%	25%
Harbor craft	6%	4%	5%	2%	6%	0%	4%
Total	100%	100%	100%	100%	100%	100%	100%

¹⁰ Criteria pollutant and GHG emissions are from the 2020 National Emissions Inventory: <https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data>

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

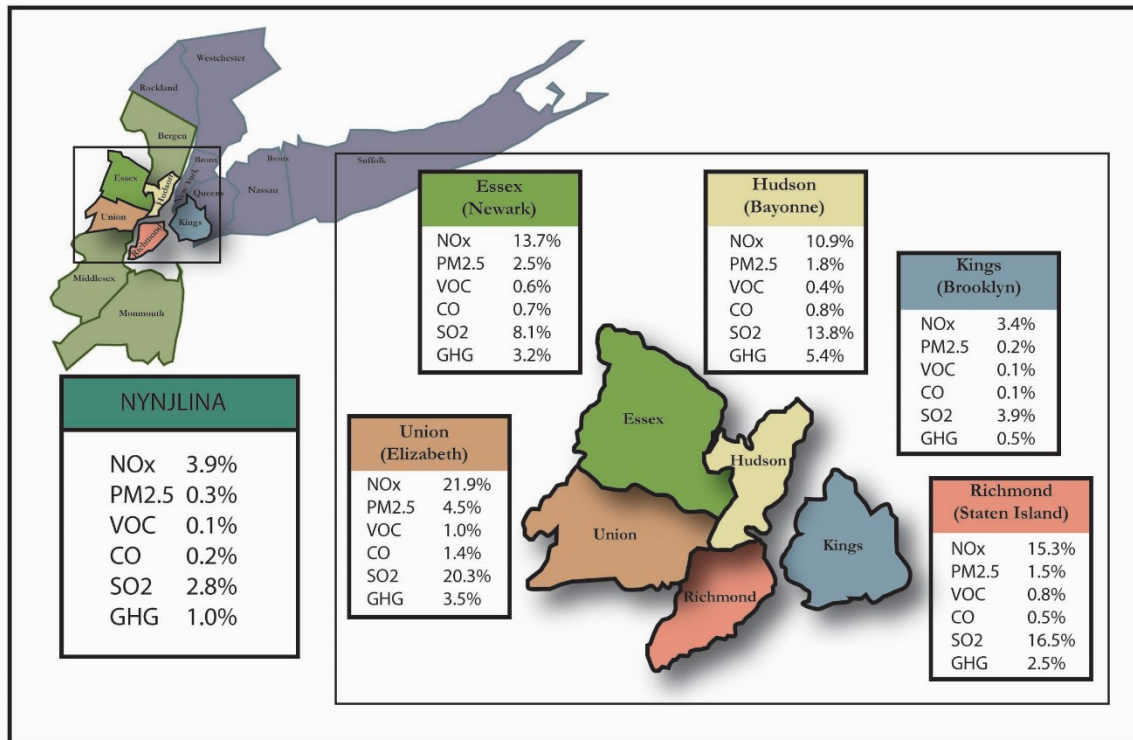


Table 1.3 summarizes by county the estimated emissions from the Authority marine terminal-related activities covered by this report.

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	118	4	3	5	47	0	29,994
Essex	NJ	1,171	34	31	61	282	22	197,570
Hudson	NJ	653	18	17	35	155	13	103,924
Middlesex	NJ	237	7	7	11	96	0	64,608
Monmouth	NJ	279	3	3	11	26	5	12,616
Union	NJ	1,612	60	56	91	461	31	348,671
New Jersey subtotal		4,070	125	117	215	1,067	71	757,383
Bronx	NY	12	0	0	1	5	0	3,415
Kings	NY	378	7	6	21	48	9	25,372
Nassau	NY	7	0	0	0	2	0	1,448
New York	NY	8	0	0	0	2	0	1,023
Orange	NY	65	2	2	3	27	0	18,369
Queens	NY	173	2	2	7	18	3	9,462
Richmond	NY	599	13	12	38	89	10	50,999
Rockland	NY	59	2	1	2	20	0	10,526
Suffolk	NY	13	0	0	0	4	0	1,959
Westchester	NY	13	0	0	1	5	0	2,997
New York subtotal		1,327	26	25	74	220	22	125,570
PANYNJ Total		5,397	152	142	289	1,287	93	882,964

Table 1.4 lists total emissions of each criteria pollutant by county and state, as reported in the 2020 NEI,¹¹ which represents the best source of area-wide emissions data and is the most current year available. The 2020 NEI emissions are lower for most pollutants than the previous 2017 NEI, except for PM emissions which are higher in 2020. The overall regional reduction in emissions may be due to stricter regulations for various sources not related to maritime. Table 1.5 provides the comparison of the two inventories for NYNJLINA.

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

Table 1.5: Comparison of NYNJLINA Emissions from 2017 and 2020 NEI, tpy

State	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
2017 NYNJLINA	195,448	70,552	31,889	252,955	1,011,780	8,568	106,102,779
2020 NYNJLINA	137,049	95,410	40,985	220,174	838,105	3,327	92,488,145
Change	-30%	35%	29%	-13%	-17%	-61%	-13%

¹¹ 2020 National Emissions Inventory, the most recent year’s inventory available from EPA.
<https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data>

1.5 Comparison of 2022 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.

The previous year (2021) and baseline (2006) emissions remain the same in this comparison as those published in the 2021 EI report because there were no methodology changes.

Table 1.6 presents the annual emissions in 2006, 2021, and 2022. The emissions are expressed in both tons per year and as percentage increases or decreases between 2022 and previous years. The last column includes the cargo throughput in M TEUs to compare the increased activity to the emission changes.

Table 1.6: Port Related Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM₁₀ tons	PM_{2.5} tons	VOC tons	CO tons	SO₂ tons	CO₂e tons	Throughput M TEUs
2022	5,397	152	142	288	1,287	93	882,964	9.49
2021	5,294	157	146	296	1,264	79	824,072	8.99
2006	9,498	690	588	497	1,948	4,019	648,284	5.09
2021-2022, Change (%)	2%	-3%	-3%	-3%	2%	17%	7%	6%
2006-2022, Change (%)	-43%	-78%	-76%	-42%	-34%	-98%	36%	86%

Table 1.7 presents the 2022 and 2006 emissions comparison by emission source category. Overall, the 2022 emissions are significantly lower than 2006, except for GHG emissions which are higher by 36% due to increased activity associated with the 86% increase in TEU throughput. In 2022, there are GHG emissions increases in all emission source categories, except for ocean-going vessels (OGV). Heavy duty trucks and locomotives saw the largest increases in GHG emissions. For OGV, the fewer and larger vessels calling the Port in 2022 are the primary reason for no change or increase in GHG emissions in 2022 despite the 86% increase in TEU throughput.

Since 2006, SO₂ 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 (PM₁₀ and PM_{2.5}) is lower due to a combination of factors including the Authority’s Truck Replacement Program that has brought many newer trucks into the fleet of 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 tariff 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 is due to fleet turnover.

Table 1.7: Port Related 2022-2006 Emissions Comparison by Source Category

	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
	tons	tons	tons	tons	tons	tons	tons
2022							
Cargo handling equipment	362	27	26	32	166	0.5	172,640
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	2,799	53	49	140	296	90.2	220,987
Harbor craft	321	7	6	7	81	0.3	35,772
Total	5,397	152	142	288	1,287	93	882,964
2006							
Cargo 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 2022 (percent)							
Cargo handling equipment	-76%	-73%	-72%	-76%	-67%	-100%	12%
Heavy-duty vehicles	-45%	-65%	-65%	-38%	-29%	-86%	90%
Locomotives	13%	13%	14%	25%	66%	-99%	88%
Ocean-going vessels	-33%	-86%	-84%	-25%	-18%	-98%	0%
Harbor craft	-49%	-81%	-79%	-69%	-17%	-99%	6%
Total	-43%	-78%	-76%	-42%	-34%	-98%	36%

Table 1.8 presents the 2022 and 2021 emissions comparison by source category. In 2022, a 6% increase in TEU throughput resulted in higher overall emissions as compared to 2021 for all pollutants. Additionally, post pandemic supply chain disruptions caused significant vessel delays at West Coast ports in 2021 resulting in both vessel and cargo diversions to East Coast ports which continued through all of 2022. In 2022, there were more vessels at anchorage than in previous years. The cruise vessel operations returned to normal in 2022 after hardly any activity two years prior. The increased cruise vessel activity and vessels at anchorage resulted in higher OGV emissions in 2022 compared to 2021.

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 1.8: Port Related 2022-2021 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
2022							
Cargo handling equipment	362	27	26	32	166	0.5	172,640
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	2,799	53	49	140	296	90.2	220,987
Harbor craft	321	7	6	7	81	0.3	35,772
Total	5,397	152	142	288	1,287	92.8	882,964
2021							
Cargo handling equipment	379	28	27	33	175	0.5	166,170
Heavy-duty vehicles	1,747	65	60	100	669	1.4	403,806
Locomotives	327	12	11	25	73	0.3	27,691
Ocean-going vessels	2,535	46	43	131	267	76.6	190,931
Harbor craft	307	6	6	6	79	0.3	35,475
Total	5,294	157	146	296	1,264	79.1	824,072
Change between 2021 and 2022 (percent)							
Cargo handling equipment	-5%	-3%	-3%	-5%	-6%	3%	4%
Heavy-duty vehicles	-9%	-17%	-17%	-14%	0%	7%	5%
Locomotives	-1%	-2%	-1%	-1%	-1%	-9%	0%
Ocean-going vessels	10%	14%	14%	6%	11%	18%	16%
Harbor craft	5%	6%	6%	3%	2%	1%	1%
Total	2%	-3%	-3%	-3%	2%	17%	7%

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
- GCT New York at Howland Hook Marine Terminal on Staten Island
- APM Terminal at the Elizabeth-Port Authority Marine Terminal
- Maher Terminal at the Elizabeth-Port Authority Marine Terminal
- Port Newark Container Terminal (PNCT) at Port Newark
- GCT Bayonne at the Port Jersey-Port Authority Marine Terminal
- Cape Liberty Cruise Terminals at the Port Jersey-Port Authority Marine Terminal
- Brooklyn Cruise Terminals at the Brooklyn-Port Authority Marine Terminal

The limited amount of 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
- RMG crane
- RTG crane
- Skid steer loader
- Straddle carrier
- Ship to shore crane
- Sweeper
- Top handler
- Tractor
- Truck
- Yard tractor

2.1 Emission Estimates

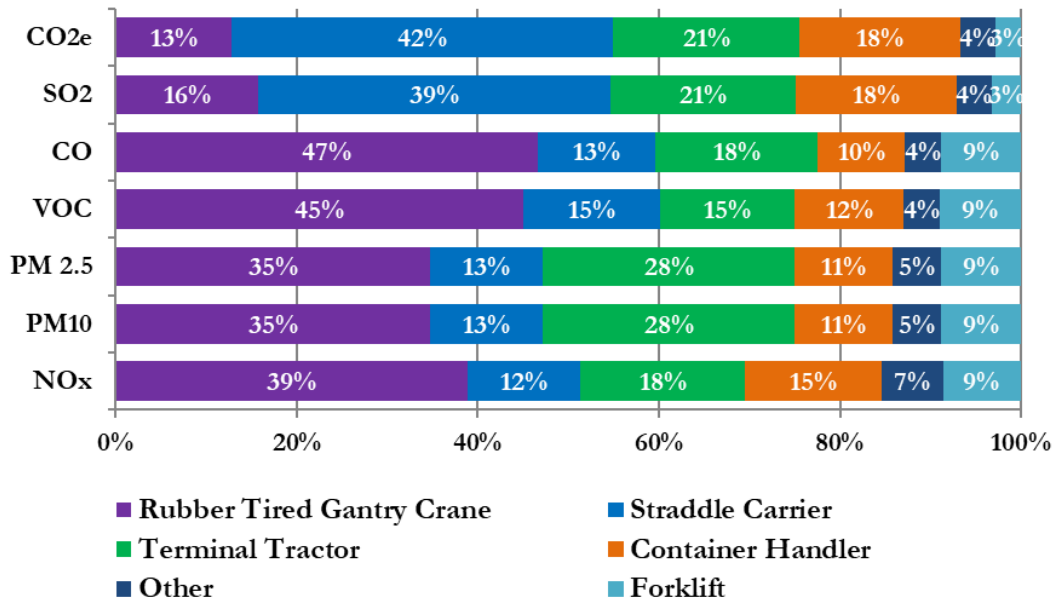
Table 2.1 presents emissions sorted by equipment type for all terminals combined.

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	66	7.5	7.2	4.7	29.6	0.10	35,667
Straddle Carrier	45	3.4	3.3	4.9	21.5	0.20	72,758
Forklift	31	2.4	2.3	2.8	14.5	0.02	4,946
Empty Container Handler	26	1.4	1.4	1.9	6.8	0.03	9,605
Loaded Container Handler	29	1.5	1.4	2.0	9.1	0.06	20,951
Rubber Tired Gantry Crane	141	9.3	9.0	14.5	77.3	0.08	22,053
Reach Stacker	18	0.7	0.6	0.9	4.4	0.02	5,159
Other Equipment	7	0.8	0.8	0.4	2.4	0.00	1,501
Totals	362	27	26	32	166	0.50	172,640

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 PANYNJ 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. The 2021 MHE emissions contribution is also included in the table for context as the earlier published percent contribution changed.

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

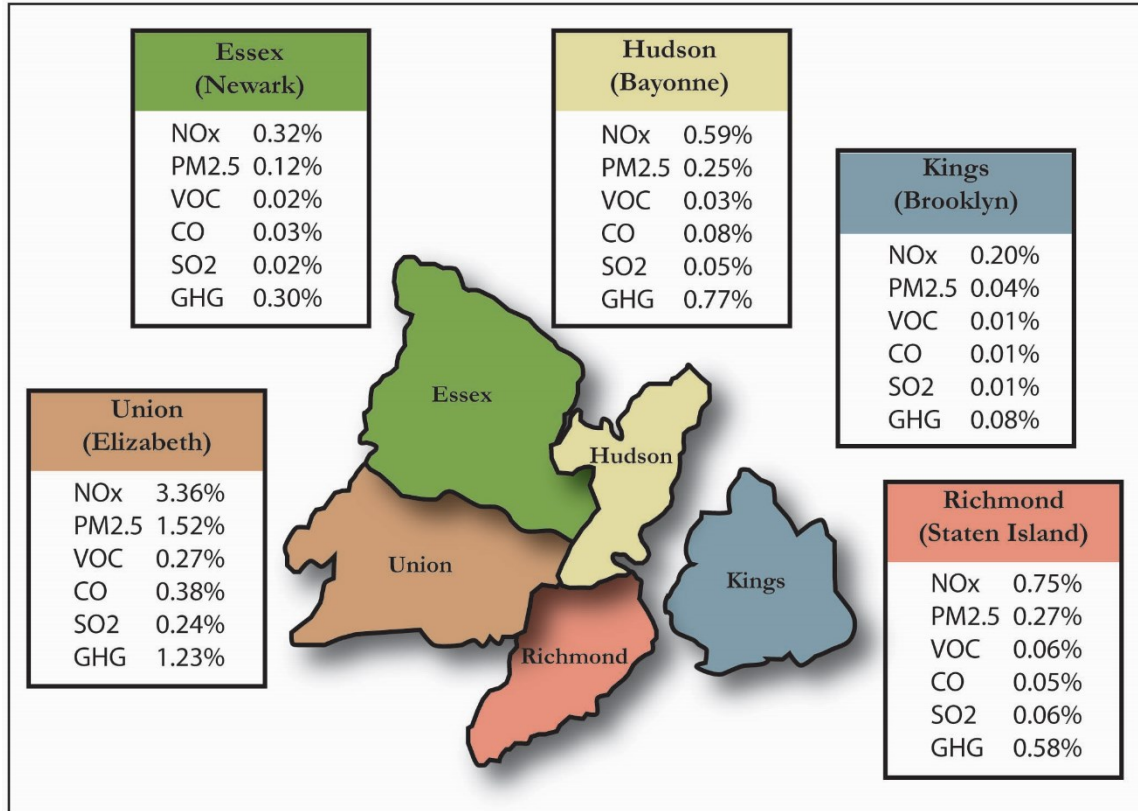
Geographical Extent / Source Category	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
NY and NJ	288,737	403,780	130,494	882,141	1,948,186	14,400	178,760,766
NYNJLINA	137,049	95,410	40,985	220,174	838,105	3,327	92,488,145
2022 CHE	362	27	26	32	166	1	172,640
2022 % of NYNJLINA Emissions	0.26%	0.03%	0.06%	0.01%	0.02%	0.015%	0.19%
2021 % of NYNJLINA Emissions	0.28%	0.03%	0.07%	0.02%	0.02%	0.015%	0.18%

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	0	0.00	0
Essex	NJ	27	1.6	1.5	1.9	11	0.05	18,816
Hudson	NJ	35	2.4	2.3	2.7	16	0.04	14,757
Middlesex	NJ	0	0.0	0.0	0.0	0	0.00	0
Monmouth	NJ	0	0.0	0.0	0.0	0	0.00	0
Union	NJ	247	19.4	18.9	23.4	121	0.36	123,264
New Jersey subtotal		310	23.4	22.7	27.9	148	0.46	156,838
Bronx	NY	0	0.0	0.0	0.0	0	0.00	0
Kings	NY	23	1.3	1.3	1.9	7	0.01	4,071
Nassau	NY	0	0.0	0.0	0.0	0	0.00	0
New York	NY	0	0.0	0.0	0.0	0	0.00	0
Orange	NY	0	0.0	0.0	0.0	0	0.00	0
Queens	NY	0	0.0	0.0	0.0	0	0.00	0
Richmond	NY	29	2.1	2.1	1.7	10	0.03	11,731
Rockland	NY	0	0.0	0.0	0.0	0	0.00	0
Suffolk	NY	0	0.0	0.0	0.0	0	0.00	0
Westchester	NY	0	0.0	0.0	0.0	0	0.00	0
New York subtotal		52	3.4	3.3	3.6	18	0.05	15,802
TOTAL		362	26.9	26.1	31.5	166	0.50	172,640

The following figure 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 2022, the previous year, and 2006 estimates. In 2022, cargo throughput increased by 6% from the previous year, and emissions decreased for most pollutants. The SO₂ and CO_{2e} emissions which are dependent on fuel consumption increased due to activity increase.

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	Million TEUs
2022	362	27	26	32	166	1	172,640	9.49
2021	379	28	27	33	175	0	166,170	8.99
2006	1,503	100	92	132	495	233	154,184	5.09
2021-2022, Change (%)	-5%	-3%	-3%	-5%	-6%	3%	4%	6%
2006-2022, Change (%)	-76%	-73%	-72%	-76%	-67%	-100%	12%	86%

For most pollutants, emissions from MHE were significantly lower in 2022 as compared to 2006 despite the 86% 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 (CO₂ equivalents) were 12% higher in 2022 than in 2006 because the primary contributor to CO₂, diesel fuel, is still heavily relied upon to power MHE engines.

The following figure graphically illustrates the changes in MHE emissions between the 2006 baseline emissions inventory and 2022, with emission trend lines superimposed over the annual M TEU throughput.

Figure 2.3: MHE Emissions Relative to TEU Throughput

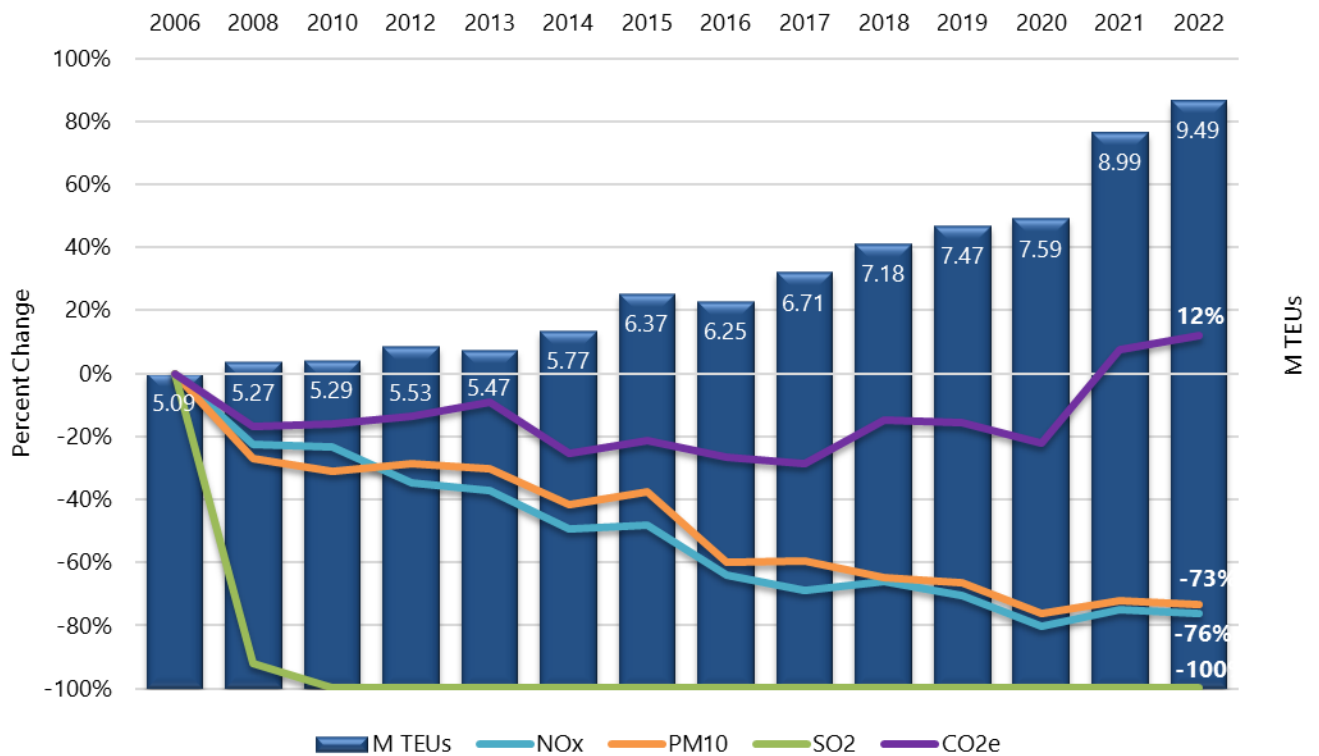


Table 2.5 compares emissions efficiency per M TEUs.

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 ₂ e
2022	38	3	3	3	17	0.053	18,185
2021	42	3	3	4	20	0.054	18,492
2006	295	20	18	26	97	46	30,274
2021-2022, Change (%)	-10%	-9%	-9%	-10%	-11%	-3%	-2%
2006-2022, Change (%)	-87%	-86%	-85%	-87%	-82%	-100%	-40%

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.¹² 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.

¹² <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	2270003040	0.43	Other industrial equipment
Empty container handler			
Rubber tired gantry crane	2270003050	0.21	Other material handling equipment
Straddle carrier			
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 (107 in 2022) 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	2006 Count	2021 Count	2022 Count
	Category Code			
Aerial lift	2270003010	11	21	22
Crane	2270002045	13	4	4
Diesel forklift	2270003020	0	145	163
Propane forklift	2267003020	87	103	90
Other industrial equipment	2270003040	143	199	217
Other material handling equipment	2270003050	260	457	457
Offroad truck	2270002051	9	13	13
Signal board / light plant	2270002027	12	12	12
Skid-steer Loader	2270002072	0	18	18
Sweeper / scrubber	2270003030	2	3	4
Terminal tractor	2270003070	350	418	435
Totals		887	1,393	1,435

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 (87%) of equipment is diesel powered, as illustrated in Figure 2.4. The inventory also includes 90 propane powered forklifts and 107 pieces of electric equipment. The electric equipment includes two aerial platforms, 18 forklifts, 24 RMG cranes, and 63 ship to shore cranes. In 2021, there are fewer electric forklifts which resulted in overall less electric equipment in addition to more diesel equipment than the previous year.

Figure 2.4: Material Handling Equipment Count by Fuel Type

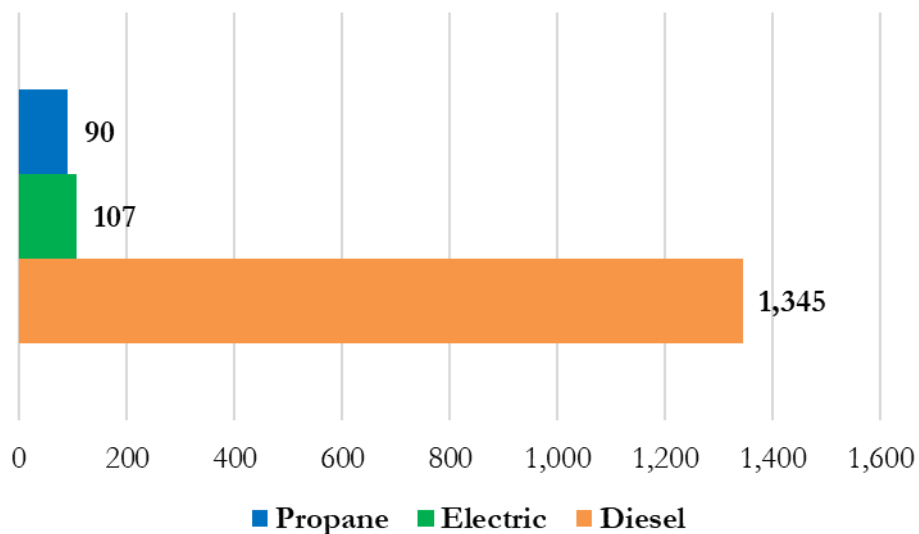


Table 2.8 summarizes the 2022 fleet characteristics of the MHE, including electric equipment, in terms of equipment count, model year, horsepower, and annual operating hours. As noted above, emissions were estimated using equipment-specific values for each piece of equipment. When the model year, horsepower 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

Equipment Type	Count	Power (hp)			Model Year			Annual Activity Hours		
		Min	Max	Average	Min	Max	Average	Min	Max	Average
Aerial platform	24	49	200	63	2004	2022	2014	0	592	169
Crane	4	900	950	925	1981	1999	1991	23	498	261
Empty Container Handler	86	160	252	204	1995	2022	2014	0	6,481	2,155
Forklift	271	42	350	93	1987	2022	2012	6	8,440	705
Light Tower	12	50	50	50	2001	2001	2001	0	400	167
Reach Stacker	44	200	382	335	1999	2021	2011	3	2,672	1,352
RMG Crane (electric)	24									
RTG Crane	64	450	1,000	591	2001	2022	2006	292	8,400	4,319
Skid Steer Loader	18	38	49	47	2004	2019	2017	10	341	176
Straddle Carrier	393	193	450	354	2006	2022	2016	0	7,204	3,279
STS Crane (electric)	63									
Sweeper	4	38	38	38	2005	2019	2012	200	300	275
Top Handler	87	284	388	358	2004	2022	2015	0	6,324	2,666
Tractor	4	38	38	38	2014	2014	2014	10	20	13
Truck	13	240	325	263	2002	2016	2009	0	2,600	1,005
Yard tractor	431	145	245	170	1999	2022	2015	0	5,684	2,127
Total	1,542									

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

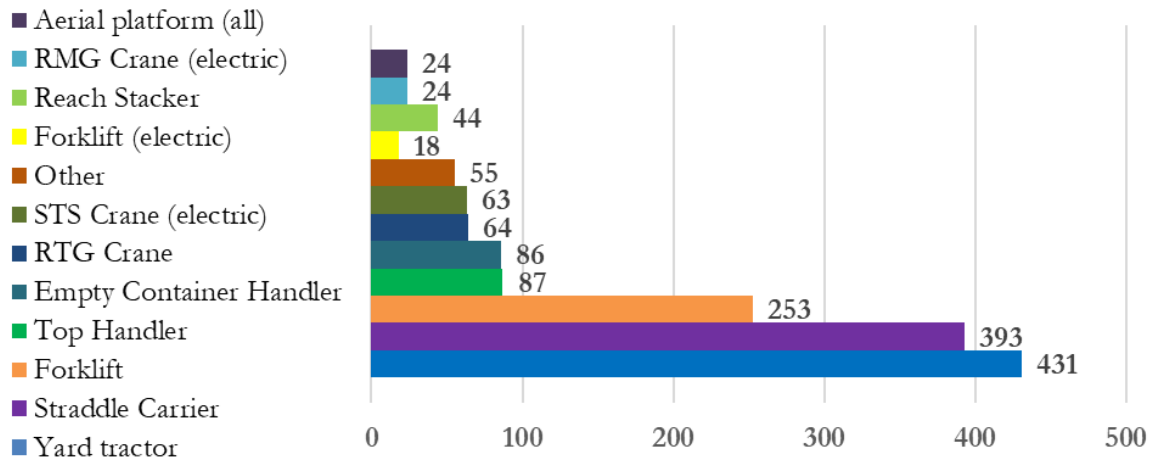


Table 2.9 presents the diesel engines by Tier in the 2022 inventory for 1,345 diesel engines. In 2022, equipment turnover to Tier 4 engines continued. The previous year’s percentages were included for comparison. The table includes diesel equipment count only and does not match the overall equipment 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	3	22	15	45	0	86
Forklift	13	17	11	6	59	57	0	163
Loaded Container Handler	0	0	2	14	8	63	0	87
Reach Stacker	0	2	8	5	5	15	9	44
RTG Crane	0	7	30	18	3	6	0	64
Straddle Carrier	0	0	0	35	47	311	0	393
Terminal Tractor	0	6	20	66	37	302	0	431
Other	4	13	10	6	2	33	9	77
2022 Total	18	45	84	172	176	832	18	1,345
2022 Percent	1%	3%	6%	13%	13%	62%	1.3%	
2021 Percent	1%	4%	7%	15%	14%	59%	0.9%	

Figure 2.6: MHE Diesel Engine Tier Count Distribution

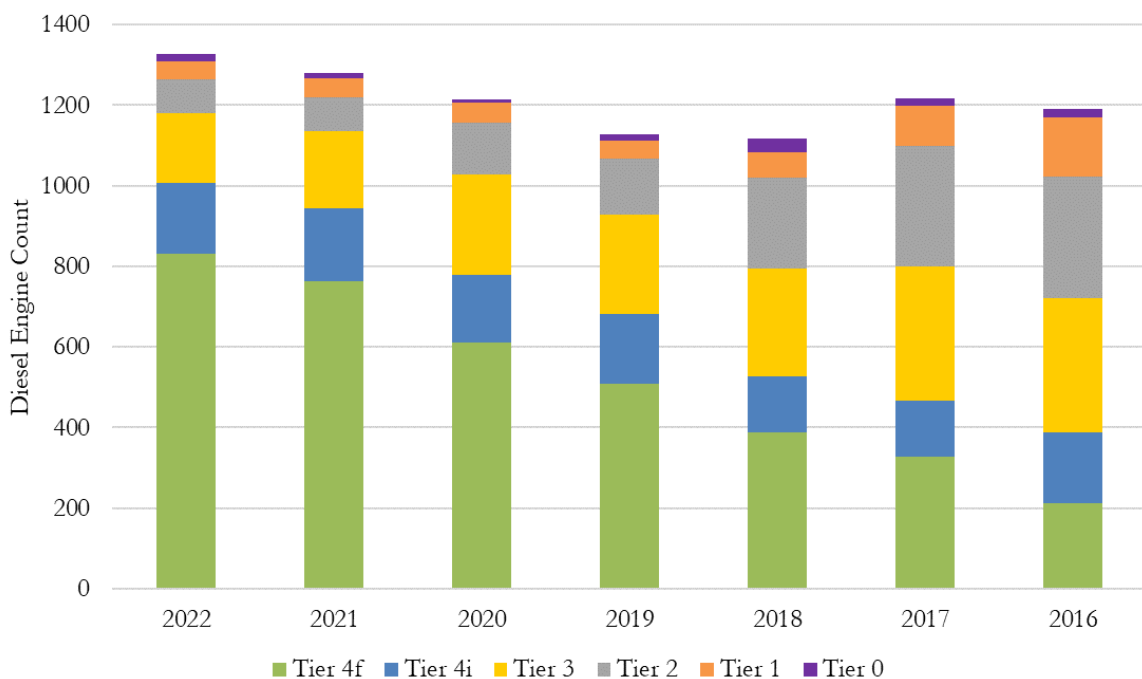


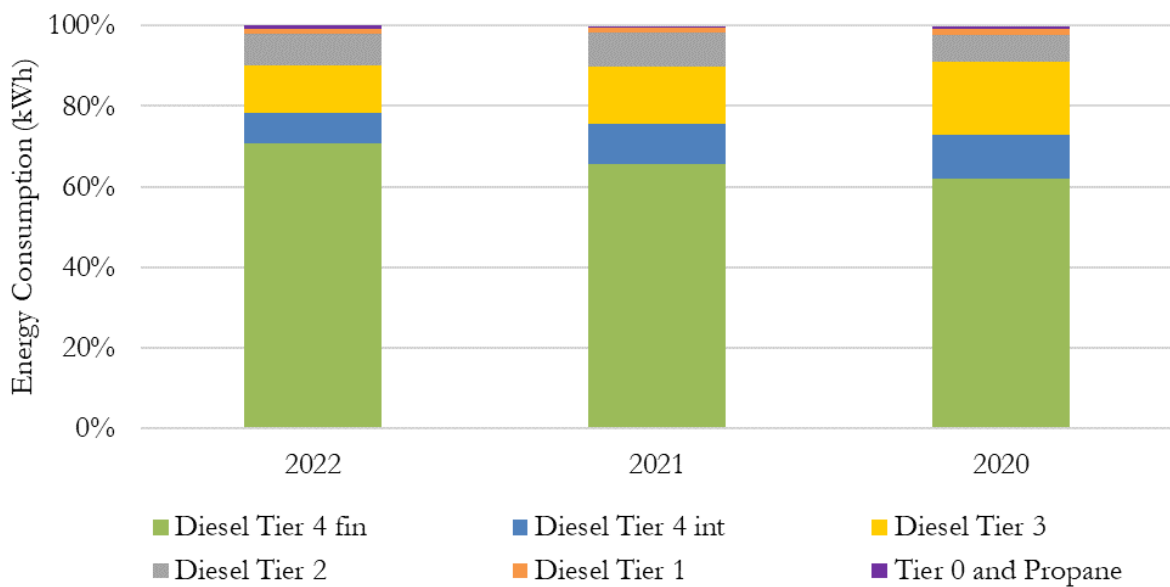
Table 2.10 shows the 2022 MHE energy consumption for propane and diesel equipment by Tier level. About 90% of total equipment energy usage in terms of kWh is from diesel Tier 3 and Tier 4 equipment. The newer pieces of equipment are being used more, especially Tier 4, and produce lower emissions.

Table 2.10: MHE Energy Consumption

Engine Type and Tier	Energy Consumption kWh	Percent Total 2022	Percent Total 2021
Propane	375,885	0.2%	0.2%
Diesel Tier 0	1,151,523	0.6%	0.2%
Diesel Tier 1	2,293,091	1%	1%
Diesel Tier 2	15,981,627	8%	9%
Diesel Tier 3	23,377,531	12%	14%
Diesel Tier 4 int	14,948,176	8%	10%
Diesel Tier 4 fin	141,067,515	71%	66%
Total	199,195,349	100%	

Figure 2.7 shows the comparison in energy consumption (kWh) distribution since 2020 when data is 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 equipment 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 MOVES3b 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	96	3.4	3.1	5.5	44	0.07	20,550
On-Terminal Idling	184	8	8	17	73	0.13	26,839
On-Road Driving	1,311	42	39	63	554	1.28	378,561
Totals	1,592	54	50	85	671	1.48	425,950

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%	47	1.6	1.5	2.5	20	0.04	12,664
Non-tenant trucks	97%	1,544	52	48	83	651	1.44	413,286
All Trucks	100%	1,592	54	50	85	671	1.48	425,950

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	95	3.3	3.1	5.4	44	0.07	20,293
On-Terminal Idling	167	7	7	15	66	0.11	24,298
New Jersey subtotal	262	11	10	20	110	0.18	44,592
New York							
On-Terminal Driving	1.2	0.04	0.04	0.07	0.6	0.001	257
On-Terminal Idling	17	0.8	0.7	1.5	6.7	0.01	2,541
New York subtotal	18	0.8	0.8	1.6	7.3	0.01	2,797
Total NJ & NY	280	12	11	22	117	0.20	47,389

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	Vehicle Miles Traveled (VMT)	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
New Jersey	177,465,827	1,178	38	35	57	497	1.2	340,053
New York	20,096,546	133	4	4	6	56	0.1	38,508
Total	197,562,373	1,311	42	39	63	554	1.3	378,561

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 2022 HDV emission estimates with the results of the previous year (2021) 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 NEI¹³. 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 PANYNJ HDV emissions make up of overall NYNJLINA emissions. Due to using 2020 NEI values which are lower than the 2017 NEI values used in the previous report, the NO_x and CO₂ percentages are higher in this inventory than in the previous report. But the percent of PANYNJ HDV emissions are lower in 2022 than in the previous year if the 2020 NEI values were to be used for both 2021 and 2022 to compare the percent contribution of PANYNJ HDV.

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
HDDV	1,592	54	50	85	671	1	425,950
2022 % of NYNJLINA Emissions	1.16%	0.06%	0.12%	0.04%	0.08%	0.04%	0.46%
2021 % of NYNJLINA Emissions	1.27%	0.07%	0.15%	0.05%	0.08%	0.04%	0.44%

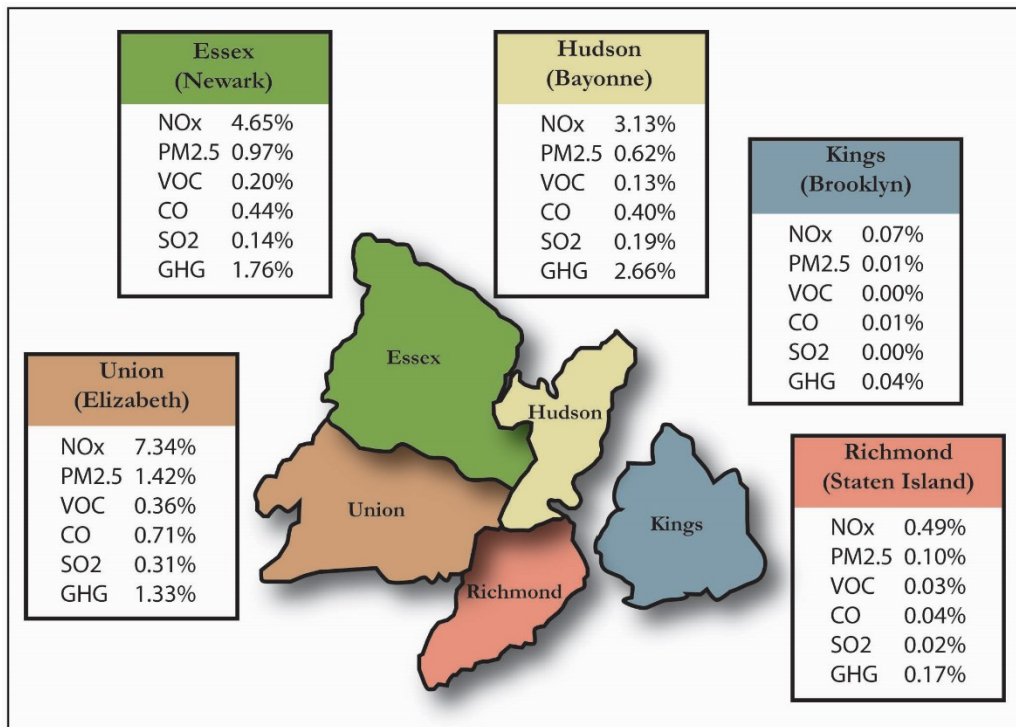
¹³ Accessed at: <https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data>

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	95	3.1	2.8	5	40	0.09	27,390
Essex	NJ	398	13.2	12.2	21	169	0.38	109,143
Hudson	NJ	188	6.3	5.8	10	79	0.18	51,334
Middlesex	NJ	217	7.0	6.5	11	92	0.21	62,753
Monmouth	NJ	1	0.0	0.0	0	0	0.00	266
Union	NJ	540	19.1	17.6	32	227	0.48	133,758
New Jersey subtotal		1,440	49	45	77	607	1.34	384,644
Bronx	NY	12	0.4	0.3	1	5	0.01	3,387
Kings	NY	8	0.3	0.3	0	3	0.01	2,005
Nassau	NY	4	0.1	0.1	0	2	0.00	1,246
New York	NY	2	0.1	0.1	0	1	0.00	520
Orange	NY	63	2.0	1.9	3	27	0.06	18,195
Queens	NY	8	0.2	0.2	0	3	0.01	2,202
Richmond	NY	19	0.8	0.7	2	8	0.01	3,357
Rockland	NY	22	0.7	0.7	1	9	0.02	6,388
Suffolk	NY	4	0.1	0.1	0	2	0.00	1,270
Westchester	NY	9	0.3	0.3	0	4	0.01	2,734
New York subtotal		152	5	5	8	64	0.14	41,306
Total NJ & NY		1,592	54	50	85	671	1.48	425,950

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



3.2.2 Comparisons with Prior Year Emission Estimates

Table 3.7 presents annual HDV emissions in 2022, 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 increase 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	Emissions / M TEUs							Throughput M TEUs
	NO _x tons	PM ₁₀ tons	PM _{2.5} tons	VOC tons	CO tons	SO ₂ tons	CO _{2e} tons	
2022	1,592	54	50	85	671	1	425,950	9.49
2021	1,747	65	60	100	669	1	403,806	8.99
2006	2,911	154	141	139	951	10	224,050	5.09
2021-2022, Change (%)	-9%	-17%	-17%	-14%	0.3%	7%	5%	6%
2006-2022, Change (%)	-45%	-65%	-65%	-38%	-29%	-86%	90%	86%

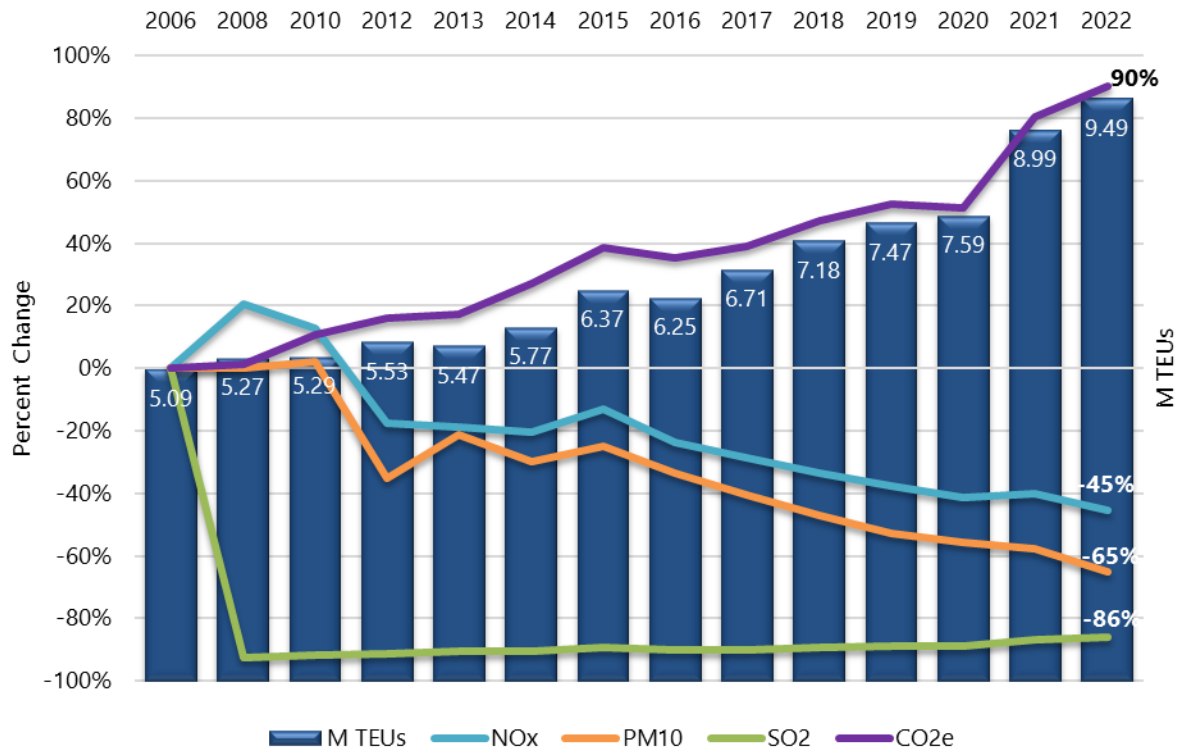
Table 3.8 compares emissions per M TEUs.

Table 3.8: HDV Emission per M TEUs Comparison

Inventory Year	Emissions / M TEUs						
	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
2022	168	6	5	9	71	0.16	44,867
2021	194	7	7	11	74	0.15	44,938
2006	572	30	28	27	187	2.05	43,992
2021-2022, Change (%)	-14%	-22%	-22%	-19%	-5%	2%	0%
2006-2022, Change (%)	-71%	-81%	-81%	-67%	-62%	-92%	2%

The following figure graphically illustrates the changes in HDV emissions between the 2006 baseline emissions inventory and the 2022 update. The PM₁₀ and PM_{2.5} emissions track closely together, with a 77% emission reduction in 2022 as compared to 2006.

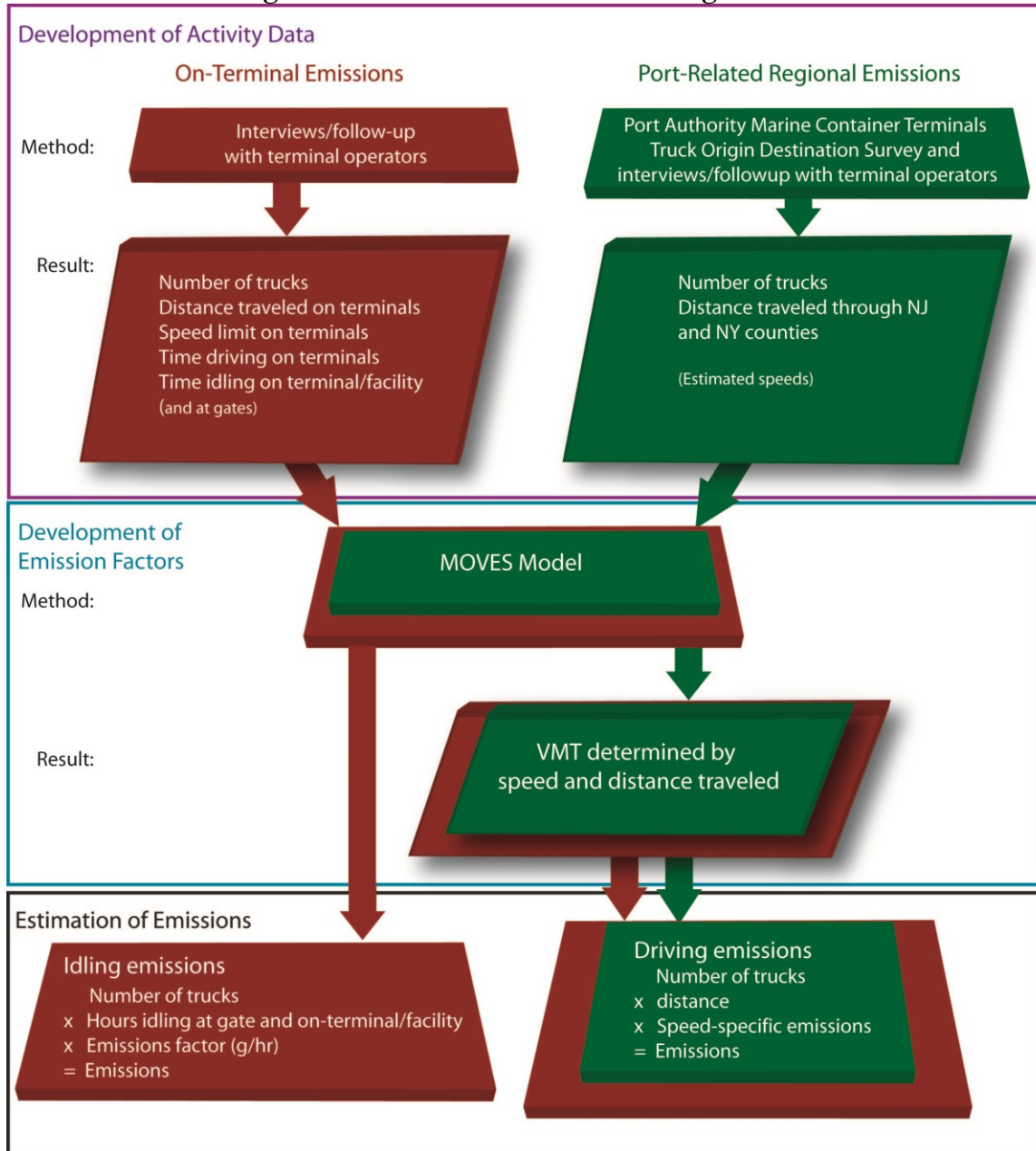
Figure 3.2: HDV Emissions Relative to M TEU Throughput



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, 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	2,427,184	3,640,777	1,128,641
Container B	1,504,299	1,504,299	804,800
Container C	1,011,863	1,618,980	394,626
Container D	737,850	737,850	243,490
Container E	549,881	54,988	250,196
Container F	82,636	41,318	36,360

The average idling times were based on information previously provided by the terminals. In addition, the prevalence of idling by trucks waiting at warehouses was evaluated by site observations made on two different days during a previous drayage truck survey conducted in 2008, to account for the fact that not all trucks idle while they are being unloaded or loaded at the warehouses. On average, 35% of trucks were observed to be idling while at the warehouses. While a 3-minute idling limit rule is in place on and around the terminals, the aggregate of several 3-minute (or less) periods of idling during a truck's transit through a terminal (stop-and-go activity) can produce total idling times as shown in the table.

On-Road

Vehicle miles of travel (VMT) were estimated for regional HDV activity by estimating the average distances between the terminals and origin or destination locations in the NYNJLINA or, for trips that start in or extend into adjacent counties or states, to/from the boundary of the NYNJLINA. These VMT estimates were used with the number of truck trips and appropriate emission factors to estimate on-road 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 Hatch¹⁴ 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.

¹⁴ 2017 Origin & Destination Study. Hatch, draft report 2017.

Figure 3.4 below illustrates the changes in model year distributions of the trucks serving the Authority terminals in calendar years 2008, 2010, and 2012 through 2022. 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.

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 2022, 69% 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

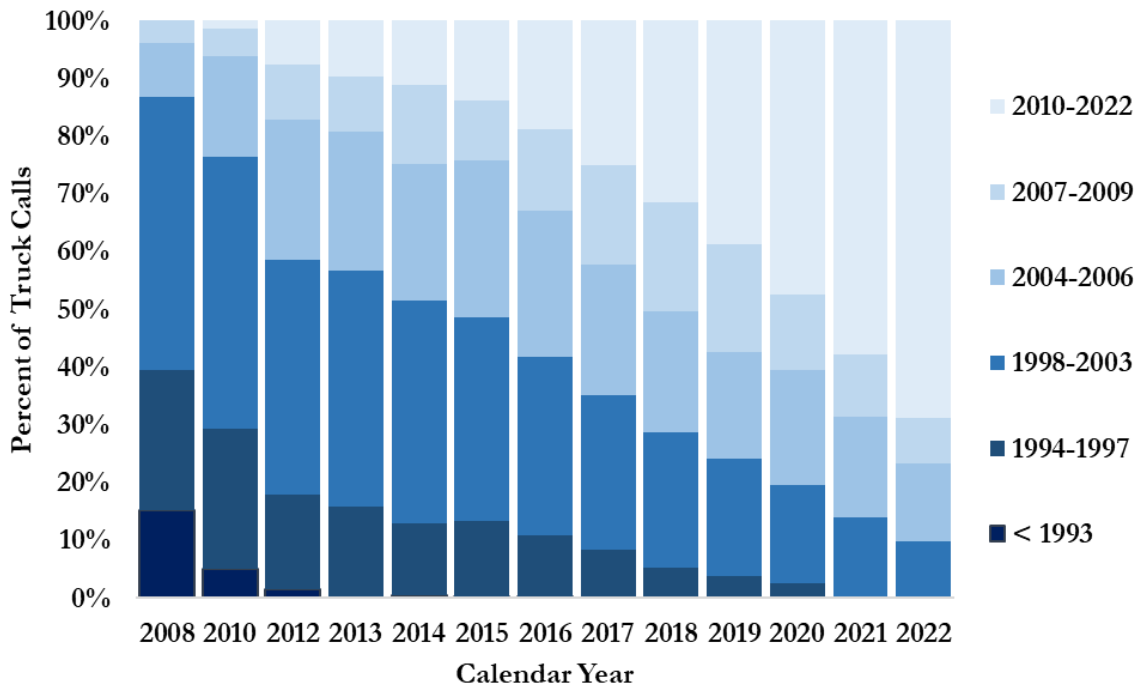


Figure 3.5 illustrates the model year distribution of HDV during 2022 in more detail. This figure shows that 1998 through 2003 trucks made up 10% of calls, model years 2004 through 2006 made up 13% of calls, model years 2007 through 2009 made up 8% of the calls, and, as noted above, 69% of calls were made by trucks of model year 2010 and newer (up to 2022 model year trucks).

Providing yet more detail, Figure 3.6 breaks out the distribution of the newest model year group, those that are in the lowest emissions group subject to the 2010+ emission standards. This figure shows that the predominant model years were 2011 through 2015, with newer model year trucks (2016 – 2021) making up 19% of this cleanest group.

Figure 3.5: 2022 Distribution of Model Year Groups

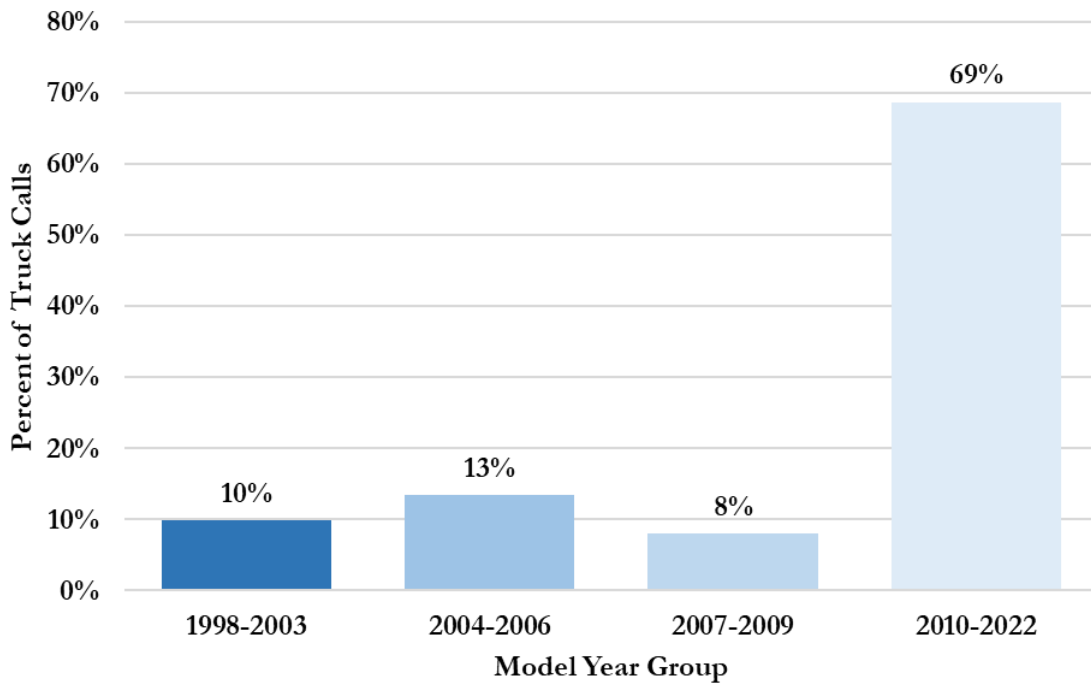
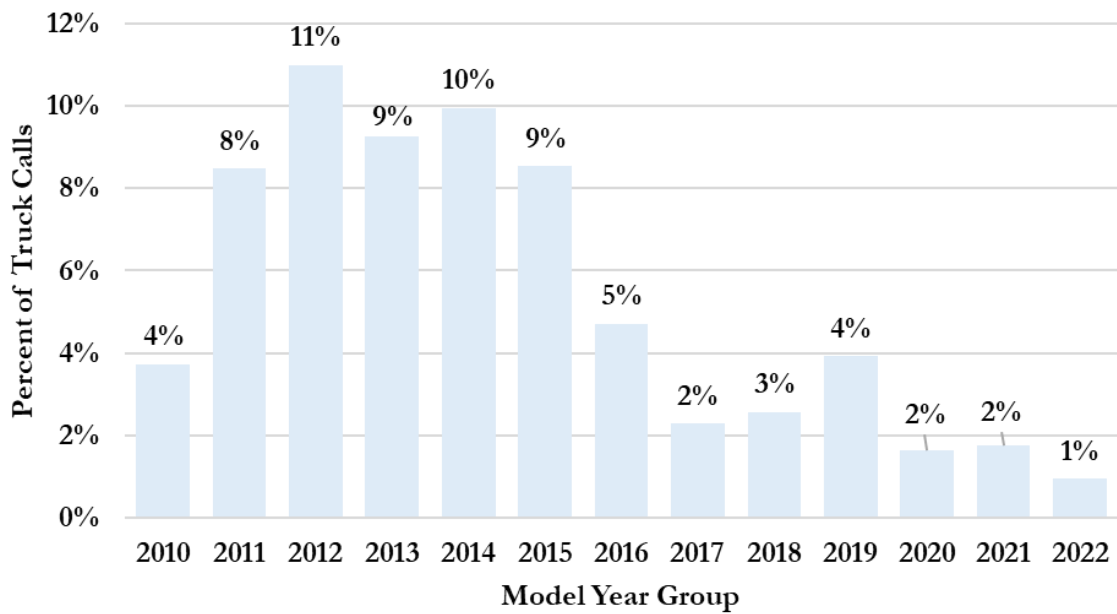


Figure 3.6: 2022 Distribution of 2010+ Model Years



3.3.2 Emission Estimating Methodology

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

$$E = EF \times Act$$

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 MOVES3b, which is the latest mobile source emissions model developed by EPA. Vehicle types, time periods, geographical areas, pollutants, vehicle operating characteristics, and road types are supplied by the user. MOVES3b has been used to estimate emission factors for the pollutants included in this emissions inventory, in grams per mile and grams per hour, for combination short-haul trucks of each model year. Combination short-haul truck is the vehicle type in MOVES3b most closely associated with the trucks serving the marine terminals, defined in the model as combination tractor/trailer trucks with more than four tires with a range of operation up to 200 miles. The emission factors developed by 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 MOVES3b 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 MOVES3b model was also used to develop emission factors for the very slow-speed driving within the tenant terminal boundaries, which averages a reported 15 miles per hour, and for on-terminal idling, both the low-idle experienced during the short-term idling of trucks in normal operation on the container terminals, and high idle rates utilized by automobile transport trucks to load vehicles at the auto terminals. MOVES3b 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 MOVES3b model run are specified in a dataset known as a “runspec”

that is produced during the setup of the model run. Runspecs for the model runs used in this emissions inventory are included in Appendix A.

On-terminal and on-road emissions were calculated in a similar manner, by multiplying the activity value by the relevant emission factor. As an example, a mileage total of 100,000 VMT would be multiplied by the relevant NO_x emission factor (e.g., 11.283 g/mi for on-road travel):

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

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:

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

The MOVES3b-derived driving and idling emission factors for the 2022 EI model year distribution of combination short-haul trucks used in the emission estimates are presented in Table 3.10. The on-terminal (g/mi) EF are based on 15 mph average speed, while the on-road (g/mi) EF are based on MOVES3 highway/local average speeds.

Table 3.10: 2022 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 ₂ O	CH ₄
Short-Term Idle (g/hr)	54.688	2.454	2.258	4.848	21.368	0.038	8,010	0.083	0.355
Extended Idle (g/hr)	75.769	2.133	1.963	9.426	43.916	0.036	7,656	0.000	0.926
On-Terminal (g/mi)	11.285	0.395	0.364	0.644	5.207	0.008	2,415	0.006	0.059
On-Road (g/mi)	6.021	0.195	0.179	0.291	2.542	0.006	1,737	0.002	0.024

The extended idling emission rates shown in Table 3.10 are applicable for periods of idling above normal engine idling speeds to run equipment needed for safety, comfort, or operation of ancillary equipment. Container and warehouse trucks are not believed to idle for extended periods due to regulations, increased anti-idling signage, and reported verbal warnings from terminal operators. This is supported by observations made by surveyors (including a primary author of this emissions inventory report) during the 2012 drayage truck survey at New Jersey and New York container terminals, when it was observed that 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 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	<ul style="list-style-type: none"> ➤ 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	<ul style="list-style-type: none"> ➤ 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	<ul style="list-style-type: none"> ➤ 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

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.

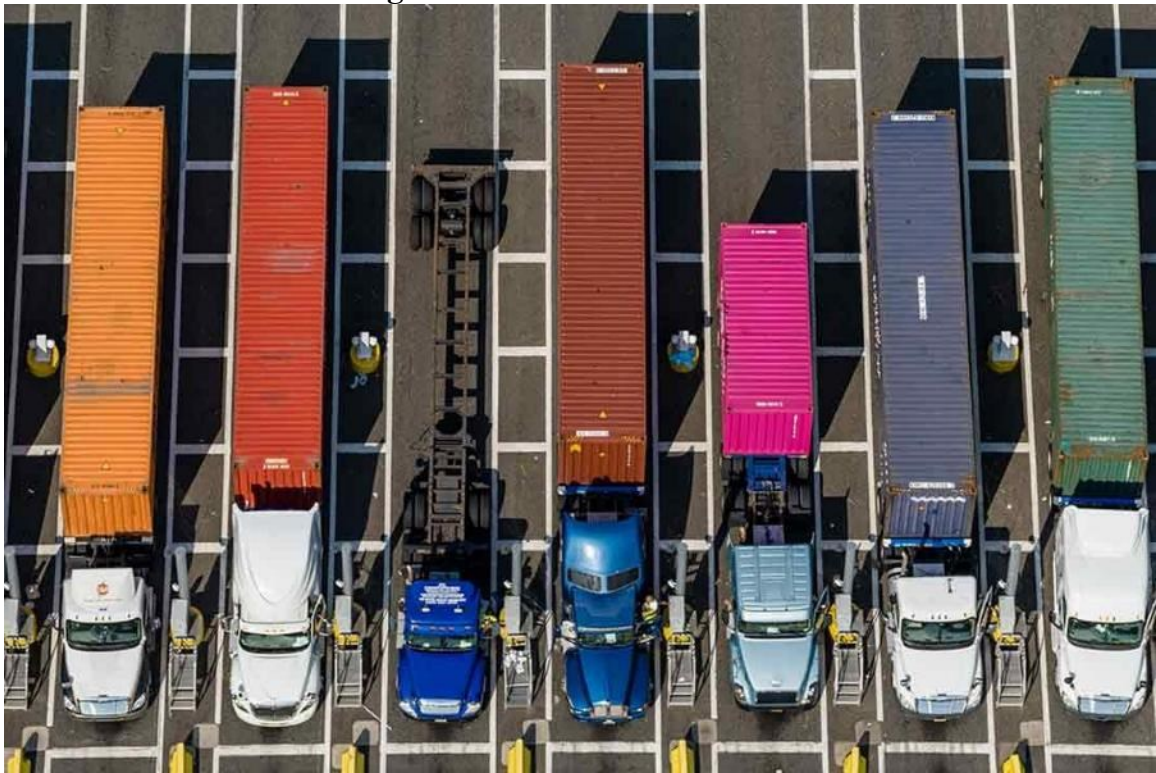
The “first point of rest” is the location at which import cargo (received from ships) is transferred from the first means of transport out of the arrival terminal to the ground or to another mode of transportation (such as truck-to-rail transfer). This occurs, for example, at the warehouse facilities 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. For developing the emissions estimates, locomotive activity has been considered in two general categories, line haul and switching activity. Line haul activity refers to the movement of import and export cargo from and to the Authority marine terminals to and from locations outside the boundary of the Authority facilities but within the NYNJLINA, or to and from the boundary of the NYNJLINA for trains that travel beyond the area. Switching locomotive activity includes activity related to movement of cargo within the boundaries of the following 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. In addition, 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. The relationships between these emissions and overall county and state emissions are presented and discussed in subsection 4.2. Table 4.1 summarizes the line haul and switching emissions.

Table 4.1: Locomotive Emission Estimates, tpy

Locomotive Type	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO ₂ e
tons per year							
Line Haul	112	2.5	2.3	4	34	0.1	12,943
Switching	212	9.0	8.4	21	40	0.2	14,673
Totals	324	11.5	10.7	25	73	0.3	27,616

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 2022 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.¹⁵

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

Geographical Extent / Source Category	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
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	324	12	11	25	73	0.3	27,616
2022 % of NYNJLINA Emissions	0.24%	0.01%	0.03%	0.01%	0.01%	0.01%	0.03%
2021 % 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.¹⁶ 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.

¹⁵ 2020 National Emission Inventory Databases, US EPA, as cited above.

¹⁶ Accessed at: <https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data>

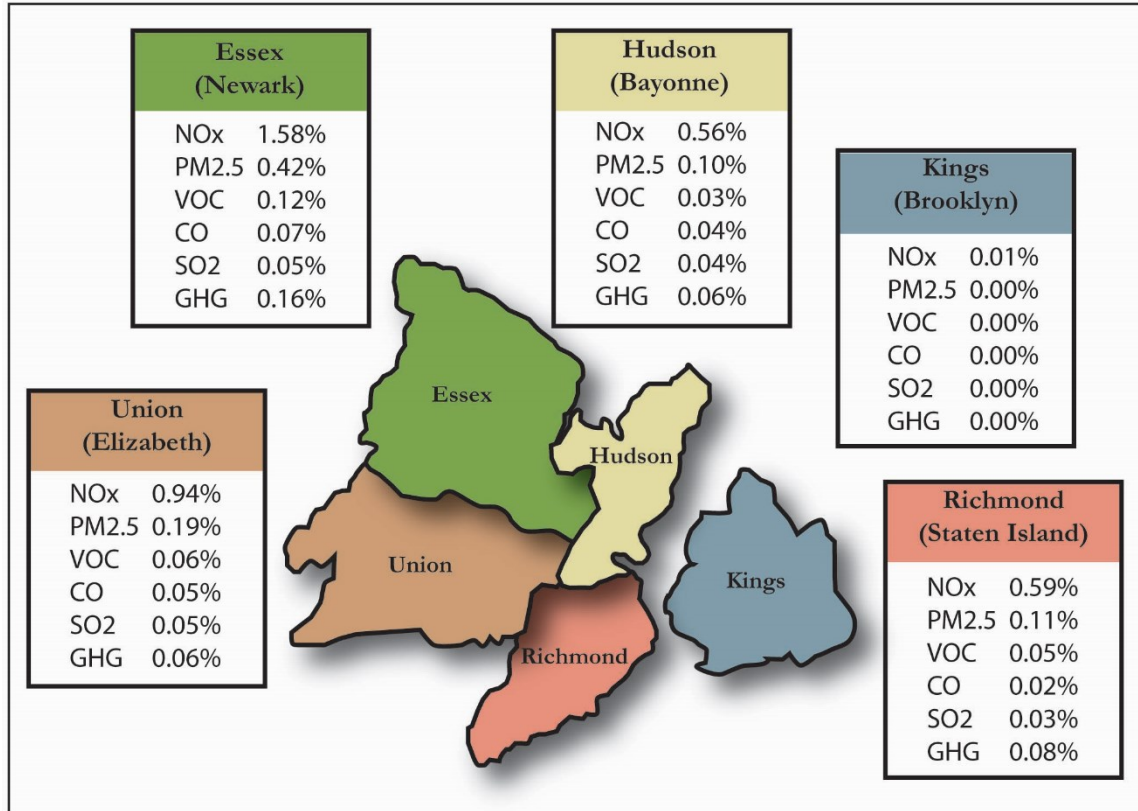
Table 4.3 presents estimated criteria pollutant emissions from the Authority marine terminal-related locomotive activity reported in this current inventory, at the county level.

Table 4.3: Summary of Locomotive Emissions by County, tpy

County	State	tons per year						
		NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
Bergen	NJ	21.2	0.5	0.4	0.8	6.4	0.0	2,453
Essex	NJ	135.2	5.6	5.2	13.1	26.3	0.1	9,786
Hudson	NJ	33.5	1.0	0.9	2.1	8.6	0.0	3,282
Middlesex	NJ	6.8	0.2	0.1	0.3	2.1	0.0	790
Monmouth	NJ	0.0	0.0	0.0	0.0	0.0	0.0	0
Union	NJ	69.0	2.6	2.4	5.7	15.1	0.1	5,694
New Jersey subtotal		266	9.8	9.1	22	58	0.3	22,004
Bronx	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Kings (Brooklyn)	NY	1.0	0.0	0.0	0.0	0.4	0.0	148
Nassau	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
New York	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Orange	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Queens	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Richmond (Staten Isl)	NY	23.3	0.9	0.9	2.3	4.2	0.0	1,538
Rockland	NY	34.0	0.8	0.7	1.2	10.2	0.0	3,925
Suffolk	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Westchester	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
New York subtotal		58	1.7	1.6	3.5	15	0.1	5,611
Total		324	11.5	10.7	25	73	0.3	27,616

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 were almost unchanged between 2021 and 2022, with 1% to 2% decreases of NO_x and PM, while there was a 0.3% decrease in on-dock rail lifts during the same period. Between 2006 and 2022, with the exception of SO₂, the locomotive emissions increased but at a lower rate than the increase in cargo moved by rail into and out of the Port. The pollutants NO_x and PM increased 13% to 14%, compared to the 109% increase in the number of on-dock lifts. The SO₂ emissions are significantly lower (2006 to 2022) due to the use of lower sulfur fuel. The on-dock rail throughput more than doubled between 2006 and 2022 but the increases in CO and CO₂ were 66% and 88%, respectively, likely due to incremental efficiency improvements implemented by the railroads and the Authority.

Table 4.4 presents the 2022 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 ₂ e tons	On-dock Lifts
2022	324	12	11	25	73	0	27,616	706,774
2021	327	12	11	25	73	0	27,691	709,094
2006	286	10	9	20	44	32	14,710	338,884
2021-2022, Change (%)	-1%	-2%	-1%	-1%	-1%	-9%	0%	-0.3%
2006-2022, Change (%)	13%	13%	14%	25%	66%	-99%	88%	109%

The following figure graphically illustrates the changes in locomotive emissions of NO_x, PM₁₀, SO₂ and CO₂ between the 2006 baseline emissions inventory and the 2022 update, with emission trend lines superimposed over the annual on-dock lift throughput (in thousands of lifts). The NO_x and PM₁₀ emission changes track closely together and may be hard to distinguish from one another in the figure. The NO_x and PM₁₀ emissions are 13% higher in 2022 than in 2006.

Figure 4.2: Locomotive Emissions Relative to On-dock Lifts

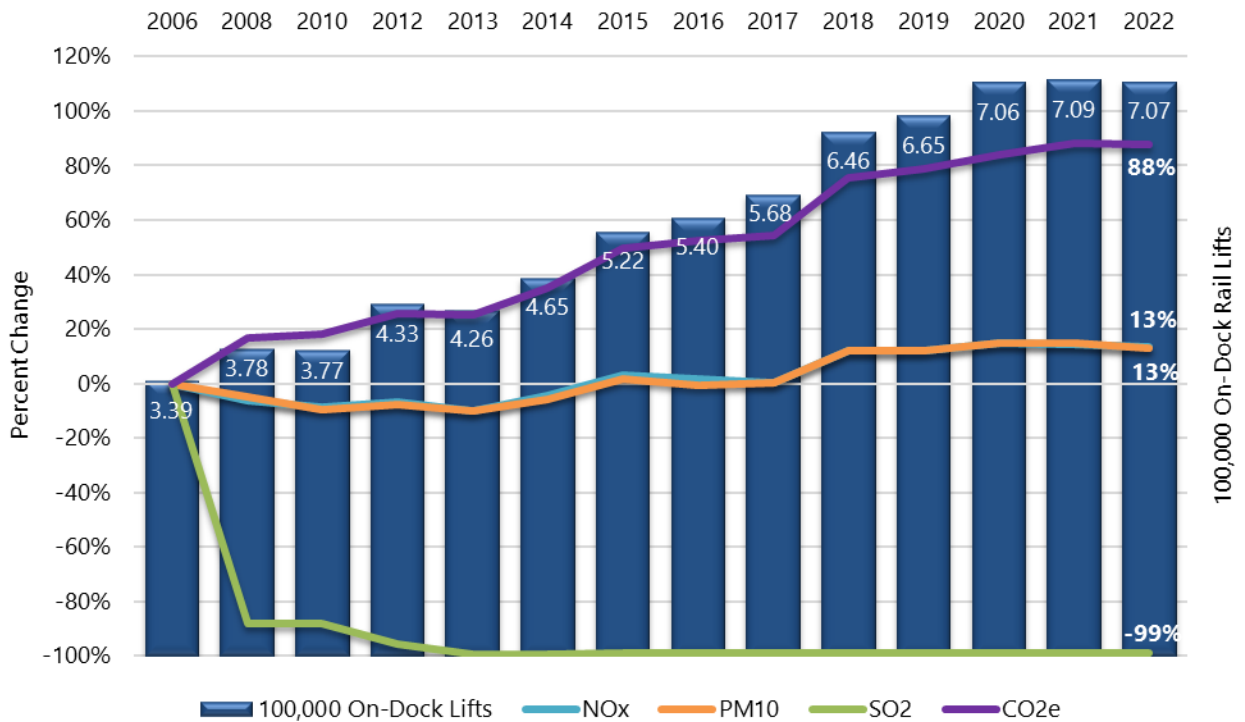


Table 4.5 compares emissions per 100,000 lifts which is a better metric for locomotives.

Table 4.5: Locomotive Emission per Lifts Comparison

Inventory Year	Emissions per 100,000 Lifts						
	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
2022	45.8	1.6	1.5	3.5	10.3	0.04	3,907
2021	46.1	1.7	1.5	3.6	10.3	0.05	3,905
2006	84.4	3.0	2.8	5.9	13.0	9.44	4,341
2021-2022, Change (%)	-1%	-2%	-1%	-1%	0%	-9%	0.1%
2006-2022, Change (%)	-46%	-46%	-45%	-40%	-20%	-100%	-10%

4.3 Locomotive Emission Calculation Methodology

There is no regulatory model available for estimating locomotive emissions, such as the MOVES3b 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,¹⁷ 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.

The emission factors for most pollutants (NO_x, PM, VOCs, CO) come from an EPA publication¹⁸ issued in support of locomotive rulemaking. The emission factors are published for each engine tier level and also (for NO_x, PM, and VOCs) for annual fleet composites representing EPA’s projection of fleet turnover and the makeup of the nationwide locomotive fleet annually through calendar year 2040. The fleet composite emission factors for calendar

¹⁷ Information provided by PANYNJ by email August 2023.

¹⁸ "Emission Factors for Locomotives," EPA-420-F-09-025, Office of Transportation and Air Quality, April 2009

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 SO₂ and CO₂ have been developed using a mass balance approach based on the typical amounts of sulfur and carbon in diesel fuel. The SO₂ emission factor assumes diesel fuel sulfur content of 15 ppm in 2022. The emission factors for N₂O and CH₄ were obtained from an EPA publication on greenhouse gases.¹⁹

The emission factors for line haul locomotives are presented in Table 4.6. The published g/gal emission factors for 2022 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 ₂ O	CH ₄
g/gal	89	2.0	1.8	3.2	26.7	0.10	10,186	0.25	0.79
g/hp-hr	4.3	0.10	0.09	0.15	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.²⁰ 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.

¹⁹ Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2021; April 2023; Table A- 114: Emission Factors for N₂O Emissions from Non-Highway Mobile Combustion (g gas/kg fuel) and Table A- 115: Emission Factors for CH₄ Emissions from Non-Highway Mobile Combustion (g gas/kg fuel).

²⁰ 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.

$$\begin{aligned} &\textbf{Train length} \\ &= \textbf{Number of cars} \times \textbf{Car length} \times \textbf{Number of locomotives} \\ &\times \textbf{Locomotive length} \end{aligned}$$

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

Parameters	Trains - Railroad "A"			Trains - Railroad "B"		
	Outbound	Outbound	Inbound	Outbound	Outbound	Inbound
# of 5-platform cars per train	29	30	30	30	30	26
Length of 5-platform car, feet	300	300	300	300	300	300
Length of cargo, feet	8,700	9,000	9,000	9,000	9,000	7,800
Length of 1 locomotive, feet	70	70	70	70	70	70
# of locomotives per train	2	2	2	2	2	2
Total locomotive length, feet	140	140	140	140	140	140
Total train length	8,840	9,140	9,140	9,140	9,140	7,940

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

$$\begin{aligned} &\textbf{Train capacity} \\ &= \textbf{Number of cars} \times \textbf{Number of platforms/car} \times \textbf{TEUs} \\ &\textbf{/platform} \times \textbf{Density} \times \textbf{TEUs/container} \end{aligned}$$

Where:

- Train capacity = Estimated number of containers per train
- Number of cars = Number of multi-platform rail cars per train
- Number of platforms/car = 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 actually 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

Parameters	Trains - Railroad "A"			Trains - Railroad "B"		
	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)	580	600	600	600	600	520
Average "density"	100%	100%	100%	100%	100%	100%
TEUs per train (adjusted)	580	600	600	600	600	520
Average TEUs per container:	1.80	1.80	1.80	1.80	1.80	1.80
Containers per train (average)	321	333	333	333	333	288

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

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

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 2022 on-dock rail throughput to within approximately four hundredths of a percent (estimated total of 359,268 + 347,256 = 706,524, versus actual 706,774). 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	116,844	121,212	121,212	121,212	121,212	104,832
Total estimated containers:	359,268			347,256		

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.

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

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 2021 submittals of an annual report known as the "R-1."²¹ 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-platform 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)	145	150	150	150	150	130
Gross tons per platform	90	90	90	90	90	90
Gross weight of train	13,045	13,494	13,494	13,494	13,494	11,695

²¹ *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2021* (Norfolk Southern Railroad) and *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2021* (CSX Transportation, Inc.). https://www.stb.gov/stb/industry/econ_reports.html

Overall annual gross tonnage for each railroad is the gross weight of each train multiplied by the number of trains per year. These figures total approximately 14.57 million gross tons for the railroad whose trains are represented by the left three columns in the previous tables, and approximately 14.08 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 2022 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	Gallons
		Gross Ton-Miles	Fuel
North Route			
Essex	3	43,716,653	43,279
Hudson	13	189,438,828	187,544
Bergen	15	218,583,263	216,397
Rockland	24	349,733,220	346,236
South Route			
Essex	5	70,405,096	69,701
Union	15	211,215,288	209,103
Middlesex	5	70,405,096	69,701
Total	80	1,153,497,443	1,141,962

The last step is to apply the emission factors (Table 4.5) 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 2021 and 2022. The scaling of activity with growth in container throughput by rail should provide a reasonable estimate of activity growth. The 2002 emission estimates were based on the number and duration of daily shift operations, and the later estimates have been made using the ratios of container throughputs by rail. For example, 706,800 containers moved by rail in 2022 divided by 709,000 containers moved by rail in 2021 results in a growth factor of 0.9969 or a 0.31% decrease in throughput; this was multiplied by the 2021 operating hours estimate of 71,633 for a 2022 estimate of 71,411 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.²² 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 ₂ O	CH ₄
Tier 0 emission factors									
g/gal	191	6.1	6.1	15.2	27.3	0.00	10,182	0.000	1.52
g/hp-hr	12.6	0.40	0.40	1.00	1.80	0.00	672	0.000	0.10
Tier 1 emission factors									
g/gal	150	6.5	6.1	15.3	27.7	0.10	10,182	0.258	0.76
g/hp-hr	9.9	0.43	0.40	1.01	1.83	0.01	672	0.017	0.05
Tier 4i emission factors									
g/gal	68	0.2	0.2	1.2	27.7	0.10	10,182	0.26	0.76
g/hp-hr	4.5	0.015	0.014	0.080	1.83	0.01	672	0.017	0.05
Tier 4 emission factors									
g/gal	15	0.2	0.2	1.2	27.7	0.15	10,182	0.26	0.76
g/hp-hr	1.0	0.015	0.014	0.080	1.83	0.01	672	0.017	0.05

²² 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 SO₂ and CO₂ have been developed using a mass balance approach (based on the typical amounts of sulfur and carbon in diesel fuel) and emission factors for N₂O and CH₄ 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 71,411 hours by the average in-use horsepower of 264 results in an estimate of approximately 18.9 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.

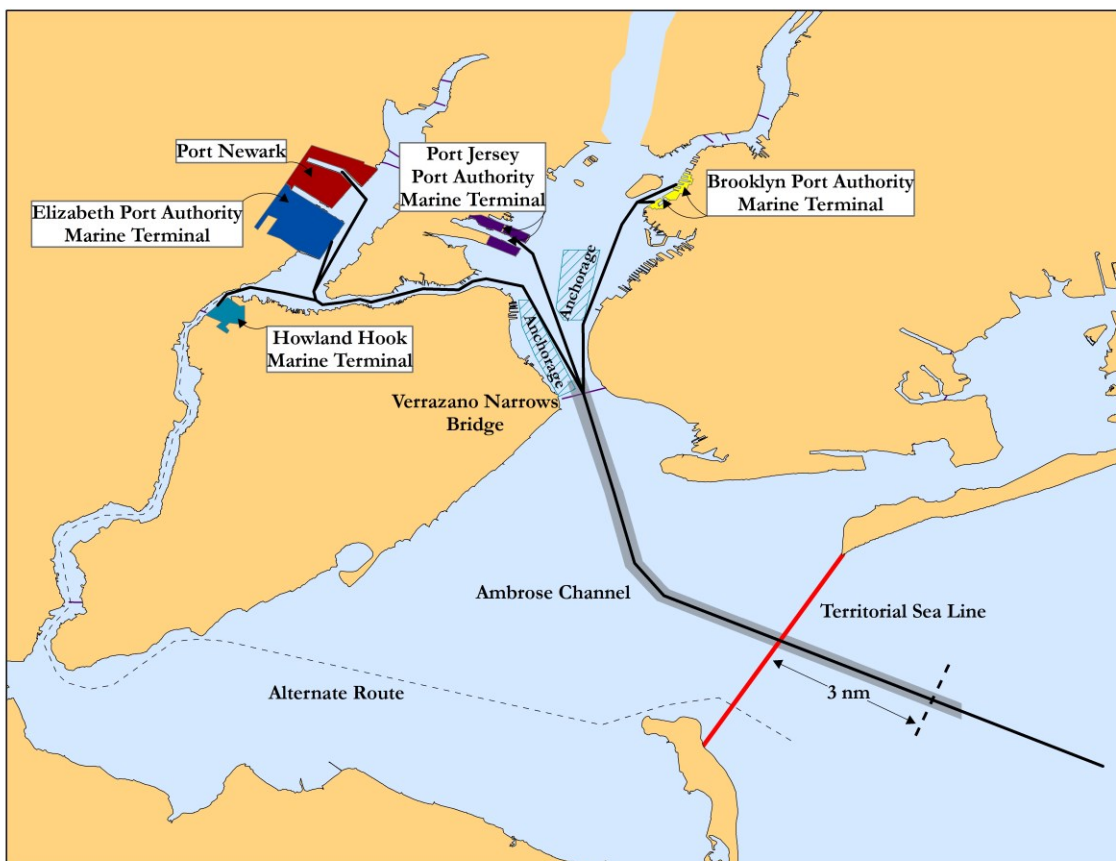
In many cases, vessel travel lanes do not fall neatly within one or another county. Best efforts have been made to reasonably allocate emissions to the relevant counties (and states).

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 2022, there were more vessels at anchorage than 2021 (126 vessels arrivals in 2022 vs 26 vessel arrivals in 2021). The increase of vessels at anchorage is a reason for the increase in emissions from 2021 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. In 2022, the cruise ships were back to normal operations and thus the cruise ship emissions are significantly higher than in 2021.

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	179	3.1	2.9	7.9	18.4	5.5	12,854
Bulk Carrier	72	1.4	1.3	2.6	6.9	3.2	5,609
Container - 1000	78	1.8	1.7	3.1	8.2	4.3	7,683
Container - 2000	111	1.9	1.7	4.5	10.6	3.7	7,836
Container - 3000	47	0.8	0.8	2.0	4.6	1.5	3,679
Container - 4000	233	4.0	3.7	12.2	23.9	7.2	16,057
Container - 5000	156	2.7	2.5	8.9	16.6	3.8	11,253
Container - 6000	260	4.9	4.5	19.8	32.8	7.1	17,796
Container - 7000	33	0.6	0.5	2.0	3.5	1.0	2,281
Container - 8000	502	8.7	8.0	22.4	47.9	14.4	37,457
Container - 9000	173	3.2	3.0	8.4	17.5	4.5	14,353
Container - 10000	45	0.8	0.7	2.1	4.3	0.9	3,478
Container - 11000	106	2.1	1.9	7.2	12.9	2.7	8,266
Container - 12000	29	0.8	0.7	2.3	4.9	0.8	3,380
Container - 13000	261	5.3	4.9	10.9	26.2	7.7	24,299
Container - 14000	94	2.0	1.8	4.5	10.3	3.5	8,581
Container - 15000	23	0.8	0.8	2.1	4.7	1.8	3,339
Container - 16000	11	0.2	0.2	1.0	1.6	0.5	826
Cruise Ship	209	4.2	3.8	8.3	21.9	9.2	16,538
General Cargo	16	0.3	0.3	0.6	1.6	0.7	1,279
RoRo	63	1.1	1.0	3.3	7.3	0.8	4,762
Tanker	98	2.3	2.1	3.7	9.6	5.5	9,379
Total	2,799	53	49	140	296	90	220,987

Table 5.2 presents the OGV emissions by engine type. Table 5.3 differentiates emissions according to transit and dwelling (hoteling) activity. Due to more time spent at berth and anchorage, the auxiliary engines and boiler emissions are higher in 2022.

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	910	9	9	64	93	12	30,975
Auxiliary Engines	1,751	31	28	69	189	50	121,224
Boilers	138	13	12	7	14	28	68,788
Total	2,799	53	49	140	296	90	220,987

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	1,223	15	14	76	126	23	55,605
Dwelling	1,576	38	35	64	170	67	165,381
Total	2,799	53	49	140	296	90	220,987

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. The towboats/pushboats average engine horsepower are higher in 2022 than in previous years which resulted in higher emissions.

Table 5.4: Harbor Craft Emissions, tpy

Vessel Type	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
Towboats/Pushboats	195	4	4	4	39	0.1	15,638
Assist Tugs	125	3	3	2	42	0.2	20,134
Total	321	7	6	7	81	0.3	35,772

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 2022 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. Due to using latest 2020 NEI regional emissions, the percent contribution was recalculated for 2021 to use in comparison to the 2022 percent contribution.

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	2,799	53	49	140	296	90	220,987
Harbor Craft	321	7	6	7	81	0.3	35,772
Total Commercial Marine Vessels	3,120	60	55	146	378	91	256,759
2022 % of NYNJLINA Emissions	2.3%	0.06%	0.13%	0.07%	0.05%	2.7%	0.3%
2021 % of NYNJLINA Emissions	2.1%	0.06%	0.12%	0.06%	0.04%	2.3%	0.2%

5.2.1 OGV Emission Comparisons with County and Regional Emissions

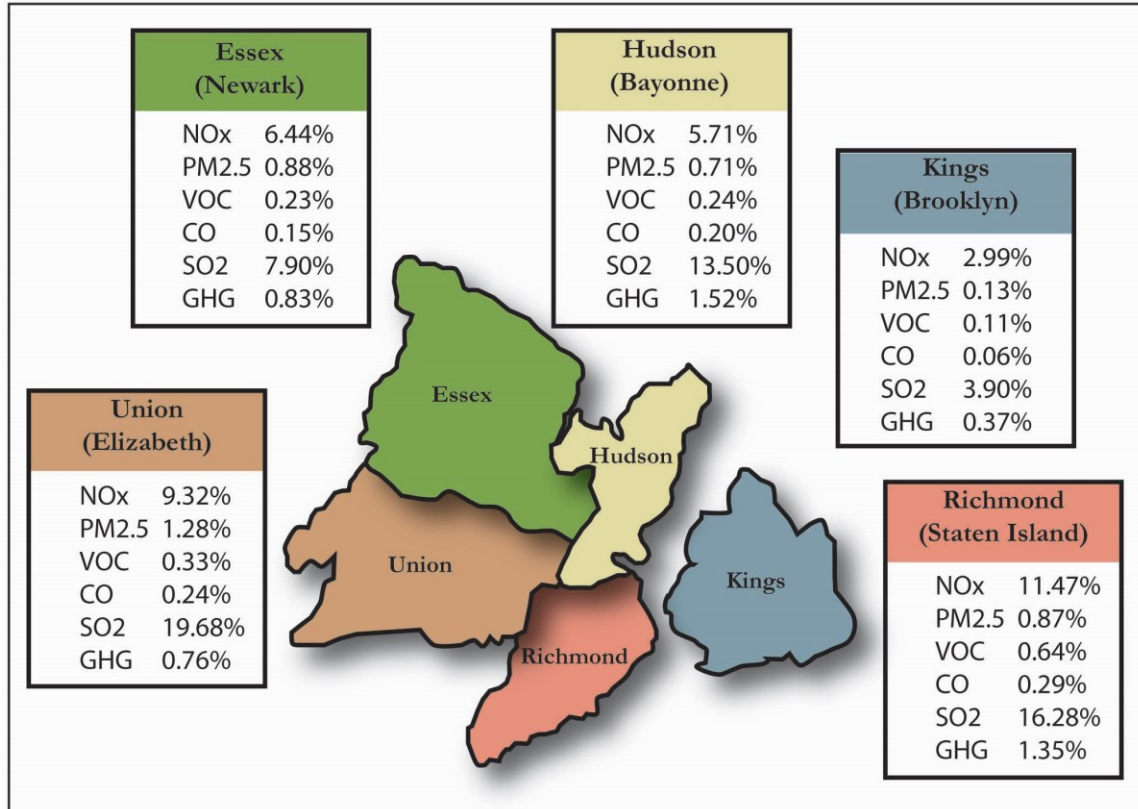
Table 5.6 summarizes estimated criteria pollutant and GHG emissions from OGVs at the county level. All counties within the inventory area are listed, so counties without associated OGV emissions are shown with zero emissions. The percentage allocation of emissions per county are based on the geographical 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	552	12	11	24	58	21	51,326
Hudson	NJ	343	7	7	19	39	12	29,398
Middlesex	NJ	0	0	0	0	0	0	1
Monmouth	NJ	268	3	3	11	24	5	11,566
Union	NJ	686	17	16	29	77	30	76,344
New Jersey subtotal		1,849	39	36	83	197	68	168,635
Bronx	NY	0	0	0	0	0	0	0
Kings	NY	335	5	4	19	34	8	17,909
Nassau	NY	0	0	0	0	0	0	0
New York	NY	3	0	0	0	0	0	232
Orange	NY	0	0	0	0	0	0	0
Queens	NY	161	2	2	6	14	3	6,953
Richmond	NY	450	7	7	31	50	10	27,247
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		950	14	13	56	99	22	52,341
Total		2,799	53	49	140	296	90	220,976

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

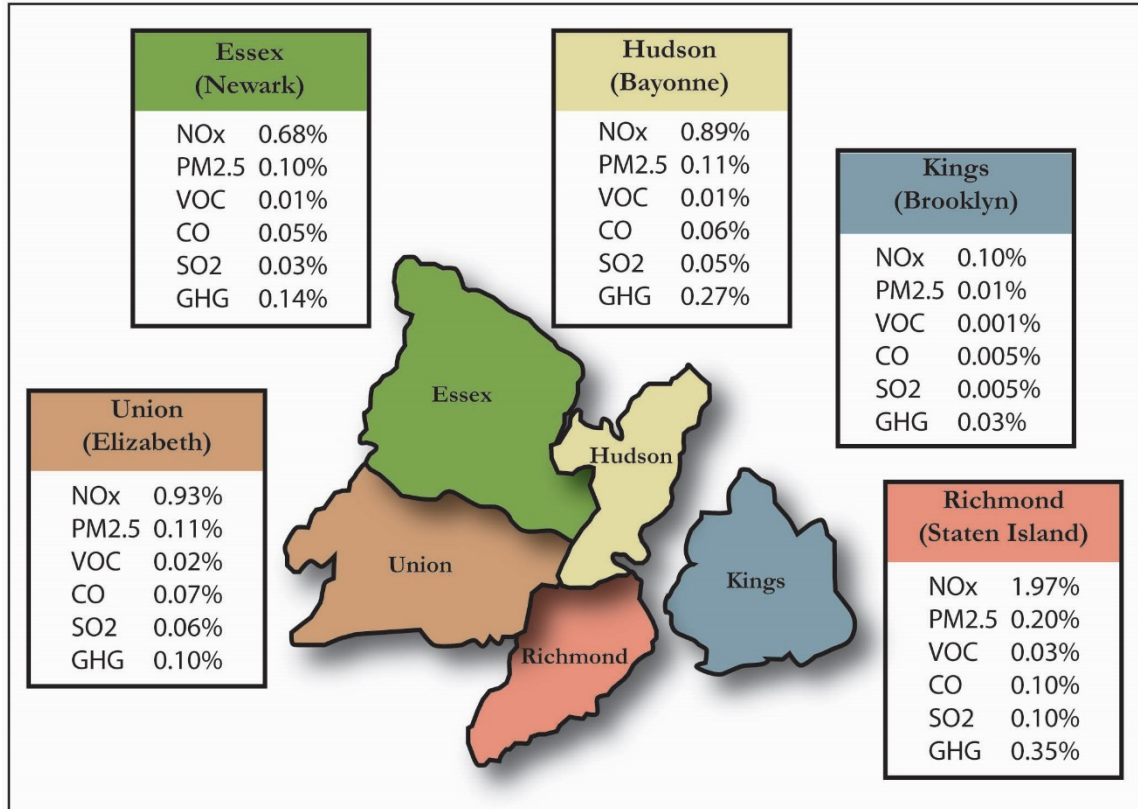
Table 5.7 summarizes estimated emissions from assist tugs and tow boats at the county level.

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	0.38	0.00	151
Essex	NJ	59	1.22	1.21	1.15	18.23	0.07	8,499
Hudson	NJ	54	1.09	1.06	1.14	12.19	0.05	5,153
Middlesex	NJ	13	0.27	0.26	0.29	2.66	0.01	1,064
Monmouth	NJ	10	0.20	0.19	0.21	1.96	0.01	784
Union	NJ	69	1.43	1.42	1.36	20.77	0.08	9,611
New Jersey subtotal		206	4.2	4.2	4.2	56.2	0.22	25,261
Bronx	NY	0	0.01	0.01	0.01	0.07	0.00	28
Kings	NY	11	0.23	0.22	0.23	2.82	0.01	1,238
Nassau	NY	3	0.05	0.05	0.05	0.50	0.00	202
New York	NY	3	0.06	0.06	0.06	0.64	0.00	270
Orange	NY	2	0.04	0.04	0.05	0.43	0.00	174
Queens	NY	4	0.08	0.08	0.08	0.77	0.00	308
Richmond	NY	77	1.57	1.53	1.65	17.07	0.06	7,127
Rockland	NY	3	0.05	0.05	0.06	0.53	0.00	213
Suffolk	NY	9	0.17	0.17	0.19	1.72	0.01	689
Westchester	NY	3	0.07	0.06	0.07	0.66	0.00	263
New York subtotal		115	2.3	2.3	2.5	25.2	0.09	10,511
TOTAL		321	6.6	6.4	6.6	81.4	0.32	35,772

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 2022 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 2022 vs 2021, the main differences are more vessels at anchorage in 2022, more cruise ship vessels calling, and for the first time, LNG fueled containerships called the Port.

There is no change to the emission estimating methodology used to calculate 2022 emissions compared to the previous year’s inventory. Therefore, the previous year emissions shown in this report remain the same as published in the previous report.

Programs that had an impact on OGV emissions in calendar year 2022 are listed below.

- In 2022, cruise ship operations resumed after 2 years of low activity due to the COVID pandemic. This resulted in higher calls and emissions for cruise ships.
- In 2022, there were more vessels at anchorage than in previous years. This was due to both vessel and cargo diversions to East Coast ports in 2022 after supply chain disruptions caused significant vessel delays at West Coast ports 2021-2022.
- Larger vessels continued to make calls to the terminals in 2022.
- This was the first year that LNG fueled containership 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 2022. In 2022, there were 1,663 calls to the Authority marine terminals by vessels enrolled in the program, with 539 individual vessels making 928 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 2022 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 2022 were higher by 6% to 18% (depending on pollutant) compared to 2021, while the TEU throughput and vessel movements increased by 5%. The OGV emission increases in 2022 were mainly due to more cruise vessels, more vessels at anchorage, and the 6% increase in TEU throughput.

Table 5.8: OGV Emissions Comparison, tpy and %

Inventory Year	NO _x tons	PM ₁₀ tons	PM _{2.5} tons	VOC tons	CO tons	SO ₂ tons	CO ₂ e tons	Throughput M TEUs
2022	2,799	53	49	140	296	90	220,987	9.49
2021	2,535	46	43	131	267	77	190,931	8.99
2006	4,165	392	314	185	360	3,681	221,638	5.09
2021-2022, Change (%)	10%	14%	14%	6%	11%	18%	16%	6%
2006-2022, Change (%)	-33%	-86%	-84%	-25%	-18%	-98%	-0.3%	86%

The following figure graphically illustrates the percent change in NO_x, PM₁₀, PM_{2.5} (same as PM₁₀ trend), SO₂, and CO_{2e} emissions from OGVs between the 2006 baseline emissions inventory and the 2021 update, with emission trend lines superimposed over the annual M TEU throughput. The PM₁₀ and PM_{2.5} emissions track closely together.

Figure 5.4: OGV Emissions Relative to TEU Throughput

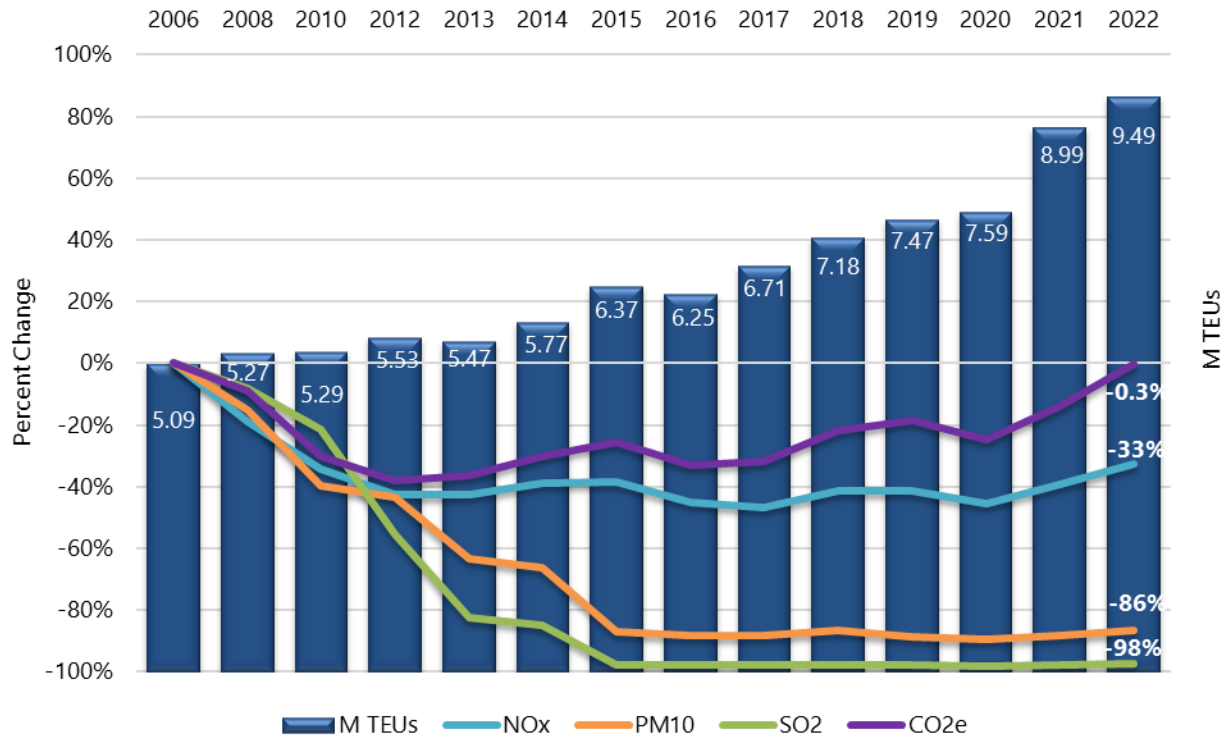


Table 5.9 compares emissions per M TEUs. Emissions per TEU are higher in 2022 than 2021 for OGV. This is due to: more vessels at anchorage and more cruise ship calls. Both increased emissions and do not necessarily track cargo throughput, thus the increase (inefficiency) in the efficiency metric (emissions per M TEUs).

Table 5.9: OGV Emission per M TEUs Comparison

Inventory Year	Emissions / M TEUs						
	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO _{2e}
2022	295	6	5	15	31	9	23,277
2021	282	5	5	15	30	9	21,248
2006	818	77	62	36	71	723	43,518
2021-2022, Change (%)	5%	8%	8%	1%	5%	11%	10%
2006-2022, Change (%)	-64%	-93%	-92%	-60%	-56%	-99%	-47%

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 previous year, overall harbor craft emissions increased due to more towboats with larger engines in 2022. Compared to 2006, the emission reductions are due to fleet turnover to newer vessels. Compared to 2021, emissions are higher due to updated fleet information used which has higher average engine horsepower rating than 2021 fleet. Updated towboat fleet information was obtained from the 2022 AIS data.

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 ₂ e tons	Throughput M TEUs
2022	321	7	6	7	81	0	35,772	9.49
2021	307	6	6	6	79	0	35,475	8.99
2006	633	34	31	21	98	62	33,703	5.09
2021-2022, Change (%)	5%	6%	6%	3%	2%	1%	1%	6%
2006-2022, Change (%)	-49%	-81%	-79%	-69%	-17%	-99%	6%	86%

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 (commonly known as “Lloyd’s data” due to previous company ownership) has been used to develop profiles of the physical and operational parameters of OGVs along with the information from Starcrest’s Vessel Boarding Program (VBP) data system.

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 2022, the cruise ship vessel arrivals are 86% higher than 2021 due to cruise ship activity returning to normal. In 2022, 4 fueled LNG containerships called for a total of 5 arrivals to the Port for the first time.

Table 5.11: Vessel Movements for the Authority Marine Terminals

Vessel Type	Arrivals	Departures	Shifts	Total
Auto Carrier	321	321	48	690
Bulk Carrier	108	107	44	259
Container - 1000	214	214	8	436
Container - 2000	224	225	16	465
Container - 3000	78	77	3	158
Container - 4000	268	268	17	553
Container - 5000	152	152	13	317
Container - 6000	233	233	18	484
Container - 7000	28	28	0	56
Container - 8000	351	352	26	729
Container - 9000	121	121	15	257
Container - 10000	31	31	3	65
Container - 11000	92	91	1	184
Container - 12000	26	26	3	55
Container - 13000	165	164	2	331
Container - 14000	73	75	0	148
Container - 15000	28	28	0	56
Container - 16000	7	8	1	16
Cruise Ship	124	124	0	248
General Cargo	23	23	3	49
RoRo	88	88	44	220
Tanker	71	71	51	193
Total	2,826	2,827	316	5,969

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. The high tanker hours are due to a single incident involving a tanker with a fire aboard while in the New York harbor. This vessel was towed to an anchorage area initially and then to a lay berth in 2022.

Table 5.12: Average Dwell Times at Berth, hours

Vessel Type	Min	Max	Average
Auto Carrier	3	253	23
Bulk Carrier	16	509	110
Container - 1000	4	169	26
Container - 2000	23	127	60
Container - 3000	10	115	49
Container - 4000	32	173	66
Container - 5000	17	200	81
Container - 6000	29	249	65
Container - 7000	39	145	84
Container - 8000	43	102	67
Container - 9000	6	64	24
Container - 10000	5	77	27
Container - 11000	3	72	29
Container - 12000	2	75	36
Container - 13000	7	89	33
Container - 14000	7	105	38
Container - 15000	5	187	50
Container - 16000	0	131	56
Cruise Ship	3	62	12
General Cargo	13	174	53
RoRo	4	117	23
Tanker	5	1,727	83

In 2022, there were 80% more vessel calls at anchorage than the previous year with 128 vessel arrivals at anchorage as compared to 26 in 2021. The emissions for vessels at anchorage within the study area are included in the emissions inventory. The supply chain disruption and diversion of vessels from the West Coast resulted in the increased vessels at anchorage in 2022.

Table 5.13: Anchorage Arrivals Comparison

Vessel Type	2022 Calls	2021 Calls
Auto Carrier	13	1
Bulk	19	1
Containership	57	6
General Cargo	2	1
Tanker	37	17
2022	128	26

Table 5.14 shows the average dwell time per vessel type for 2022.

Table 5.14: Average Dwell Times at Anchorage, hours

Vessel Type	Min	Max	Average	Vessel Count
Auto Carrier	2	14	7	13
Bulk	3	144	26	18
Containership	0.4	90	14	53
General Cargo	11	12	11	2
Tanker	1	107	18	33
2022	0	144	16	119
2021	4	83	20	26

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 2022. In 2021, the fleet mix of assist tugs was updated to include only the latest Z-drive propulsion tugboats for assist and escort work. These newer and more powerful tugboats are used due to the larger vessels calling the Port and for greater maneuverability through restricted channels and turning basins.

Table 5.15 lists the number of vessel assists for the various vessel types during the calendar year of the study. In 2022, there were 10% fewer vessel assists than in 2021.

Table 5.15: Assist Tug Operating Data and Assumptions

Vessel Type	Total Assists
Auto Carrier	1,324
Bulk Carrier	450
Containership	7,132
Cruise Ship	193
General Cargo	86
RoRo	390
Tanker	314
Total	9,889

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 in the 2022 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 in 2022 were studied and the engine characteristics updated for this inventory. In 2022 EI, the average towboats have larger engines.

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:

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

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:

$$Energy_i = Load \times Act$$

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 (first time in 2022). 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)²³.

²³ <https://www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance>

The PM₁₀ emission factors are based on the following equation:

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

Where:

PM EF = PM₁₀ 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/kW-hr)

= 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 = PM₁₀ emission factor in g/kW-hr

Fraction = PM_{2.5} to PM₁₀ ratio dependent on fuel type

= 0.8 for HFO

= 0.92 for MGO and MDO

The SO_x emission factor is based on the following equation:

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

Where:

SO₂ 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 SO₂ and

2 is the ratio of molecular weights of SO₂ and S.=64/32 = 2

The CO₂ emission factor is based on the following equation:

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

Where:

CO₂ EF = CO₂ emission factor (g/kW-hr)

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

CCF= carbon content factor as a function of fuel type (CO₂/g fuel)

= 3.206 for MGO/MDO

= 3.114 for HFO

= 2.750 for LNG

Table 5.16 shows BSFC by engine type used in equations for PM, SO_x and CO₂ emission factors.

Table 5.16: BSFC by Engine Type and Fuel Type for Ocean Going Vessels, g/kW-hr

Using HFO Fuel			
Engine Category	IMO Tier	Model Year Range	BSFC
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 propulsion engine and boiler	All	All	305
Gas Turbine	All	All	305
Using MGO 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 propulsion engine 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 5.17 compares 2022 and 2021 OGV calls by engine Tiers. For 2022 and 2021, 3% of the vessel calls were made by Tier 3 vessels while most of the vessel calls made of Tier 1 and 2 vessels.

Table 5.17: Vessel Propulsion Engine Tier Calls Comparison

Tiers	2022	2021	2022	2021
	Calls	Calls	Percent	Percent
0	156	129	6%	4%
I	1,765	2,283	62%	68%
II	800	875	28%	26%
III	95	91	3%	3%
blank	13	0	0%	0%
Total	2,829	3,378	100%	100%

Tables 5.18 and 5.19 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 NO_x emission factors from Engine International Air Pollution Prevention²⁴ (EIAPP) certificates are used instead of the default values for propulsion and auxiliary engines.

Table 5.18: 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 ₂ O	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 5.19: 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 ₂ O	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 manufacturers²⁵ and classification societies²⁶ 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.

²⁴ See: <https://www.navsregs.wordpress.com/2017/01/03/engine-international-air-pollution-prevention-certificate-a-band-y-guide/>

²⁵ See: MAN Diesel & Turbo, "Tier III Two-Stroke Technology"

²⁶ DNV-GL, "NO_x Tier III Update: Choices and challenges for on-time compliance," November 2017.

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 5.20 shows the emission factors used for the auxiliary boilers.

Table 5.20: 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 ₂ O	CH ₄
Auxiliary Boiler	All	2.0	0.20	0.19	0.10	0.20	0.59	962	0.075	0.002

In 2022, 4 LNG containerships called the Port for the first time. Table 5.21 shows the emission factors used for 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 Study²⁷. The brake specific fuel consumption (BSFC) used for LNG fuel in this report is 166 g/kWh. In 2022, there were four containerships that used LNG.

Table 5.21: Emission Factors for Engines and Boilers using LNG fuel, g/kW-hr

Engine Category	Year	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO ₂	N ₂ O	CH ₄
Propulsion engines	All	1.3	0.03	0.028	0.00	1.3	0.005	456.5	0.029	0.00
Auxiliary engines	All	1.3	0.03	0.028	0.00	1.3	0.005	456.5	0.029	0.00
Steam Boilers	na	1.3	0.03	0.028	0.00	1.3	0.005	456.5	0.029	0.00

²⁷ 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 Report²⁸.

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 2022. 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 recently published defaults used for other port EIs.²⁹

²⁸ Starcrest Consulting Group, LLC, 2021, San Pedro Bay Ports Emissions Inventory Methodology Report (Version 2, pp 15-25)

²⁹ See: Port of Los Angeles 2021 Air Emissions Inventory, 2022 and Port of Long Beach 2021 Air Emissions Inventory, 2022

Table 5.22 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 5.22: OGV Auxiliary Engine Load by Mode, kW

Vessel Type	Transit (kW)	Maneuvering (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
General Cargo	471	1,098	778	180
RoRo	590	1,187	1,048	565
Tanker - Chemical	427	510	1,048	384

House load defaults for cruise ships (diesel electric and non-diesel electric) are listed in Table 5.23. Most of the cruise ships that called the cruise terminal were diesel electric. Cruise ships typically do not spend time dwelling at anchorage (Table 5.13 shows no cruise ships at anchorage for 2022), so auxiliary engine loads at anchorage were not utilized in the calculations and are therefore not included in the table below.

Table 5.23: Cruise Ship Auxiliary Engine Load, kW

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

5.3.2.5 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.

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

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

Table 5.24: Auxiliary Boiler Load Defaults by Mode, kW

Vessel Type	Mode			
	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
Cruise Ship	282	361	612	306
General Cargo	72	161	207	207
RoRo	91	186	313	303
Tanker - Chemical	85	134	446	250

Table 5.25 presents the load defaults for the auxiliary boilers for diesel electric cruise ships.

Table 5.25: Auxiliary Boiler Load Defaults by Mode for Diesel Electric Vessels, kW

Vessel Type	Passenger Count	Transit (kW)	Maneuvering (kW)	Berth
				Dwelling (kW)
Cruise	0-1,499	992	784	867
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	596	602	895
Cruise	3,000-3,499	697	1,199	1,984
Cruise	3,500-3,999	401	347	989
Cruise	4,000-4,499	0	0	503
Cruise	4,500-4,999	0	0	1,414

5.3.2.6 Assist Tugs, Tomboats (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,³⁰ 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%.

³⁰ <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 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 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 2022 AIS data. Table 5.26 lists the assist tug emission factors and Table 5.27 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 5.26: Assist Tug Emission Factors, g/kW-hr

Engine	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO ₂	N ₂ O	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 5.27: Towboat Emission Factors, g/kW-hr

Engine	NO _x	PM ₁₀	PM _{2.5}	VOC	CO	SO ₂	CO ₂	N ₂ O	CH ₄
Main Engines	8.62	0.17	0.17	0.19	1.73	0.01	679	0.03	0.004
Auxiliary Engines	8.12	0.22	0.22	0.26	1.30	0.01	679	0.03	0.005

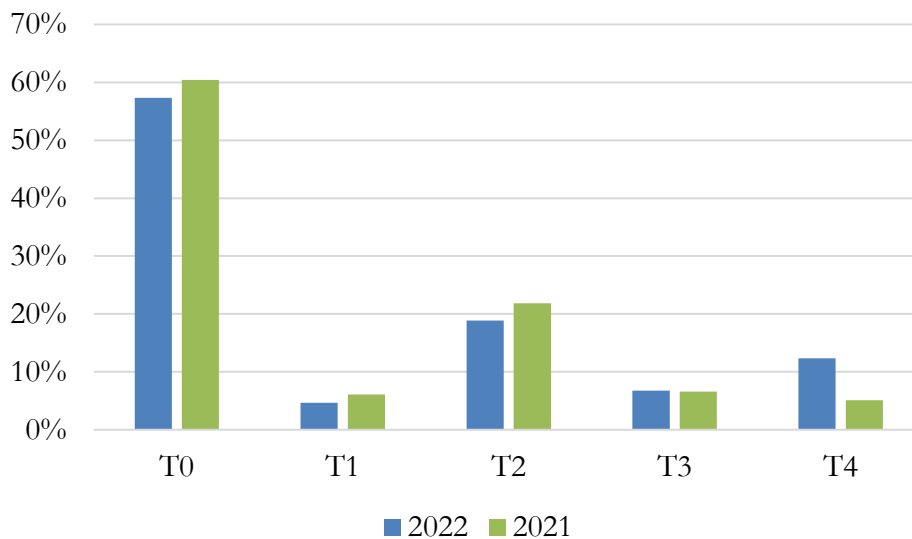
The engine emission factors are based on marine engine standards (i.e., Tier 1, Tier 2, Tier 3, and Tier 4). For the emissions inventory, the weighted assist tug emission factors were based on current tugboat fleet data. For 2022, the assist and escort services fleet were the same as what was used in 2021.

For towboats that transited the NYNJ harbor, the engine activity and engine Tier was updated based on 2022 information. The towboat emission factors were updated in 2022 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 2022. Table 5.26 presents the tier distribution of the harbor craft fleet in 2022. The assist tug engine tiers remained the same, but the towboat engine tiers were updated and show more Tier 4 engines in 2022 than in 2021.

Table 5.28: 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	57%	5%	19%	7%	12%
Towboat	Auxiliary	61%	6%	19%	13%	0%

Figure 5.5: 2022 vs 2021 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

