2015 HARBOR-WIDE COMMERCIAL MARINE VESSEL EMISSIONS INVENTORY

USACE - New York District

June 2019

Prepared by:

STARCREST CONSULTING GROUP, LLC

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Commercial Marine Vessel Emissions Inventory

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Prepared for:
U.S. Army Corp of Engineers - New York District

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AIS	automatic identification system
CF	control factor
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DPM	diesel particulate matter
DWT	deadweight tonnage
E	emissions
ECA	emission control area
EF	emission factor
EI	emissions inventory
EPA	U.S. Environmental Protection Agency
FCF	fuel correction factor
g/kW-hr	grams per kilowatt-hour
GIS	geographic information system
GHG	greenhouse gas
GWP	global warming potential
HC	hydrocarbons
HFO	heavy fuel oil
hp	horsepower
hrs	hours
IFO	intermediate fuel oil
IMO	International Maritime Organization
kW	kilowatt
kW-hr	kilowatt hour
LF	load factor
LLA	low load adjustment
MCR	maximum continuous rating
MDO	marine diesel oil
MGO	marine gas oil
MMSI	maritime mobile service identity
MOVES	EPA emission estimating model
MY	model year
N_2O	nitrous oxide
nm	nautical miles
NO_x	oxides of nitrogen
NR	not reported
OGV	ocean-going vessel
PM	particulate matter
PM_{10}	particulate matter less than 10 µm diam
$PM_{2.5}$	particulate matter less than 2.5 µm diam
ppm	parts per million
RORO	roll-on roll-off vessel
S	sulfur
SFC	specific fuel consumption
SO_x	oxides of sulfur
TEU	twenty-foot equivalent unit
tonnes	metric tons
tpy	tons per year
U.S.	United States
ULSD	ultra-low sulfur diesel
USCG	U.S. Coast Guard
VOC	volatile organic compound

EXECUTIVE SUMMARY

This commercial marine vessel emissions inventory (CMVEI) is being prepared in completion of the requirement to develop "a new marine vessel inventory" after completion of the Harbor Deepening Project (HDP), set forth in the conditional Statement of Conformity (cSOC) signed on 3 April 2002 that enabled the HDP to proceed. In general, this new emissions inventory follows the original in terms of geographic scope and the types of vessels that are included. However, the accepted methods of estimating emissions from ocean-going vessels have advanced considerably since the original, so a new methodology has been used that is consistent with the annual CMV emissions inventories developed for the Port Authority of New York & New Jersey (Port Authority). The Port Authority's emissions inventory covers a subset of the CMV activity in the New York/New Jersey Harbor, and this inventory report presents the emissions estimated for the Port Authority and the additional emissions from vessel traffic within the New York/New Jersey Harbor. This provides a complete accounting of commercial vessel activity that is comparable in scope to the original CMVEI.

Vessel activity has been analyzed for this inventory using data collected through the Automatic Identification System (AIS). The AIS data source allows us to track each vessel call within the inventory area, including routes and transit speeds, and to calculate dwelling (hoteling) times while the vessels are at berth. The inventory covers calendar year 2015 because this corresponds with the last year during which major activity associated with the HDP occurred. The geographic region that is covered is the same as for the 2000 CMVEI. This allows for a limited comparison of the 2015 results with the 2000 results, although the necessary use of different emission estimating methodologies limits the comparability.

Emissions are reported as tons per year for most pollutants (criteria pollutants and their precursors) while, following common convention, greenhouse gas emissions are reported as metric tons. Table ES.1 provides a top-level summary of estimated emissions in 2015 from ocean-going vessels (OGVs) and harbor craft listed by county and state. More detailed breakouts are provided in Section 2 of the report.

Table ES.2 shows the 2015 and 2000 CMV emissions by emission source category (OGVs and harbor craft). The differences between estimates for 2015 and 2000 should be considered only approximate indicators of increases or decreases between 2000 and 2015 because of the considerable differences in methodologies used to estimate emissions for the 2000 inventory compared with the current 2015 inventory. However, the switch to fuels with much lower sulfur content that has occurred between the two inventory years has resulted in dramatic reduction in emissions of sulfur oxides (SOx) and, to a lesser extent, in lower particulate emissions.

Table ES.1: Commercial Marine Vessel Emission Summary, tpy

County / State	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2e
				tpy				MT
Bergen	102	3	3	3	4	21	0	5,746
Essex	833	23	21	19	32	107	29	63,425
Hudson	1,525	46	43	42	53	261	31	105,441
Middlesex	466	16	15	13	15	78	16	40,382
Monmouth	845	19	18	19	31	115	12	40,392
Union	464	14	13	12	18	71	17	39,565
New Jersey total	4,234	121.9	112.8	108.1	152.9	653.2	105.0	294,952
Bronx	212	7	7	7	7	47	0	12,763
Kings	823	22	20	20	31	129	17	50,309
Nassau	322	11	10	11	10	68	1	18,951
New York	1,325	38	35	38	41	232	16	75,582
Ocean	330	12	11	12	10	65	0	19,787
Orange	289	9	9	9	9	60	1	16,794
Queens	529	11	10	11	21	69	9	24,279
Richmond	1,674	53	49	43	66	268	57	136,687
Rockland	393	12	11	12	12	84	1	22,980
Suffolk	1,165	36	33	35	37	223	9	69,764
Westchester	423	14	12	13	13	89	2	25,000
New York total	**7,485**	**225.0**	**207.8**	**212.0**	**257.7**	**1,331.3**	**111.6**	**472,895**
Total 2015	**11,719**	**346.9**	**320.6**	**320.2**	**410.6**	**1,984.4**	**216.6**	**767,847**

Table ES.2: 2015 and 2000 Emission Estimates, tpy

Emission Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x
			tpy			
2015						
Ocean-Going Vessels	4,458	100	94	188	411	213
Harbor Craft	7,260	247	227	222	1,574	4
Total 2015	**11,718**	**347**	**321**	**410**	**1,985**	**217**
2000						
Ocean-Going Vessels	4,139	235	216	155	723	4,302
Harbor Craft	7,967	267	246	295	1,162	2,365
Total 2000	**12,106**	**502**	**462**	**450**	**1,885**	**6,667**

SECTION 1: INTRODUCTION

1.1 Purpose

This commercial marine vessel emissions inventory (CMVEI) is being prepared in completion of the requirement to develop "a new marine vessel inventory" after completion of the Harbor Deepening Project (HDP), set forth in the conditional Statement of Conformity (cSOC) signed on 3 April 2002 that enabled the HDP to proceed. In general, this new emissions inventory follows the original in terms of geographic scope and the types of vessels that are included. However, the accepted methods of estimating emissions from ocean-going vessels have advanced considerably since the original, so a new methodology has been used that is consistent with the annual CMV emissions inventories developed for the Port Authority of New York & New Jersey (Port Authority). The Port Authority's emissions inventory covers a subset of the CMV activity in the New York/New Jersey Harbor, and this inventory report presents the emissions estimated for the Port Authority and the additional emissions from vessel traffic within the New York/New Jersey Harbor. This provides a complete accounting of commercial vessel activity that is comparable in scope to the original CMVEI.

1.2 Approach

Vessel activity has been analyzed using data collected through the Automatic Identification System (AIS). The AIS data source allows us to track each vessel call within the inventory area, including routes and transit speeds, and to calculate dwelling (hoteling) times while the vessels are at berth. Dwelling locations have been identified in general terms, but identification of specific berths would require highly time-intensive setup of parameters in the geographic information system (GIS) software used in the analysis. This additional work would be beyond the budgetary scope of the CMVEI.

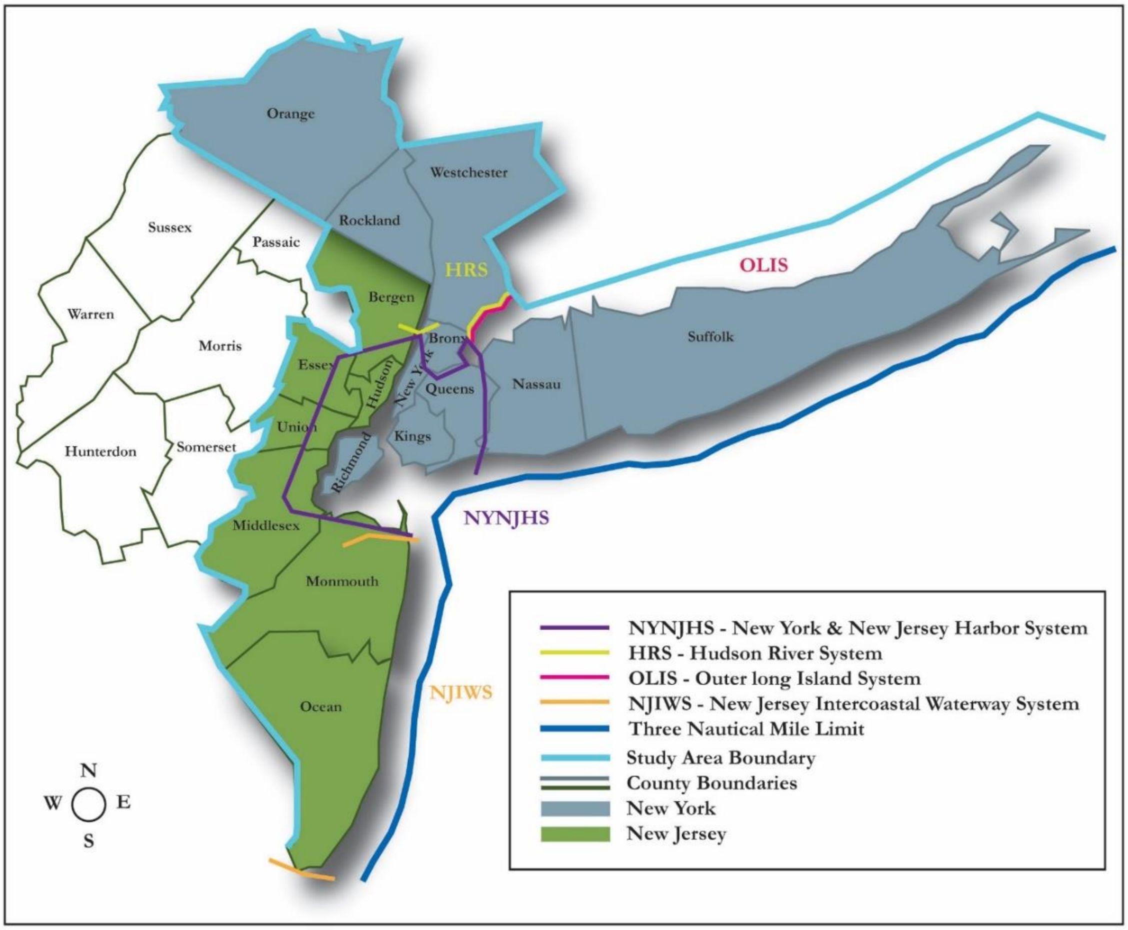
Inventory year
The CMVEI covers vessel activities that occurred during calendar year 2015. This corresponds with the last year during which major activity associated with the HDP occurred.

Geographical area
The geographic region that is covered is the same as for the 2000 CMVEI. This allows for a limited comparison of the 2015 results with the 2000 results, although the necessary use of different emission estimating methodologies limits the comparability. Vessel activities within the following counties are included in the evaluation.

- New York Counties:
  - Bronx
  - Kings
  - Nassau
  - New York
  - Orange
  - Queens
  - Richmond
  - Rockland
  - Suffolk
  - Westchester
- New Jersey Counties:
  - Bergen
  - Essex
  - Hudson
  - Middlesex
  - Monmouth
  - Ocean
  - Union

Figure 1.1 illustrates the area covered by the emissions inventory.

Figure 1.1: Geographic Extent



Vessel types

The vessel types that are included are the same as reported in the Port Authority's marine vessel emissions inventories. These vessel types are listed below.

- OGVs:
  - Bulk (dry) carriers
  - Car carriers
  - Containerships – by size class
  - Cruise ships
  - General cargo vessels
  - RORO vessels
  - Tankers – by size class
- Harbor Craft:
  - Assist tugs
  - Tow boats
  - Ferries/excursion
  - Commercial fishing
  - Government vessels
  - Dredges

Emission Source Types

Emission estimates have been developed for the three combustion emission source types associated with marine vessels: main (or propulsion) engines, auxiliary engines, and, for OGVs, auxiliary boilers. Propulsion engines are primarily diesel-fueled engines that provide power for moving the vessel through the water, while auxiliary engines are used to run generators that provide electrical power for ship-board use. Some vessels, notably many cruise ships, are designed with a diesel-electric configuration in which all engines operate generators that power electric propulsion engines and provide for ship-board electrical needs. Auxiliary boilers provide steam for ship-board hot water and, if needed, for heating fuel. Some liquid bulk tankers are equipped with steam-powered pumps that are used to off-load product to shore-side facilities.

Operating Modes

OGV activity as determined through the analysis of AIS data is segregated into three modes of operation: transit, maneuvering, and dwelling (also known as hoteling).

- Transit occurs as the vessel moves through the harbor system between sea and berth
- Maneuvering occurs when the vessel moves at very slow speeds in approaching or departing the berth
- Dwelling occurs when the vessel is stationary while at berth or at anchorage

The main and auxiliary engines are operating while the vessel is transiting. The boiler may be operating, depending on steam needs and on how much heat is being recovered from the waste heat boiler (economizer) that most ships use to recover heat from their main engine exhausts. During maneuvering the main engine may operate intermittently, and the auxiliary engines and auxiliary boiler are operating. When dwelling, the main engine is turned off while the auxiliary engines and auxiliary boiler are operating. Data and assumptions regarding these operating modes are provided in the methodology section of this report.

Pollutants

This inventory estimates and reports the quantity of emissions based on activities that occurred during calendar year 2015 and are reported in tons per year (tpy). Emissions of the following criteria pollutants or precursors are included:

- Oxides of nitrogen (NO_X), an ozone precursor
- Particulate matter less than 10 microns in diameter (PM_{10})
- Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$)
- Volatile organic compounds (VOCs), an ozone precursor
- Carbon monoxide (CO)
- Sulfur dioxide (SO_2)

The following fuel combustion-related greenhouse gas emissions are also included (reported as metric tons, MT, per year):

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

GHG emissions are presented in terms of CO_2 equivalents (CO_2e), a measure that weights each gas by its global warming potential (GWP) relative to CO_2. The CO_2e emissions include CO_2, CH_4, and N_2O; the CO_2e value is calculated by multiplying each GHG's total emissions by its corresponding GWP value from EPA's latest report, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016*.[1] The sum of the three GHGs is reported as one CO_2e value using the following GWP values.

- CO_2 – 1 N_2O – 298 CH_4 – 25

1.3 Summary of Results

The following table provides a top-level summary of estimated emissions from OGVs and harbor craft. More detailed breakouts are provided in Section 2, with a discussion of data collection and emission estimation methods following in Section 3. The emissions of NOx from harbor craft reflect the 754 tons of reductions achieved in 2015 through the various emission reduction programs implemented in support of the HDP.

Table 1.1: Commercial Marine Vessel Emission Summary, tpy

Emission Source	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2e
Category				tpy				MT
New Jersey								
Ocean-Going Vessels	2,144	50.3	46.9	36.5	89.1	200.1	103.8	168,492
Harbor Craft	2,056	72	66	72	64	453	1	126,460
New Jersey total	**4,200**	**121.9**	**112.8**	**108.1**	**152.9**	**653.2**	**105.0**	**294,952**
New York								
Ocean-Going Vessels	2,314	50.2	47.0	37.2	99.3	210.6	108.7	163,482
Harbor Craft	5,204	175	161	175	158	1,121	3	309,413
New York total	**7,519**	**225.0**	**207.8**	**212.0**	**257.7**	**1,331.3**	**111.6**	**472,895**
Total 2015	**11,719**	**346.9**	**320.6**	**320.2**	**410.6**	**1,984.4**	**216.6**	**767,847**

1.4 Comparison with 2000 Emissions Inventory

The following tables and discussion present the results of this emissions inventory in comparison with the 2000 CMVEI.

Table 1.2 lists 2015 and 2000 CMV emissions by state and by general category of CMV (OGVs and harbor craft), showing tons per year of the pollutants included in the 2000 CMVEI and the percentage difference between 2000 and 2015. The comparison between estimates for 2015 and 2000 should be considered approximate because of the considerable differences in methodologies used to estimate emissions for the 2000 inventory compared with the current 2015 inventory.

[1] *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016*

Table 1.2: Comparison of 2015 and 2000 Emission Estimates, tpy & %

State / Emission Source category		NO_x	PM_{10}	$PM_{2.5}$ tpy	VOC	CO	SO_x
2015							
New Jersey	Ocean-Going Vessels	2,144	50	47	89	200	104
	Harbor Craft	2,307	72	66	64	453	1
	New Jersey 2015	**4,451**	**122**	**113**	**153**	**653**	**105**
New York	Ocean-Going Vessels	2,314	50	47	99	211	109
	Harbor Craft	5,708	175	161	158	1,121	3
	New York 2015	**8,022**	**225**	**208**	**257**	**1,332**	**112**
NJ&NY totals	Ocean-Going Vessels	4,458	100	94	188	411	213
	Harbor Craft	8,015	247	227	222	1,574	4
	Total 2015	**12,473**	**347**	**321**	**410**	**1,985**	**217**
2000							
New Jersey	Ocean-Going Vessels	2,108	127	117	83	378	2,156
	Harbor Craft	3,353	115	106	129	476	992
	New Jersey 2000	**5,461**	**242**	**223**	**212**	**854**	**3,148**
New York	Ocean-Going Vessels	2,031	108	99	72	345	2,146
	Harbor Craft	4,614	152	140	166	686	1,373
	New York 2000	**6,645**	**260**	**239**	**238**	**1,031**	**3,519**
NJ&NY totals	Ocean-Going Vessels	4,139	235	216	155	723	4,302
	Harbor Craft	7,967	267	246	295	1,162	2,365
	Total 2000	**12,106**	**502**	**462**	**450**	**1,885**	**6,667**
Percent difference, 2015 compared with 2000							
New Jersey	Ocean-Going Vessels	2%	-61%	-60%	7%	-47%	-95%
	Harbor Craft	-31%	-37%	-38%	-50%	-5%	-100%
	New Jersey total	-18%	-50%	-49%	-28%	-24%	-97%
New York	Ocean-Going Vessels	14%	-54%	-53%	38%	-39%	-95%
	Harbor Craft	24%	15%	15%	-5%	63%	-100%
	New York total	21%	-13%	-13%	8%	29%	-97%
NJ&NY totals	Ocean-Going Vessels	8%	-57%	-56%	21%	-43%	-95%
	Harbor Craft	1%	-7%	-8%	-25%	35%	-100%
	Overall difference	**3%**	**-31%**	**-31%**	**-9%**	**5%**	**-97%**

1.4.1 Ocean-Going Vessels

The differences in emission estimates between the 2000 and the 2015 EIs are reasonable despite the different methodologies and data sources underlying the estimates. The overall estimate of NO_x emissions in 2015 is 8% higher than the 2000 estimate, while the PM_{10} and $PM_{2.5}$ estimates are 57% and 56% lower, respectively, than the corresponding 2000 estimates and the SO_x estimate for 2015 is 95% lower than the 2000 estimate.

Differences in emissions from OGVs between years are affected by numerous factors, including cargo throughput differences, the number of calls of different types of vessels, the amount of cargo discharged or loaded during each vessel call, the characteristics of the vessels themselves, and the type and sulfur content of the fuels used. Emissions of SOx and, to a lesser extent, of PM_{10} and $PM_{2.5}$ would be expected to decrease between 2000 and 2015 due to the significant reduction in fuel sulfur content over that period. The North American Emission Control Area (ECA) was in effect in 2015 and it was the first year to change the fuel sulfur content limit for OGVs operating within the ECA from 1.0% S to 0.1% S.

Table 1.3 compares cargo volumes for the Port of New York & New Jersey in 2015 and 2000.[2] These cargo volumes are footnoted "Including The Port Authority of New York & New Jersey (PANYNJ) and non-PANYNJ facilities" so are not limited to Port Authority facilities but are representative of facilities in the harbor system as a whole. This table shows a two-fold increase in container throughput measured as containers (boxes), while measured as twenty-foot equivalent units (TEUs) the increase has been by a factor of 2.09. The difference in increase between containers and TEUs is due to an increase in the number of containers larger than 20 feet, resulting in an average container size of 1.74 TEU/container in 2015 compared with 1.67 TEU/container in 2000. Table 1.3 also shows an almost two-fold increase in general cargo throughput accompanied by a 20% reduction in bulk cargo throughput, with a slight overall increase (approximately 14%) in combined bulk and general cargo throughput. Automobile exports were over five times higher in 2015 than in 2000, while imports were slightly lower in 2015 than in 2000.

These differences in cargo throughput, along with other factors such as vessel size and the amount of cargo discharged and loaded during each call, resulted in the differences in OGV calls shown in Table 1.4. This table shows that containerships were the predominant vessel type in 2000 and were even more so in 2015, increasing from 36% of vessel calls in 2000 to 52% of vessel calls in 2015. The number of containership calls also increased, reflecting the increase in containerized cargo. Tankers (liquid bulk) were the second most common vessel to call in both inventory years, decreasing from 27% of calls in 2000 to 23% of calls in 2015, and decreasing in number of calls as well. These decreases may be the result of a decrease in throughput of bulk cargo, as reflected in Table 1.3, and possibly to an increase in vessel capacities. The differences in most other vessel types can be attributed to throughput or business changes, such as the increase in cruise ship calls and the increase in the total of automobile carriers and RORO ships. Automobile carriers and ROROs should be compared in combination because they are closely related vessel types and there may have been classification differences between the two years. The lower number of dry bulk vessel calls in 2015 as compared with 2000 may be due to a combination of lower throughput, larger vessel sizes, and more complete utilization of vessel capacity. Regarding bulk vessel size, the 2000 CMVEI reported that 166 of 203 bulk vessels that called in the inventory area (82%) were in the 10,000-49,999 deadweight ton (DWT) size range, while in 2015 the average DWT of bulk vessels calling in the inventory area was nearly 54,000. The 2000 report did not include cargo capacity information.

[2] Accessed at *https://www.panynj.gov/port/trade-stats.html*

Table 1.3: Comparison of Cargo Throughput, 2015 and 2000

Cargo Type	**Cargo Measure**		
Containerized cargo	Boxes	TEUs	TEU/cont
2015	3,664,013	6,371,720	1.74
2000	1,828,636	3,050,746	1.67
Growth factor	**2.00**	**2.09**	**1.04**
General cargo, MT	Total	Imports	Exports
2015	36,781,069	26,138,101	10,642,968
2000	18,874,726	13,532,021	5,342,705
Growth factor	**1.95**	**1.93**	**1.99**
Bulk cargo, MT	Total	Imports	Exports
2015	36,827,254	32,724,146	4,103,108
2000	45,942,548	44,778,692	1,163,856
Growth factor	**0.80**	**0.73**	**3.53**
Gen'l and bulk, MT	Total	Imports	Exports
2015	73,608,323	58,862,247	14,746,076
2000	64,817,274	58,310,713	6,506,561
Growth factor	**1.14**	**1.01**	**2.27**
Motor vehicles	Total	Imports	Exports
2015	644,286	433,822	210,464
2000	564,718	527,822	36,896
Growth factor	**1.14**	**0.82**	**5.70**

Table 1.4: Comparison of Vessel Calls and Shifts, 2015 and 2000

Vessel Type	**2015 Data**				**2000 Data**			
	Calls (arr.)	**Shifts**	**Total**	**Percent**	**Calls**	**Shifts**	**Total**	**Percent**
Containership	2,211	145	2,356	52%	1,643	115	1,758	36%
Tanker	982	1,398	2,380	23%	1,255	355	1,610	27%
Auto Carrier	431	95	526	10%	166	56	222	4%
Cruise	247	3	250	6%	100	2	102	2%
Bulk	174	119	293	4%	1,142	111	1,253	25%
RoRo	101	81	182	2%	256	57	313	6%
General cargo*	81	41	122	2%	43	1	44	1%
Totals	**4,227**	**1,882**	**6,109**	**100%**	**4,605**	**697**	**5,302**	**100%**

* The category in the 2000 EI is "Miscellaneous" – probably does not refer to the same types of vessels

1.4.2 Harbor Craft

Differences in emissions from various types of harbor craft between years are affected by some of the same factors that influence changes in OGV emissions, including cargo throughputs, number of OGV visits, and fuel sulfur content changes. Emissions are also affected by other factors including tourism levels (affecting ferries and excursion vessels), government and security functions, and business/operating practices. These factors were not investigated during the development of this CMVEI. When viewed in total, the 2015 harbor craft emission estimates are similar to the 2000 estimates, with 2015 NO_x being 1% higher and 2015 PM_{10} and $PM_{2.5}$ being 7% and 8% lower, respectively. Emissions of SO_x were dramatically lower in 2015 than in 2000 due to the almost exclusive sale and use of ultra-low sulfur diesel fuel (ULSD) prior to 2015.

Differences in data collection resulted in more vessel types being included in the harbor craft category in the 2015 CMVEI compared with the 2000 CMVEI. The use of AIS data allowed the inclusion of all marine vessel activity including, for example, fishing vessels that were not included in the 2000 study. These additional vessel types made up about 4% of harbor craft emissions included in this CMVEI.

SECTION 2 DETAILED RESULTS

The emissions summarized above are presented in more detail in this section.

2.1 Ocean-Going Vessels

OGV emissions are summarized by vessel type, emission source type, operating mode, state, and county in the following tables. Table 2.1 lists emissions by state and by vessel type, Table 2.2 lists emissions by state and by emission source type (main and auxiliary engines, and boilers), Table 2.3 lists emissions by state and by activity mode (dwelling at anchorage and at berth, transit, and maneuvering), and Table 2.4 lists emissions by state and by county.

Table 2.1: OGV Emissions by Vessel Type and State, tpy

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2e
				tpy				MT
New Jersey								
Containership	1,272	27.3	25.4	21.7	57.9	121.2	46.8	85,597
Cruise	185	3.8	3.6	3.8	6.7	17.2	6.9	9,967
Auto Carrier	127	2.8	2.6	2.3	4.6	11.7	5.3	8,580
Tanker	452	13.9	13.0	6.8	16.1	40.4	38.9	55,906
Bulk	42	1.1	1.0	0.8	1.5	3.9	2.6	3,805
RoRo	42	0.9	0.9	0.6	1.6	3.6	2.2	3,174
General Cargo	24	0.5	0.5	0.4	0.8	2.1	1.0	1,463
New Jersey total	**2,144**	**50.3**	**46.9**	**36.5**	**89.1**	**200.1**	**103.8**	**168,492**
New York								
Containership	759	12.3	11.5	11.5	43.2	72.4	17.1	31,156
Cruise	501	10.3	9.7	10.3	17.6	46.5	18.5	26,771
Auto Carrier	118	2.1	1.9	1.9	5.4	11.4	3.3	5,446
Tanker	797	22.8	21.4	11.2	28.0	68.2	64.1	92,164
Bulk	59	1.2	1.1	1.0	2.0	5.0	2.5	3,548
RoRo	26	0.4	0.4	0.4	1.2	2.4	0.8	1,155
General Cargo	54	1.1	1.1	1.0	1.9	4.8	2.3	3,243
New York total	**2,314**	**50.2**	**47.0**	**37.2**	**99.3**	**210.6**	**108.7**	**163,482**
Total 2015	**4,458**	**100.5**	**93.9**	**73.8**	**188.4**	**410.8**	**212.5**	**331,974**

Table 2.2: OGV Emissions by Emission Source Type, tpy

Emission Source Type	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2e
				tpy				MT
New Jersey								
Main Engines	546	7.6	7.1	7.6	32.3	50.5	10.5	17,473
Auxiliary Engines	1,424	28.9	27.0	28.9	48.0	132.1	46.0	75,685
Boilers	174	13.8	12.8	0.0	8.8	17.6	47.4	75,333
New Jersey total	**2,144**	**50.3**	**46.9**	**36.5**	**89.1**	**200.1**	**103.8**	**168,492**
New York								
Main Engines	948	12.9	12.1	12.8	51.0	83.9	18.8	30,509
Auxiliary Engines	1,205	24.4	22.9	24.4	40.2	110.4	42.2	63,271
Boilers	161	12.8	12.0	0.0	8.1	16.3	47.7	69,702
New York total	**2,314**	**50.2**	**47.0**	**37.2**	**99.3**	**210.6**	**108.7**	**163,482**
Total 2015	**4,458**	**100.5**	**93.9**	**73.8**	**188.4**	**410.8**	**212.5**	**331,974**

Table 2.3: OGV Emissions by Operating Mode, tpy

Operating Mode	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2e
				tpy				MT
New Jersey								
Dwelling - Anchorage	0	0.0	0.0	0.0	0.0	0.0	0.0	0
Dwelling - Berth	1,410	38.7	36.0	25.2	50.4	132.2	86.5	139,672
Maneuvering	316	5.9	5.5	5.6	24.5	34.6	7.6	12,840
Transit	418	5.8	5.4	5.7	14.2	33.3	9.7	15,979
New Jersey total	**2,144**	**50.3**	**46.9**	**36.5**	**89.1**	**200.1**	**103.8**	**168,492**
New York								
Dwelling - Anchorage	136	3.6	3.3	2.4	4.7	12.4	8.6	12,398
Dwelling - Berth	898	26.6	24.9	15.4	32.3	83.4	68.9	100,501
Maneuvering	644	11.2	10.5	10.8	41.7	64.6	16.4	26,434
Transit	636	8.8	8.2	8.7	20.6	50.2	14.8	24,148
New York total	**2,314**	**50.2**	**47.0**	**37.2**	**99.3**	**210.6**	**108.7**	**163,482**
Total 2015	**4,458**	**100.5**	**93.9**	**73.8**	**188.4**	**410.8**	**212.5**	**331,974**

Table 2.4: OGV Emissions by County, tpy

County	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2e
				tpy				MT
Bergen	16	0.3	0.3	0.3	1.6	2.1	0.4	574
Essex	616	15.1	14.1	11.4	24.7	59.0	28.9	49,848
Hudson	575	14.6	13.6	10.5	24.6	55.7	30.2	48,761
Middlesex	179	5.6	5.3	2.8	6.5	16.3	15.6	22,457
Monmouth	504	7.5	7.0	7.3	20.4	42.6	12.1	20,055
Union	254	7.2	6.7	4.2	11.4	24.4	16.6	26,797
New Jersey total	**2,144**	**50.3**	**46.9**	**36.5**	**89.1**	**200.1**	**103.8**	**168,492**
Bronx	5	0.1	0.1	0.1	0.2	0.4	0.3	384
Kings	407	8.1	7.5	6.4	18.0	36.9	16.3	25,071
Nassau	29	0.4	0.4	0.4	0.9	2.3	0.9	1,261
New York	423	8.6	8.1	8.5	15.0	39.1	15.5	22,591
Orange	25	0.4	0.3	0.3	0.8	1.9	0.7	1,062
Queens	360	5.4	5.1	5.3	15.7	31.2	8.5	14,135
Richmond	810	22.4	20.9	12.5	38.9	77.7	56.1	83,749
Rockland	17	0.2	0.2	0.2	0.6	1.3	0.5	706
Suffolk	201	3.8	3.6	2.9	8.0	16.8	8.5	12,633
Westchester	38	0.6	0.6	0.6	1.2	3.0	1.3	1,892
New York total	**2,314**	**50.2**	**47.0**	**37.2**	**99.3**	**210.6**	**108.7**	**163,482**
Total 2015	**4,458**	**100.5**	**93.9**	**73.8**	**188.4**	**410.8**	**212.5**	**331,974**

2.2 Harbor Craft

Harbor craft emissions are summarized by vessel type, emission source type, state, and county in the following tables. Table 2.5 lists emissions by state and by vessel type, Table 2.6 lists emissions by state and by emission source type (main and auxiliary engines), and Table 2.7 lists emissions by state and by county. The NO_x emissions reflect the 754 tons of reductions achieved in 2015 through the various emission reduction programs implemented in support of the HDP.

Table 2.5: Harbor Craft Emissions by Vessel Type and State, tpy

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2e
	tpy							MT
New Jersey								
Towboats	1,466	47.8	43.9	47.8	43.9	309.3	0.8	83,554
Ferry/excursion	403	18.6	17.1	18.6	14.9	111.4	0.3	32,134
Government	83	1.9	1.8	1.9	2.0	14.1	0.0	4,754
Dredging	54	1.8	1.6	1.8	1.6	8.6	0.0	3,167
Fishing	16	0.5	0.4	0.5	0.4	2.4	0.0	1,001
Other	34	1.1	1.0	1.1	0.8	7.3	0.0	1,850
New Jersey total	**2,056**	**71.6**	**65.9**	**71.6**	**63.8**	**453.0**	**1.2**	**126,460**
New York								
Towboats	3,680	119.6	110.1	119.6	110.5	775.6	2.0	208,237
Ferry/excursion	760	33.3	30.7	33.3	28.0	210.5	0.6	60,009
Government	259	5.6	5.1	5.6	5.8	46.6	0.1	13,711
Dredging	233	8.6	7.9	8.6	7.6	32.9	0.1	12,409
Fishing	55	1.7	1.6	1.7	1.5	8.3	0.0	3,470
Other	219	5.9	5.4	5.9	5.0	46.8	0.1	11,577
New York total	**5,204**	**174.8**	**160.8**	**174.8**	**158.4**	**1,120.6**	**2.9**	**309,413**
Total 2015	**7,261**	**246.4**	**226.7**	**246.4**	**222.2**	**1,573.6**	**4.1**	**435,873**

Table 2.6: Harbor Craft Emissions by Emission Source Type, tpy

Emission Source Type	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2e
	tpy							MT
New Jersey								
Main Engines	1,771	58.0	53.3	58.0	54.8	390.5	1.0	104,751
Auxiliary Engines	325	13.6	12.5	13.6	9.0	62.5	0.2	21,709
New Jersey total	**2,096**	**71.6**	**65.9**	**71.6**	**63.8**	**453.0**	**1.2**	**126,460**
New York								
Main Engines	4,615	152.0	139.8	152.0	143.2	1,014.5	2.6	272,672
Auxiliary Engines	550	22.8	21.0	22.8	15.2	106.2	0.3	36,741
New York total	**5,165**	**174.8**	**160.8**	**174.8**	**158.4**	**1,120.6**	**2.9**	**309,413**
Total 2015	**7,261**	**246.4**	**226.7**	**246.4**	**222.2**	**1,573.6**	**4.1**	**435,873**

Table 2.7: Harbor Craft Emissions by County

County	NO_x	PM_{10}	$PM_{2.5}$	DPM	VOC	CO	SO_x	CO_2e
				tpy				MT
Bergen	86	2.9	2.6	2.9	2.6	18.9	0.0	5,172
Essex	217	7.5	6.9	7.5	6.8	48.2	0.1	13,577
Hudson	950	31.7	29.2	31.7	28.5	205.5	0.5	56,681
Middlesex	286	10.5	9.7	10.5	8.9	61.3	0.2	17,925
Monmouth	340	11.7	10.8	11.7	10.2	72.0	0.2	20,337
Union	210	7.3	6.7	7.3	6.7	47.1	0.1	12,769
New Jersey total	2,090	71.6	65.9	71.6	63.8	453.0	1.2	126,460
Bronx	207	7.1	6.5	7.1	6.6	46.3	0.1	12,379
Kings	416	14.0	12.9	14.0	12.8	91.8	0.2	25,238
Nassau	294	10.2	9.4	10.2	9.3	65.8	0.2	17,691
New York	902	29.3	27.0	29.3	26.4	192.5	0.5	52,991
Ocean	330	11.8	10.9	11.8	10.4	64.6	0.2	19,787
Orange	264	9.0	8.3	9.0	8.3	58.6	0.1	15,731
Queens	170	5.7	5.3	5.7	5.2	37.3	0.1	10,144
Richmond	864	30.2	27.8	30.2	26.9	189.9	0.5	52,938
Rockland	376	12.1	11.2	12.1	11.4	82.4	0.2	22,274
Suffolk	964	32.3	29.8	32.3	29.2	205.8	0.5	57,131
Westchester	386	12.9	11.9	12.9	12.0	85.6	0.2	23,108
New York total	**5,171**	**174.8**	**160.8**	**174.8**	**158.4**	**1,120.6**	**2.9**	**309,413**
Total 2015	**7,261**	**246.4**	**226.7**	**246.4**	**222.2**	**1,573.6**	**4.1**	**435,873**

SECTION 3 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. As noted in the Introduction, methodologies have been used that are consistent with the annual CMV emissions inventories developed for the Port Authority. The methodology for OGVs uses data collected through the Automatic Identification System (AIS) which allows each vessel call to be identified and analyzed for route, speed, and dwelling (hoteling) durations. AIS data is collected by the U.S. Coast Guard by recording the location signals that are sent nearly continuously by virtually all commercial marine vessels. Information on individual vessels 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 such as rated speed and main engine power. AIS data has also been used to profile the activity of harbor craft in terms of travel distances and areas of operation.

3.1 Data Sources

The sources and use of information that underlie the emission calculations for OGVs and harbor craft are discussed in turn.

3.1.1 Ocean-Going Vessels

The AIS data for vessels that operated in the NYNJHS provides the activity data that underlies the emission estimates presented in this report. The time-stamped location data points were processed to provide a vessel identifier, location, speed, and direction for every two minutes of the inventory year. This processed data was used to identify each vessel call and the call's associated transit speeds, routes, and dwelling times at berth and at anchorage. At its simplest, a call consists of an arrival from sea to a berth within the NYNJHS and a subsequent departure to sea, with a period of dwelling at the berth between arrival and departure. Some calls include one or more shifts, which are movements between berths or between berth and anchorage.

Vessel-specific data from IHS Markit was used to determine each vessel's characteristics such as engine type, engine model year, propulsion horsepower, onboard auxiliary horsepower, nation of registry, and other parameters. The IHS Markit data was also used to develop vessel type characteristic averages to be used as defaults for vessels for which specific data was not available. Data collected during the vessel boarding programs (VBP) that Starcrest has conducted at several North American ports was used to characterize auxiliary engine and boiler operating characteristics of specific vessels and for vessel type defaults for auxiliary engines and boilers because the IHS Markit data does not provide this information and it is not readily available elsewhere. When available for specific vessels, the inventory also used main engine information from the VBP dataset.

The numbers of OGV arrivals, departures, and shifts of each vessel type to the NYNJHS are listed in Table 3.1, based on Starcrest's analysis of the AIS data as described above. The arrival and departure numbers are not always an exact match for a given vessel type because of call overlap at the beginning and end of the calendar year (i.e., a vessel's arrival may have occurred at the end of 2014 and not been counted, while its departure in January would have been counted).

Table 3.1: Vessel Movements in the New York New Jersey Harbor System, 2015

Vessel Type	Arrivals	Departures	Shifts
Auto Carrier	431	431	95
Bulk	174	178	119
Container - 1000	0	0	0
Container - 2000	0	0	0
Container - 3000	0	0	0
Container - 4000	0	0	0
Container - 5000	0	0	0
Container - 6000	0	0	0
Container - 7000	0	0	0
Container - 8000	0	0	0
Container - 9000	0	0	0
Container - 10000	0	0	0
All containerships	**0**	**0**	**0**
Cruise	247	247	3
General Cargo	81	83	41
RoRo	101	102	81
Tanker - Aframax	117	118	138
Tanker - Chemical	615	624	833
Tanker - Handysize	118	122	147
Tanker - Panamax	120	121	267
Tanker - Suezmax	12	12	13
Totals	**2,016**	**2,038**	**1,737**

Table 3.2 lists the minimum, average, and maximum dwelling times (hours) at berth and at anchorage for the different OGV types and sizes that called at NYNJHS terminals.

Table 3.2: Average OGV Dwell Times at Berth, hours

	Berth Dwelling			Anchorage Dwelling		
Vessel Type	Min	**Average**	Max	Min	**Average**	Max
Auto Carrier	0	19	502	1	8	20
Bulk	2	109	467	1	26	290
Container - 1000	0	0	0	0	0	0
Container - 2000	0	0	0	0	0	0
Container - 3000	0	0	0	0	0	0
Container - 4000	0	0	0	0	0	0
Container - 5000	0	0	0	0	0	0
Container - 6000	0	0	0	0	0	0
Container - 7000	0	0	0	0	0	0
Container - 8000	0	0	0	0	0	0
Container - 9000	0	0	0	0	0	0
Container - 10000	0	0	0	0	0	0
Cruise	0	17	459	0	0	0
General Cargo	2	71	340	2	28	444
RoRo	5	43	2,255	2	11	27
Tanker - Aframax	1	38	148	1	38	182
Tanker - Chemical	1	35	486	0	17	179
Tanker - Handysize	1	36	394	0	16	105
Tanker - Panamax	2	44	309	0	29	320
Tanker - Suezmax	21	28	42	5	29	70

3.1.2 Harbor Craft

AIS data was used to identify harbor craft activity (hours) by mode of operation and county area, using vessel specific Maritime Mobile Service Identity (MMSI) numbers. The modes of operation are at berth, maneuvering, and in transit.

- At berth - Hours in this zone were assumed to apply to one operating auxiliary engine with the main (propulsion) engine off.
- Maneuvering - Hours in this zone were assumed to apply to one operating auxiliary engine and one or two operating main engines, depending on vessel type.
- Transit - Hours in this zone were assumed to apply to one operating auxiliary engine and one or two operating main engines, depending on vessel type.

Web searches were performed on the MMSI numbers of vessels catalogued from the AIS data that were not known to be harbor craft (such as the Staten Island Ferries) to determine vessel type, if possible. Vessels that were known to be harbor craft or could be verified as harbor craft using web searches were included in the vessel activity dataset.

Activity data by MMSI number was joined with IHS Markit data each vessel to determine the number of propulsion engines, total propulsion power, engine model year, vessel name, and vessel operator name. Total propulsion power was divided by the number of engines to determine the power rating of each propulsion engine. The auxiliary engine power is not available through IHS Markit data, so this information has been obtained for the Port Authority's annual EIs through contacts with various towboat operators and through their websites. The average power rating of auxiliary engines based on the data collected for those studies was used in these emission estimates.

Table 3.3 lists the minimum, average, and maximum values for propulsion engine power, annual hours of propulsion engine operation, and vessel year of build. Table 3.4 lists the minimum, average, and maximum values for auxiliary engine power and annual hours of operation.

Table 3.3: Average Harbor Craft Propulsion Engine Characteristics

	Propulsion Engine Characteristics								
Vessel Type	Power, kW			Annual Hours			Year Built		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Towboats	294	1,520	6,001	0	612	4,056	1940	1984	2015
Ferry/excursion	419	1,356	2,865	0	1,057	3,696	1954	1996	2007
Government	499	1,438	2,942	0	115	3,111	1972	1989	2006
Dredging	625	2,286	5,075	0	296	1,370	1980	1988	2006
Fishing	186	513	1,250	0	79	2,507	1965	1988	2014
Other	162	3,150	10,201	0	202	3,392	1960	1990	2012

Table 3.4: Average Harbor Craft Auxiliary Engine Characteristics

	Auxiliary Engine Characteristics								
Vessel Type	Power, kW			Total Annual Hours			Year Built		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Towboats	7	98	416	63	2,221	7,943	1940	1984	2015
Ferry/excursion	5	171	1,500	0	2,546	8,760	1954	1996	2007
Government	7	375	1,500	0	1,014	8,760	1972	1989	2006
Dredging	15	309	2,088	0	651	8,760	1980	1988	2006
Fishing	9	99	1,200	1	1,648	8,195	1965	1988	2014
Other	8	163	9,400	0	2,731	8,760	1960	1990	2012

3.1.3 Emission Estimating Methodology

Emission estimates have been developed for the three combustion emission source types associated with marine vessels: main (or propulsion) engines, auxiliary engines, and, for OGVs, auxiliary boilers. OGV emissions have been further segregated into transit (arrival/departure), maneuvering, and dwelling (at-berth and anchorage) components. Operating data and the methods of estimating emissions are discussed below for the three source types. Differences between transit and dwelling methodologies are discussed where appropriate. The estimates were made assuming that all OGVs calling the port terminals used marine diesel oil (MDO) with an average sulfur content of 0.1% per IMO's requirement for the ECA.

3.1.4 OGV Main Engines

Main engine emissions have been estimated for transiting and maneuvering modes because a vessel's main engines are typically turned off while the vessel is dwelling at berth or at anchorage. The main engine emission calculation can be described using the following equation:

Equation 1

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

Where:

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

Energy is calculated using the following equation:

Equation 2

$$Energy_i = Load \times Act$$

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

3.1.5 OGV Fuel Correction Factors and Emission Factors

Fuel correction factors (FCF) are applied to reflect the effect of fuel on emissions when the actual fuel used is different from the fuel used to develop the emission factors. Table 3.5 shows the FCF used to adjust the base emission factors (shown in Table 3.6) that are based on HFO with 2.7% sulfur.[3] The ECA was in effect in 2015 with a 0.1% fuel oil sulfur content limit for OGVs operating in the ECA. For this report, it was assumed that the vessels that operated in the NYNJHS complied with the ECA fuel requirement and all engines and auxiliary boilers used fuel with a maximum sulfur content of 0.1% sulfur, unless actual fuel information was available through the Port Authority's Clean Vessel Incentive Program, in which case the known fuel sulfur content was used.

Table 3.5: OGV Fuel Correction Factors (unitless)

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

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

The base emission factors used for main and auxiliary engines and for auxiliary boilers based on HFO with a sulfur content of 2.7% are listed in Tables 3.6 and 3.7.

Table 3.6: OGV Base Emission Factors (g/kW-hr)

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

Table 3.7: OGV GHG Emission Factors (g/kW-hr)

Engine Category	Model Year Range	CO_2	N_2O	CH_4
Slow Speed Main (Tiers 0 to 2)	All	620	0.031	0.012
Medium Speed Main (Tiers 0 to 2)	All	683	0.031	0.012
Steam Main and Boiler	All	970	0.08	0.002
Medium Auxiliary (Tiers 0 to 2)	All	722	0.031	0.008

3.1.6 OGV Auxiliary Engines Load Defaults

OGVs are equipped with two or more auxiliary engines that are operated to run at the most efficient level for a given load situation. For example, an OGV equipped with four auxiliary engines may run three at 75% load when power needs are high during maneuvering, to power bow thrusters as well as to meet general operating needs. While at berth, the vessel's power needs are lower, so instead of running the three engines at a greatly reduced load, typically only one or two will be operated at a higher load. This saves wear and tear on the other auxiliary engines and allows the operating engine(s) to run at optimal (higher) operating levels. In practice, actual auxiliary engine and auxiliary boiler loads are not readily available for specific vessels. The information used for these estimates has been collected by Starcrest during their VBP in which ships' operators (usually captains and chief engineers) are interviewed while on board the vessels to collect actual engine load information, and summaries have been published by the port(s) sponsoring these programs.[4]

[4] Port of Los Angeles Inventory of Air Emissions, 2017; and Port of Long Beach 2017 Emissions Inventory.

Table 3.8 lists the OGV auxiliary engine load assumptions by vessel type and mode that are used in this inventory.

Table 3.8: OGV Auxiliary Engine Load by Mode, kW

Vessel Type	Transit (kW)	Manuevering (kW)	Berth Hoteling (kW)	Anchorage Hoteling (kW)
Auto Carrier	510	1,516	897	622
Bulk	255	675	150	253
Container - 1000	545	1,058	429	1,000
Container - 2000	981	2,180	1,035	1,008
Container - 3000	602	2,063	516	559
Container - 4000	1,428	2,496	1,121	1,200
Container - 5000	1,716	3,288	888	967
Container - 6000	1,453	2,197	990	1,645
Container - 7000	1,491	2,897	1,250	1,000
Container - 8000	1,473	2,700	930	986
Container - 9000	1,484	2,840	1,033	968
Container - 10000	2,300	2,350	1,450	1,129
Cruise	7,058	9,718	5,353	7,782
General Cargo	520	1,419	743	180
RoRo	132	396	229	434
Tanker - Aframax	576	719	724	474
Tanker - Chemical	658	890	816	402
Tanker - Handysize	537	601	820	560
Tanker - Panamax	561	763	623	379
Tanker - Suezmax	860	1,288	2,509	773
Tankers (Diesel/Electric)	1,800	1,854	6,500	1,800

House load defaults for cruise ships (diesel electric and non-diesel electric) are listed in Table 3.9. The majority of cruise ships that called at the cruise terminal in 2015 were diesel-electric. Cruise ships do not spend time at anchorage, so auxiliary engine loads at anchorage were not needed for the calculations and are therefore not included in the table below.

Table 3.9: Cruise Ship Auxiliary Engine Load, kW

Passenger Count	Transit (kW)	Maneuvering (kW)	Berth Hoteling (kW)
0-1,499	3,500	4,000	3,000
1,500-1,999	7,000	8,000	6,500
2,000-2,499	10,500	11,500	9,500
2,500-2,999	11,000	12,000	10,000
3,000-3,499	11,500	13,000	10,500
3,500-3,999	12,000	13,500	11,000
4,000-4,599	12,500	14,000	12,000
4,500-4,999	13,000	14,500	13,000
5,000-5,499	13,500	15,500	13,500
5,500-5,999	14,000	16,000	14,000
6,000-6,499	14,500	16,500	14,500
6,500+	15,000	17,000	15,000

3.1.7 OGV Auxiliary Boilers

The auxiliary boiler daily fuel consumption information collected during VBP boardings was converted to equivalent kilowatts using factors for specific fuel consumption (SFC) found in the ENTEC 2002 study. The average SFC value for low sulfur fuel generally known as marine diesel oil (MDO) is 290 grams of fuel per kW-hour. The average kW for auxiliary boilers was calculated using the following equation.

Equation 3

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

Where:

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

No boiler load data is available from the IHS Markit database, so 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 that have been boarded and their sister ships. 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 approximately 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 calculated to be less than or equal to 20%, the auxiliary boiler load defaults shown in the table are used, depending on operating mode. Table 3.10 presents auxiliary boiler energy defaults by mode in kilowatts for each vessel type.

Table 3.10: Auxiliary Boiler Load Defaults by Mode, kW

Vessel Type	Transit (kW)	Maneuvering (kW)	Berth Hoteling (kW)	Anchorage Hoteling (kW)
Auto Carrier	87	184	314	305
Bulk	35	94	125	125
Container - 1000	106	213	273	270
Container - 2000	141	282	361	358
Container - 3000	164	328	420	416
Container - 4000	195	371	477	472
Container - 5000	247	473	579	572
Container - 6000	182	567	615	611
Container - 7000	259	470	623	619
Container - 8000	228	506	668	673
Container - 9000	381	613	677	675
Container - 10000	330	575	790	790
Cruise	282	361	612	306
General Cargo	56	124	160	160
RoRo	67	148	259	251
Tanker - Aframax	179	438	5,030	375
Tanker - Chemical	59	136	568	255
Tanker - Handysize	144	144	2,586	144
Tanker - Panamax	167	351	3,421	451
Tanker - Suezmax	144	191	5,843	503
Tankers (Diesel/Electric)	0	145	220	220

3.1.8 Harbor Craft

The basic equation used to estimate harbor vessel emissions is:

Equation 4

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

Where:

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

The sum of hours in transiting and maneuvering areas hours for each vessel as determined by the analysis of the AIS data were used to calculate harbor vessel main engine emissions, while auxiliary emissions were based on the sum of transiting, maneuvering, and dwelling emissions. The calculated grams of emissions were converted to tons per year by dividing by (2,000 lb/ton x 453.59 g/lb).

Harbor craft engines with known model year and horsepower are categorized by EPA marine engine standards. The emission factors for harbor vessels are based on marine engine standards (i.e., Tier 0 to Tier 4) and their respective EPA engine categories. EPA marine engine standards are based on the model year and horsepower of the harbor craft engines. Most commercial harbor vessels have Category 1 engines, except for some of the larger tugboats and larger commercial fishing vessels, which have Category 2 engines. For this 2015 CMVEI, approximately 82% of the diesel-powered harbor vessels inventoried had EPA Category 1 engines, the other 18% had EPA Category 2 engines. The use of a specific emission factor depends on engine power, engine model year, and displacement of a single engine cylinder.

The tier levels and emission factors used for this study are listed in Table 3.11 for diesel-fueled main propulsion and auxiliary engines. The emission factors units are grams per kilowatt-hour.

Table 3.11: Harbor Craft Emission Factors for Diesel Engines, g/kW-hr

kW Range	Year Range	NO_x	PM_{10}	$PM_{2.5}$	DPM	HC	CO	SO_x	CO_2	N_2O	CH_4	Baseline Fuel Type(1)
Category 1, Tier 0												
37 - 76	≤ 2000	10	0.4	0.37	0.4	0.27	1.7	1.3	690	0.031	0.01	Offroad Diesel (EPA)
76 - 131	≤ 2000	10	0.4	0.37	0.4	0.27	1.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
131 - 226	≤ 2000	10	0.8	0.74	0.8	0.27	1.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
226 - 561	≤ 2000	10	0.3	0.28	0.3	0.27	1.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
561 - 1,001	≤ 2000	10	0.3	0.28	0.3	0.27	1.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
1,001 - 1,400	≤ 2000	13	0.3	0.28	0.3	0.27	2.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
1,400 - 2,000	≤ 2000	13	0.3	0.28	0.3	0.27	2.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
2,000 - 3,701	≤ 2000	13	0.3	0.28	0.3	0.27	2.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
3,701 +	≤ 2000	13	0.3	0.28	0.3	0.27	2.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
Category 2, Tier 0												
≤ 600	≤ 2000	13.2	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)
600 - 1,400	≤ 2000	13.2	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)
1,400 - 2,000	≤ 2000	13.2	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)
2,000 - 3,701	≤ 2000	13.2	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)
3,701 +	≤ 2000	13.2	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)
Category 1, Tier 1												
37 - 76	2000 - 2004	9.8	0.4	0.37	0.4	0.27	1.7	1.3	690	0.031	0.01	Offroad Diesel (EPA)
76 - 131	2000 - 2004	9.8	0.4	0.37	0.4	0.27	1.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
131 - 226	2000 - 2004	9.8	0.3	0.28	0.3	0.27	1.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
226 - 561	2000 - 2004	9.8	0.3	0.28	0.3	0.27	1.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
561 - 1,001	2000 - 2004	9.8	0.3	0.28	0.3	0.27	1.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
1,001 - 1,400	2000 - 2007	9.8	0.3	0.28	0.3	0.27	2.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
1,400 - 2,000	2000 - 2007	9.8	0.3	0.28	0.3	0.27	2.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
2,000 - 3,701	2000 - 2007	9.8	0.3	0.28	0.3	0.27	2.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
3,701 +	2000 - 2007	9.8	0.3	0.28	0.3	0.27	2.5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
Category 2, Tier 1												
≤ 600	2000 - 2007	9.8	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)
600 - 1,400	2000 - 2007	9.8	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)
1,400 - 2,000	2000 - 2007	9.8	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)
2,000 - 3,701	2000 - 2007	9.8	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)
3,701 +	2000 - 2007	9.8	0.72	0.66	0.72	0.5	1.1	1.3	690	0.031	0.01	Offroad Diesel (EPA)

Table 3.11: Harbor Craft Emission Factors for Diesel Engines, g/kW-hr (cont'd)

kW Range	Year Range	NO_x	PM_{10}	$PM_{2.5}$	DPM	HC	CO	SO_x	CO_2	N_2O	CH_4	Baseline Fuel Type[1]
Category 2, Tier 1												
37 - 76	2004 - 2009	7.3	0.4	0.37	0.4	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
76 - 131	2004 - 2013	7	0.2	0.18	0.2	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
131 - 226	2004 - 2013	7	0.2	0.18	0.2	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
226 - 561	2004 - 2013	7	0.2	0.18	0.2	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
561 - 1,001	2004 - 2013	7	0.2	0.18	0.2	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
1,001 - 1,400	2007 - 2013	7	0.2	0.18	0.2	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
Category 2, Tier 1 continued												
1,400 - 2,000	2007 - 2013	7	0.2	0.18	0.2	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
2,000 - 3,701	2007 - 2013	7	0.2	0.18	0.2	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
2,000 - 3,701	2013 - 2016	7	0.12	0.11	0.12	0.2	5	0.0065	690	0.031	0.01	ULSD
3,701 +	2007 - 2013	7	0.2	0.18	0.2	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
3,701 +	2013 - 2016	7	0.2	0.18	0.2	0.2	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
Category 2, Tier 2												
≤ 600	2007 - 2014	8.2	0.5	0.46	0.5	0.5	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
600 - 1,400	2007 - 2014	8.2	0.5	0.46	0.5	0.5	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
1,400 - 2,000	2007 - 2014	8.2	0.5	0.46	0.5	0.5	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
2,000 - 3,701	2007 - 2016	9.3	0.5	0.46	0.5	0.5	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
3,701 +	2007 - 2016	9.3	0.5	0.46	0.5	0.5	5	1.3	690	0.031	0.01	Offroad Diesel (EPA)
Category 1, Tier 3												
37 - 76	2009 - 2014	7.3	0.3	0.28	0.3	0.2	5	0.0065	690	0.031	0.01	ULSD
76 - 131	2013 - 2040	5.2	0.12	0.11	0.12	0.2	5	0.0065	690	0.031	0.01	ULSD
131 - 226	2013 - 2040	5.2	0.12	0.11	0.12	0.2	5	0.0065	690	0.031	0.01	ULSD
226 - 561	2013 - 2040	5.2	0.12	0.11	0.12	0.2	5	0.0065	690	0.031	0.01	ULSD
561 - 1,001	2013 - 2017	5.2	0.12	0.11	0.12	0.2	5	0.0065	690	0.031	0.01	ULSD
1,001 - 1,400	2013 - 2017	5.2	0.12	0.11	0.12	0.2	5	0.0065	690	0.031	0.01	ULSD
1,400 - 2,000	2013 - 2016	5.2	0.12	0.11	0.12	0.2	5	0.0065	690	0.031	0.01	ULSD
Category 2, Tier 3												
≤ 600	2014 - 2040	6.5	0.34	0.31	0.34	0.5	5	0.0065	690	0.031	0.01	ULSD
600 - 1,400	2014 - 2017	6.5	0.34	0.31	0.34	0.5	5	0.0065	690	0.031	0.01	ULSD
1,400 - 2,000	2014 - 2016	6.5	0.34	0.31	0.34	0.5	5	0.0065	690	0.031	0.01	ULSD

(1) Emission factors with a baseline fuel type of "Offroad Diesel" will have a fuel correction factor applied when ULSD is the actual fuel used

The sources for the harbor craft emission factors are as follows:

- For NOx and PM, 73FR 37243, June 30, 2008, as amended at 75 FR 23012, April 30, 2010[5]
- IMO for Tier 1 NOx[6]
- EPA 1999 RIA for criteria pollutants, uncontrolled engines[7]
- ENTEC 2002 for CO_2[8]
- IVL 2004 for N2O and CH4[9]
- 40 CFR Part 94; Table 1 of 1042.101 for Tier 3 criteria pollutants[10]

Engine load factors represent the average load or the average percentage of rated engine power that is applied during the engine's normal operation. Depending on the duration of the period being estimated, the load factor can represent an hourly average, daily average, or annual average load applied to an engine while it is in operation. Table 3.12 summarizes the annual average engine load factors that were used in this inventory for the harbor craft vessel types for their propulsion and auxiliary engines. They have been primarily sourced from documentation for EPA's NONROAD model documentation.[11]

Table 3.12: Harbor Craft Load Factors

Harbor Vessel Type	Propulsion Engine	Auxiliary Engine
Towboats	0.68	0.43
Ferry/excursion	0.34	0.43
Government	0.51	0.43
Dredging	0.69	0.43
Fishing	0.30	0.30
Other	0.38	0.32

[5] Control of Emissions of Air Pollution from New CI Marine Engines at or above 37 kW, 40CFR Parts 89, 92, 64 FR 64 73300-73373, 29 Dec 1999
[6] *https://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Air-Pollution.aspx*
[7] Final Regulatory Impact Analysis: Control of Emissions from Marine Diesel Engines; EPA420-R-99-026, November 1999
[8] Entec, UK Limited, Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community, Final Report, July 2002. Prepared for the European Commission.
[9] IVL, Methodology for Calculating Emissions from Ships: Update on Emission Factors," February 2004. Prepared by IVL Swedish Environmental Research Institute for the Swedish Environmental Protection Agency. (IVL 2004)
[10] *https://cfr.regstoday.com/40cfr1042.aspx*
[11] EPA, Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, December 2002

It has been assumed that all harbor vessels used ULSD fuel during 2015. Fuel correction factors are applied to reflect the effect of fuel on emissions when the actual fuel used is different from the fuel used to develop the emission factors. Table 3.13 summarizes the fuel correction factors obtained from the latest PANYNJ emissions inventory of maritime-related diesel equipment.

Table 3.13: Harbor Craft Fuel Correction Factors for Tier 0 through Tier 2 Engines

Fuel Type	PM	NO_x	SO_x	HC	CO	CO_2	CH_4	N_2O
ULSD	0.86	1.0	0.005	1.0	1.0	1.0	1.0	1.0