PORT OF LOS ANGELES
INVENTORY OF AIR EMISSIONS - 2016

THE PORT OF LOS ANGELES

Technical Report
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Prepared by:
STARCREST CONSULTING GROUP, LLC

INVENTORY OF AIR EMISSIONS FOR CALENDAR YEAR 2016

Prepared for:

THE PORT OF LOS ANGELES

July 2017

Prepared by:

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

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Please note that there may be minor inconsistencies, due to rounding, associated with emission estimates, percent contribution, and other calculated numbers between the various sections, tables, and figures of this report. All estimates are calculated using more digits than presented in the various sections.

EXECUTIVE SUMMARY

The Port of Los Angeles (Port or POLA) annual activity-based emissions inventories serve as the primary tool to track the Port's efforts to reduce air emissions from maritime industry-related sources through implementation of measures identified in the San Pedro Bay Ports Clean Air Action Plan (CAAP) and regulations promulgated at the state and federal levels. Development of the annual air emissions estimates is coordinated with a technical working group (TWG) comprised of representatives from the Port, the Port of Long Beach, and the air regulatory agencies: U.S. Environmental Protection Agency, Region 9 (EPA), California Air Resources Board (CARB), and the South Coast Air Quality Management District (SCAQMD).

Summary of 2016 Activity and Emission Estimates

Table ES.1 presents the number of vessel calls and the container cargo throughput for calendar years 2005, 2015 and 2016. Calendar year 2016 was a record year for the Port as TEU throughput reached 8.86 million TEUs. The TEU throughput and containership calls have increased by 9% in 2016 as compared to the previous year.

Table ES.1: Container Throughput and Vessel Arrival Call Comparison

Year	TEUs	All Arrivals	Containership Arrivals	Average TEUs/Call
2016	8,856,783	1,865	1,251	7,080
2015	8,160,458	1,774	1,146	7,121
2005	7,484,625	2,516	1,479	5,061
Previous Year (2015-2016)	**9%**	**5%**	**9%**	**-1%**
CAAP Progress (2005-2016)	**18%**	**-26%**	**-15%**	**40%**

Table ES.2 summarizes the 2016 total maritime industry-related mobile source emissions of air pollutants in the South Coast Air Basin (SoCAB) by the following categories: ocean-going vessels (OGVs), harbor craft (HC), cargo handling equipment (CHE), locomotives, and heavy-duty vehicles (HDV).

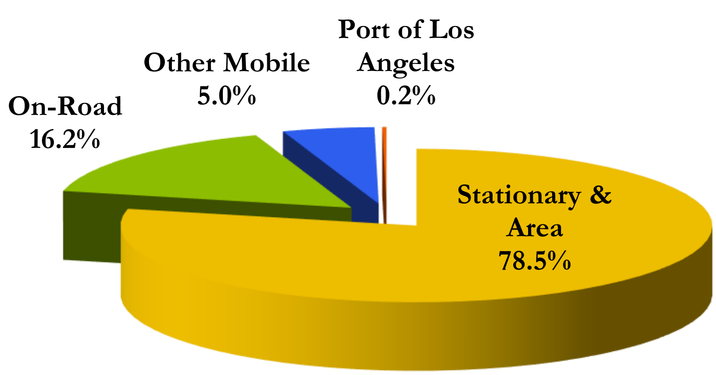
Table ES.2: 2016 Maritime Industry-related Emissions by Category

Category	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Ocean-going vessels	60.0	55.7	47.2	3,200.4	106.1	272.8	128.3	207,693
Harbor craft	26.7	24.6	26.7	750.9	0.7	486.6	77.6	58,348
Cargo handling equipment	6.5	6.0	4.8	434.7	1.7	752.5	69.0	159,658
Locomotives	28.5	27.1	28.5	780.0	0.7	191.3	43.8	67,387
Heavy-duty vehicles	8.0	7.7	7.6	1,857.0	4.3	138.5	36.3	388,411
Total	**129.6**	**121.1**	**114.8**	**7,022.9**	**113.5**	**1,841.7**	**355.0**	**881,496**

DB ID457

In order to put the maritime industry-related emissions into context, the following figures and tables compare the Port's contributions to the total emissions in the SoCAB by major emission source category. The 2016 SoCAB emissions are based on the 2016 Air Quality Management Plan (AQMP) Appendix III.[1] The category "Other Mobile" includes aircraft, trains, ships, commercial boats, recreational boats, off-road recreational vehicles, and off-road equipment. The on-road source category includes light duty vehicles, medium duty trucks, heavy duty trucks, motorcycles, and buses. It should be noted that SoCAB PM_{10} and $PM_{2.5}$ emissions for on-road vehicles include brake and tire wear emissions whereas the Port's HDV emissions are presented for exhaust emissions only.

Figure ES.1: 2016 PM_{10} Emissions in the South Coast Air Basin



[1] SCAQMD, *Final 2016 AQMP Appendix III, Base & Future Year Emissions Inventories*, March 2017

Figure ES.2: 2016 $PM_{2.5}$ Emissions in the South Coast Air Basin

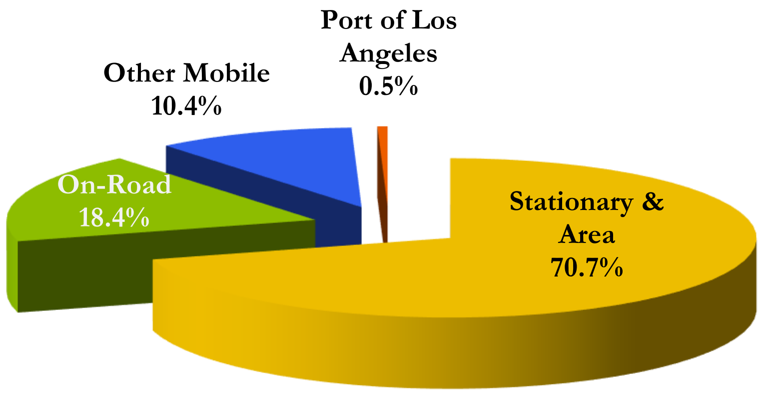


Figure ES.3: 2016 DPM Emissions in the South Coast Air Basin

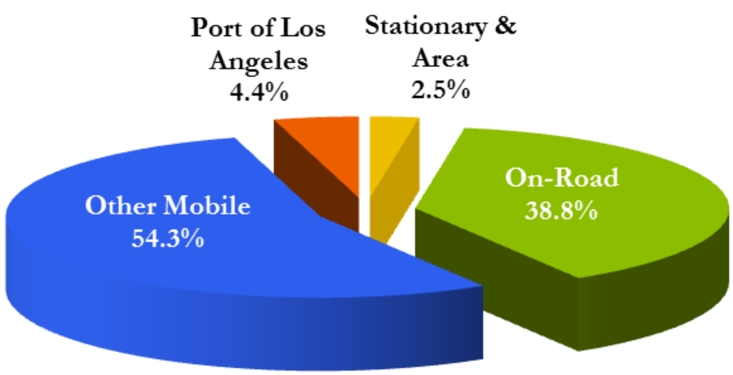


Figure ES.4: 2016 NO_x Emissions in the South Coast Air Basin

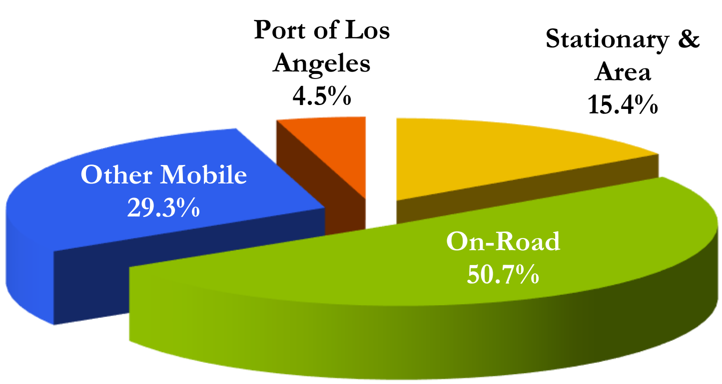


Figure ES.5: 2016 SO_x Emissions in the South Coast Air Basin

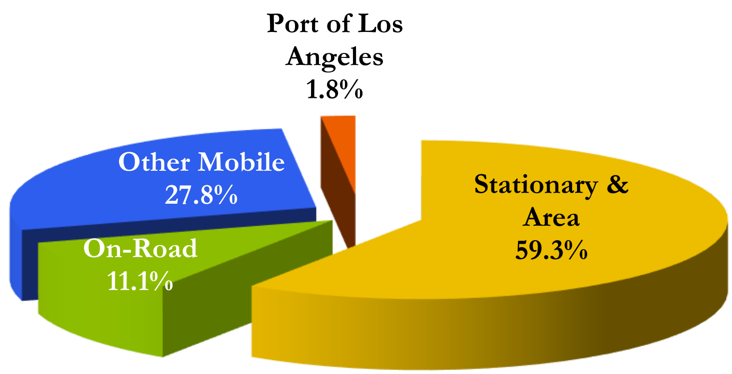


Figure ES.6 presents the decline of the maritime industry-related mobile source emissions in percentage of the total SoCAB emissions from 2005 through 2016. The Port's overall contribution to the SoCAB emissions has decreased significantly for SO_x and DPM emissions since 2005, primarily because of the implementation of various emission reduction programs by the Ports and regulatory agencies, and efficiency improvements from the maritime industry.

Figure ES.6: Port's Emission Contribution in the South Coast Air Basin

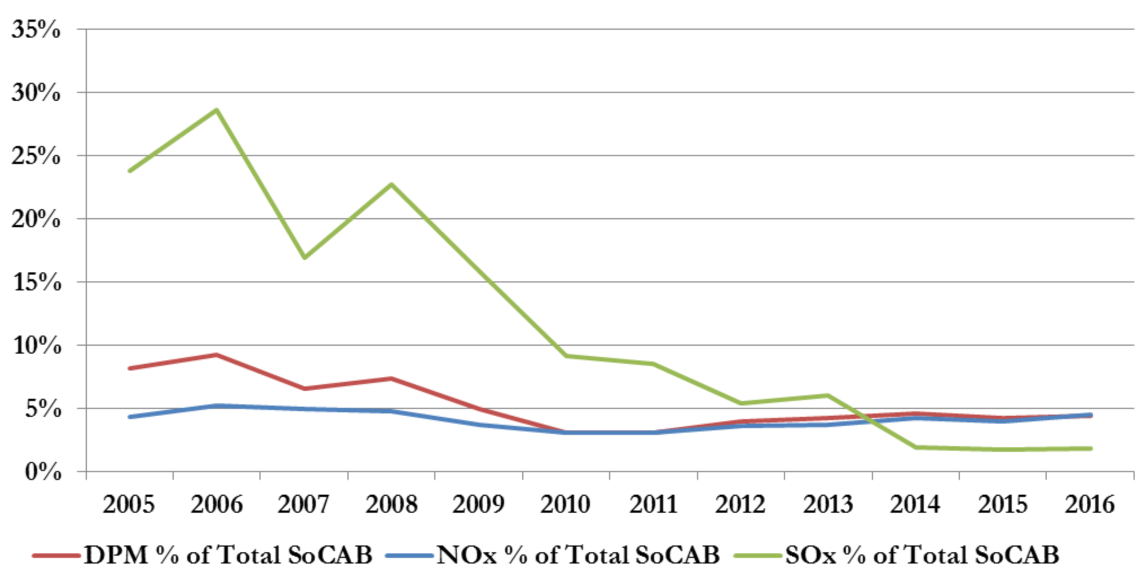


Table ES.3 presents the total net change in emissions from all source categories in 2016 as compared to the previous year and to 2005, all using 2016 methodology. In order to maintain the consistency between the years compared, the 2005 emissions are recalculated whenever new estimation methodologies or data are introduced. The emissions estimation methodology was updated for ocean-going vessels (OGV); therefore the 2005 emissions for OGV were re-estimated with the updated 2016 methodology. The updated emissions estimation methodology for OGV is described in Section 3 of this report. Except for OGV, there were no significant updates to the emission estimation methodologies for the other source categories: harbor craft, cargo-handling equipment, rail locomotives, and heavy-duty vehicles.

Table ES.3: Maritime Industry-related Emissions Comparison

EI Year	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
2016	130	121	115	7,023	114	1,842	355	881,496
2015	151	139	132	7,778	132	1,896	391	933,978
2005	948	820	879	16,206	4,983	3,757	850	1,031,258
Previous Year (2015-2016)	**-14%**	**-13%**	**-13%**	**-10%**	**-14%**	**-3%**	**-9%**	**-6%**
CAAP Progress (2005-2016)	**-86%**	**-85%**	**-87%**	**-57%**	**-98%**	**-51%**	**-58%**	**-15%**

Table ES.4 presents the 2016 and 2005 emissions comparison by source category. Reductions were seen in all pollutants when comparing 2016 to 2005, with the exception of CO emissions for harbor craft and CO_2 emissions for harbor craft and CHE. Several factors contributed to lower emissions in 2016 compared to 2005. Major highlights by source category include:

- For OGV, the primary reasons for emission reductions are: fuel switching, shore power, Port's Environmental Ship Index (ESI) Incentive Program, and Vessel Speed Reduction (VSR) compliance. The International Maritime Organization (IMO) North American Emission Control Areas (ECA) which augmented the CARB OGV Fuel Regulation by extending compliance zone from 24 nautical miles (nm) to 200 nm from the shore, continued to be in effect. In 2016, all engines for OGV continued to use fuel with 0.1% sulfur or lower. The CARB At-Berth Regulation, which focused on reducing emissions at berth (i.e., shore power), was also in effect in 2016 for the third year of compliance for certain vessel types.
- For harbor craft, the emissions in 2016 are lower than 2005 emissions due to the repowers that have occurred in the last few years as required by the CARB Harbor Craft Regulation or funding incentives, removal of older vessels due to attrition, and more efficient operations.
- For CHE, implementation of CAAP measures and CARB's Cargo Handling Equipment Regulation, along with funding incentives, resulted in replacement of older equipment with cleaner units, retrofits, and repowers, along with efficiency in operations led to lower emissions.

- For locomotives, the decreases in fleet-wide emissions from line haul locomotives are due to meeting the terms of the memorandum of understanding (MOU) with CARB, and the replacement of older switching locomotives with new low-emission and ultra-low emission switchers.
- For HDV, the 2012 implementation of the final phase of the Port's Clean Truck Program (CTP) resulted in significant turnover of older trucks to newer and cleaner trucks as compared to 2005.

Table ES.4: Maritime Industry-related 2016-2005 Emissions Comparison by Source Category

	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e MT
2016								
Ocean-going vessels	60	56	47	3,200	106	273	128	207,693
Harbor craft	27	25	27	751	1	487	78	58,348
Cargo handling equipment	6	6	5	435	2	752	69	159,658
Locomotives	28	27	28	780	1	191	44	67,387
Heavy-duty vehicles	8	8	8	1,857	4	139	36	388,411
Total	**130**	**121**	**115**	**7,023**	**114**	**1,842**	**355**	**881,496**
2005								
Ocean-going vessels	534	429	466	5,295	4,825	470	213	288,251
Harbor craft	55	51	55	1,318	6	364	87	56,925
Cargo handling equipment	54	50	53	1,573	9	822	92	134,621
Locomotives	57	53	57	1,712	98	237	89	82,201
Heavy-duty vehicles	248	238	248	6,307	45	1,865	368	469,260
Total	**948**	**820**	**879**	**16,206**	**4,983**	**3,757**	**850**	**1,031,258**
Change between 2005 and 2016 (percent)								
Ocean-going vessels	-89%	-87%	-90%	-40%	-98%	-42%	-40%	-28%
Harbor craft	-52%	-52%	-52%	-43%	-89%	34%	-11%	2%
Cargo handling equipment	-88%	-88%	-91%	-72%	-82%	-8%	-25%	19%
Locomotives	-50%	-49%	-50%	-54%	-99%	-19%	-51%	-18%
Heavy-duty vehicles	-97%	-97%	-97%	-71%	-90%	-93%	-90%	-17%
Total	**-86%**	**-85%**	**-87%**	**-57%**	**-98%**	**-51%**	**-58%**	**-15%**

Table ES.5 presents the 2016 and 2015 emissions comparison by source category. Despite a 9% increase in TEU throughput, the emissions decreased in 2016 as compared to the previous year. This is mainly due to the Port operating more efficiently than the previous year and the higher use of emission reduction technologies, newer engines for vessels and cleaner cargo handling equipment. Section 9 of this study provides more information about the energy consumption and newer technology comparison by source category.

Table ES.5: Maritime Industry-related 2016-2015 Emissions Comparison by Source Category

	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e MT
2016								
Ocean-going vessels	60	56	47	3,200	106	273	128	207,693
Harbor craft	27	25	27	751	1	487	78	58,348
Cargo handling equipment	6	6	5	435	2	752	69	159,658
Locomotives	28	27	28	780	1	191	44	67,387
Heavy-duty vehicles	8	8	8	1,857	4	139	36	388,411
Total	**130**	**121**	**115**	**7,023**	**114**	**1,842**	**355**	**881,496**
2015								
Ocean-going vessels	73	68	57	3,688	124	312	143	252,015
Harbor craft	30	28	30	819	1	495	81	61,013
Cargo handling equipment	9	9	7	557	2	760	85	170,780
Locomotives	30	28	30	819	1	194	46	68,432
Heavy-duty vehicles	8	8	8	1,895	4	135	36	381,737
Total	**151**	**139**	**132**	**7,778**	**132**	**1,896**	**391**	**933,978**
Change between previous year and 2016 (percent)								
Ocean-going vessels	-18%	-18%	-17%	-13%	-15%	-13%	-10%	-18%
Harbor craft	-11%	-11%	-11%	-8%	-4%	-2%	-4%	-4%
Cargo handling equipment	-29%	-29%	-33%	-22%	-6%	-1%	-19%	-7%
Locomotives	-6%	-1%	-6%	-5%	-1%	-2%	-4%	-2%
Heavy-duty vehicles	-4%	-4%	-2%	-2%	2%	3%	0%	2%
Total	**-14%**	**-13%**	**-13%**	**-10%**	**-14%**	**-3%**	**-9%**	**-6%**

Table ES.6 summarizes the annualized emissions efficiencies for all five source categories. The overall emission efficiency in 2016 improved for all pollutants as compared to 2005 and previous year. In Table ES.6, a positive percentage means an increase in emissions efficiency.

Table ES.6: Emissions Efficiency Metric Comparison, tons/10,000 TEUs

EI Year	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2e
2016	0.146	0.137	0.130	7.93	0.13	2.08	0.40	995
2015	0.185	0.171	0.162	9.53	0.16	2.32	0.48	1,145
2005	1.267	1.096	1.175	21.65	6.66	5.02	1.14	1,378
Previous Year (2015-2016)	**21%**	**20%**	**20%**	**17%**	**19%**	**10%**	**17%**	**13%**
CAAP Progress (2005-2016)	**88%**	**88%**	**89%**	**63%**	**98%**	**59%**	**65%**	**28%**

CAAP Standards and Progress

One of the main purposes of the annual inventories is to provide a progress update on achieving the San Pedro Bay CAAP Standards. These standards consist of the following emission reduction goals, using the 2005 published inventories as a baseline.

- Emission Reduction Standard:
  - By 2014, reduce emissions by 72% for DPM, 22% for NO_x, and 93% for SO_x
  - By 2023, reduce emissions by 77% for DPM, 59% for NO_x, and 93% for SO_x
- Health Risk Reduction Standard: 85% reduction by 2020

Due to the many emission reduction measures undertaken by the Port, as well as statewide and federal regulations and standards, the 2014 emission reduction standard continued to be met and exceeded in 2016 for DPM, NO_x and SO_x. Looking towards the future, the 2023 emission reduction standard has been met and exceeded for DPM and SO_x. Table ES.7 summarizes DPM, NO_x and SO_x percent reductions as compared to the 2014 and 2023 emission reduction standards.

Table ES.7: Reductions as Compared to 2014 and 2023 Emission Reduction Standard

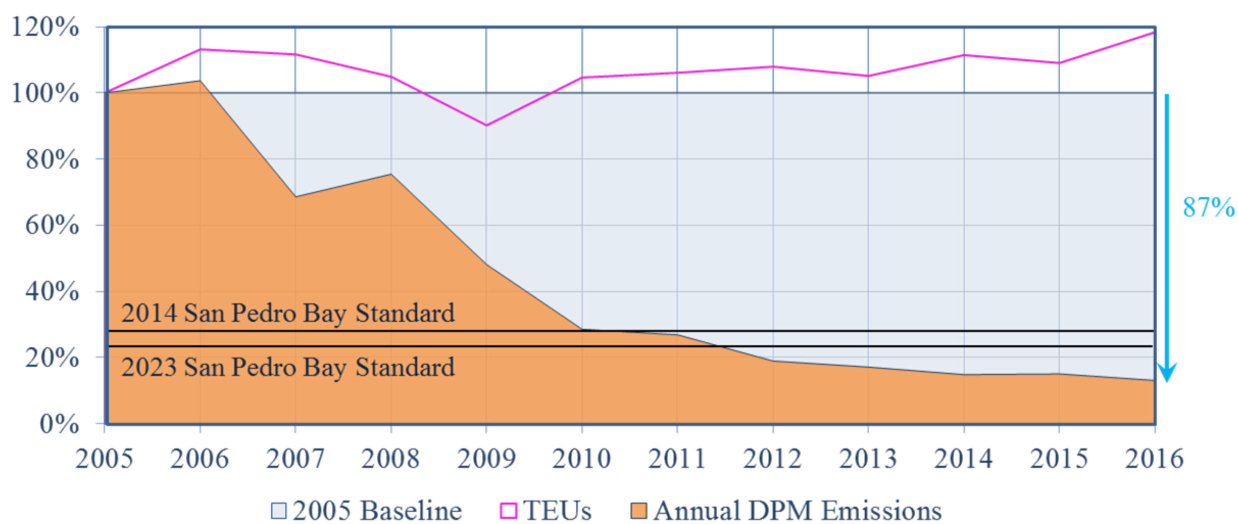
Pollutant	2016 Actual Reductions	2014 Emission Reduction Standard	2023 Emission Reduction Standard
DPM	87%	72%	77%
NO_x	57%	22%	59%
SO_x	98%	93%	93%

The emission reduction standards are represented as a percentage reduction of emissions from 2005 levels, and are tied to the regional SoCAB attainment dates for the federal $PM_{2.5}$ and ozone ambient air quality standards in the 2007 AQMP. This EI is used as a tool to track progress in meeting the emission reduction standards.

Figures ES.7 through ES.9 present the 2005 baseline emissions and the year to year percent change in emissions with respect to the 2005 baseline emissions. The 2014 and 2023 standards are also provided as a snapshot of progress to-date towards meeting those standards. The pink line in the figures represents percentage TEUs throughput as compared to 2005 TEU throughput. These figures provide context to the relative correlation between cargo throughput and emissions.

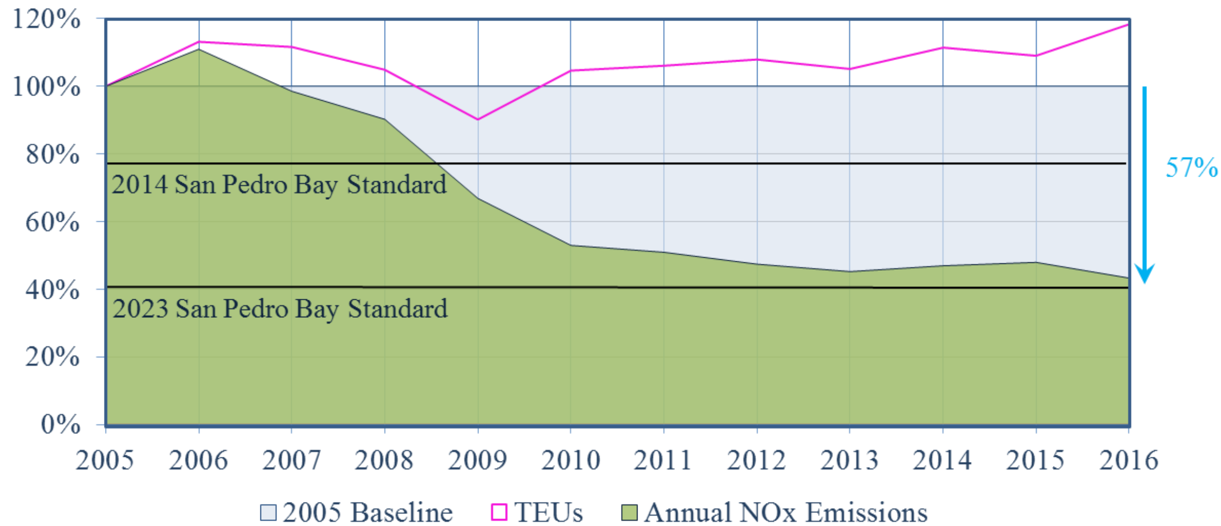
Figure ES.7 shows that the Port has surpassed the 2014 and 2023 DPM emission reduction standards with an 87% emission reduction. In 2016, 0.1% sulfur fuel for OGVs from the IMO North American ECA which augmented CARB fuel rule was in effect and there was an increase in number of ships using shore-power due to the CARB shore power rule.

Figure ES.7: DPM Reductions to Date



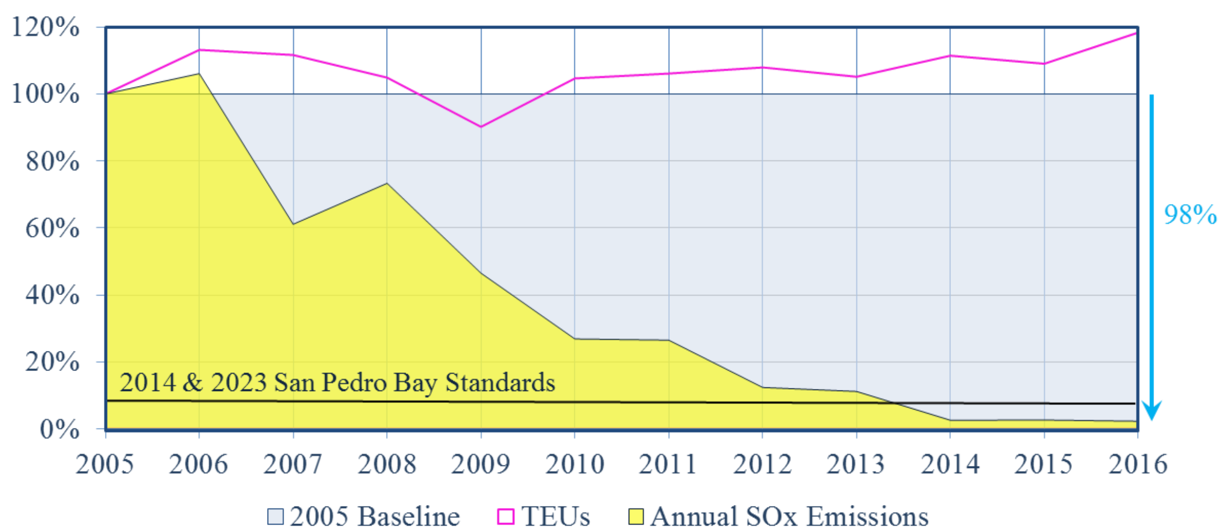
As demonstrated in Figure ES.8, the Port surpassed the 2014 NO_x mass emission reduction standard in 2016 with a 57% reduction and is close to meeting the 2023 NO_x mass emission reduction standard.

Figure ES.8: NO_x Reductions to Date



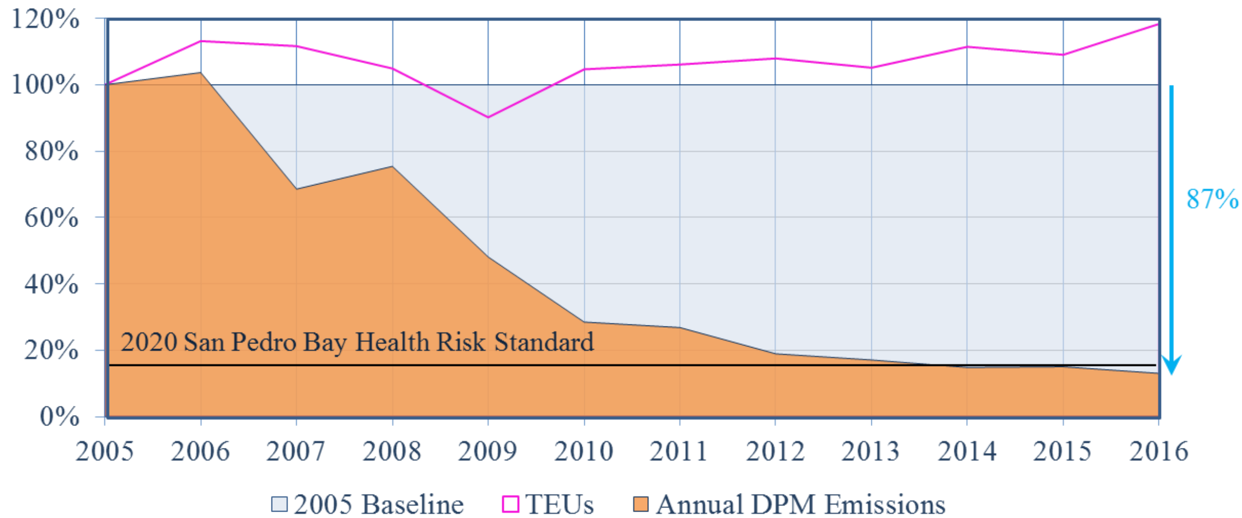
By 2016, the Port surpassed the 2014 and 2023 SO_x mass emission reduction standards with a 98% reduction. In 2016, 0.1% sulfur fuel for OGVs from the IMO North American ECA was in effect and there was an increase in number of ships using shore-power due to the CARB shore power rule, which contributed to the reduction in SO_x.

Figure ES.9: SO_x Reductions to Date



Health Risk Reduction Progress
Progress to-date on health risk reduction is determined by comparing the change in DPM mass emissions to the 2005 baseline. Figure ES.10 presents the progress of achieving the standard to date. In 2016, with an 87% reduction, the Port exceeded the 2020 Health Risk Reduction Standard (85%).

Figure ES.10: Health Risk Reduction Benefits to Date



SECTION 1 INTRODUCTION

The Port of Los Angeles (Port or POLA) 2016 Inventory of Air Emissions study presents maritime industry-related emission estimates based on 2016 activity levels. The report also includes a comparison of the estimated 2016 emissions with the 2005 baseline year and previous year emission estimates to track the Port's emission reduction progress under the San Pedro Bay Ports Clean Air Action Plan (CAAP). As in previous inventories, the following five source categories are included:

- Ocean-going vessels (OGV)
- Harbor craft
- Cargo handling equipment (CHE)
- Locomotives
- Heavy-duty vehicles (HDV)

Exhaust emissions of the following pollutants that can cause regional and local air quality impacts have been estimated:

- Particulate matter (PM) (10-micron, 2.5-micron)
- Diesel particulate matter (DPM)
- Oxides of nitrogen (NO_x)
- Oxides of sulfur (SO_x)
- Hydrocarbons (HC)
- Carbon monoxide (CO)

This study also includes estimates of greenhouse gases (GHGs) carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emitted from maritime industry-related tenant operational mobile sources. To normalize the three GHG values into a single number representing CO_2 equivalents (CO_2e) the GHG emission estimates are multiplied by the following values and summed.[2]

- CO_2 – 1
- CH_4 – 25
- N_2O - 298

For presentation purposes in the report, only CO_2e values are reported because they include all three GHGs in an equivalent measure to CO_2, which makes up by far the greatest mass of GHG emissions from the source categories included in this inventory. The greenhouse gas emissions are presented in metric tons (tonnes) while the criteria pollutant emissions are shown in tons.

[2] EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015*, April 2017.

Geographical Domain

The geographical extent of the inventory includes emissions from the aforementioned maritime industry-related emission sources operating within the harbor district. For commercial marine vessels, the domain lies within the harbor and up to the study area boundary comprised of an over-water area bounded in the north by the southern Ventura County line at the coast, and in the south with the southern Orange county line at the coast.

For rail locomotives and on-road trucks, the domain extends from the Port to the cargo's first point of rest within the South Coast Air Basin (SoCAB) or up to the SoCAB boundary, whichever comes first.

Figure 1.1 shows the geographical extent of this inventory, and other overlapping regulatory boundaries.

Figure 1.1: Emissions Inventory Geographical Extent

SECTION 2 REGULATORY AND CAAP MEASURES

This section summarizes the regulatory initiatives and Port measures related to port activity. Almost all maritime industry-related emissions come from five emission source categories: OGVs, harbor craft, CHE, locomotives, and HDVs. The responsibility for the control of emissions from the majority of these sources falls under the jurisdiction of local (South Coast Air Quality Management District [SCAQMD]), state (California Air Resources Board [CARB]), or federal (U.S. Environmental Protection Agency [EPA]) agencies. The Ports of Los Angeles and Long Beach recently released a draft report for the CAAP 2017 Update[3]. The CAAP 2017 Update contains new strategies from all sources that move cargo through the ports, including the deployment of zero and near-zero emission trucks and cargo handling equipment, and the expansion of programs that reduce ship emissions.

San Pedro Bay Emissions Reduction Standards
The 2010 CAAP Update established the San Pedro Bay Standards, the most significant addition to the original CAAP. Achievement of the standards listed below will require diligent implementation of all the current CAAP measures, additional aggressive actions to find further emissions and health risk reductions, and identification of new strategies that will emerge over time.

Health Risk Reduction Standard
To complement the CARB's Air Pollution Reduction Programs including Diesel Risk Reduction Plan, the Ports developed the following standard for reducing overall maritime industry-related health risk impacts, relative to 2005 emissions level:

- By 2020, reduce the population-weighted cancer risk of maritime industry-related DPM emissions by 85% in highly-impacted communities located proximate to Port sources and throughout the residential areas in the Port region.

Emission Reduction Standard
The Ports developed the following standards for reducing air pollutant emissions from maritime industry-related activities, relative to 2005 emission levels:

- By 2014, reduce emissions of NO_x by 22%, SO_x by 93%, and DPM by 72% to support attainment of the national fine particulate matter ($PM_{2.5}$) standards.
- By 2023, reduce emissions of NO_x by 59%, SO_x by 93%, and DPM by 77% to support attainment of the national and federal 8-hour ozone standards and national fine particulate matter ($PM_{2.5}$) standards.

The Port along with the Port of Long Beach is in the process of updating the CAAP (CAAP 2017)[4]. On July 19, 2017, the Ports released the draft report of the 2017 CAAP Update.

[3] *www.cleanairactionplan.org/documents/clean-air-action-plan-2017-draft-document-final.pdf*
[4] *www.cleanairactionplan.org/2017-clean-air-action-plan-update/*

Regulatory Programs by Source Category

The following section presents a list of current regulatory programs and CAAP measures by each major source category that influenced 2016 emissions from the maritime industry in and around the Port.

Table 2.1: OGV Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
International Maritime Organization (IMO)	NO_x Emission Standard for Marine Engines *www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Nitrogen-oxides-%28NOx%29-%E2%80%93-Regulation-13.aspx*	NO_x	2011 – Tier 2 2016 – Tier 3 for ECA only	Auxiliary and propulsion engines over 130 kW output power on newly built vessels
IMO	Emissions Control Area, Low Sulfur Fuel Requirements for Marine Engines *www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-%28SOx%29-%E2%80%93-Regulation-14.aspx*	DPM, PM, and SO_x	2012 ECA – 1% Sulfur 2015 ECA – 0.1% Sulfur	Significantly reduce emissions due to low sulfur content in fuel by creating Emissions Control Area (ECA)
IMO	Energy Efficiency Design Index (EEDI) for International Shipping *www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Technical-and-Operational-Measures.aspx*	CO_2 and other pollutants	2013	Increases the design efficiencies of ships relating to energy and emissions
EPA	Emission Standards for Marine Diesel Engines above 30 Liters per Cylinder (Category 3 Engines); Aligns with IMO Annex VI marine engine NO_x standards and low sulfur requirement *www.epa.gov/otaq/oceanvessels.htm#engine-fuel*	DPM, PM, NO_x, and SO_x	2011 – Tier 2 2016 – Tier 3	Auxiliary and propulsion category 3 engines on US flagged new built vessels and requires use of low sulfur fuel

Table 2.1: OGV Emission Regulations, Standards and Policies (cont'd)

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
CARB	Regulation to Reduce Emissions from Diesel Auxiliary Engines on Ocean-Going Vessels While At-Berth at a California Port *www.arb.ca.gov/regact/2007/shorepwr07/shorepwr07.htm* and *www.arb.ca.gov/ports/shorepower/forms/regulatoryadvisory/regulatoryadvisory12232013.pdf*	DPM, PM, NO_x, SO_x, CO_2	2014 – 50% 2017 – 70% 2020 – 80%	Shore power (or equivalent) requirements. Vessel operators, based on fleet percentage visiting the ports.
CARB	Ocean-going Ship Onboard Incineration *www.arb.ca.gov/ports/shipincin/shipincin.htm*	DPM, PM, and HC	2007	All vessels cannot incinerate within 3 nm of the California coast
CAAP	CAAP Measure – OGV 1 Vessel Speed Reduction (VSR) Program *www.cleanairactionplan.org/strategies/ships/*	All	2008	Vessel operators within 20 nm and 40 nm of Point Fermin
CAAP	CAAP Measure – OGV 2 Reduction of At-Berth OGV Emissions *www.cleanairactionplan.org/strategies/ships/*	All	2014	Vessel operators and terminals
CAAP	CAAP Measure – OGV 5 and 6 Cleaner OGV Engines and OGV Engine Emissions Reduction Technology Improvements and Environmental Ship Index (ESI) Program *www.portoflosangeles.org/environment/ogv.asp*	DPM, PM, and NO_x	2012	Vessel operators who choose to participate in ESI and/or technology demonstrations.

Table 2.2: Harbor Craft Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
EPA	Emission Standards for Harbor Craft Engines *www3.epa.gov/otaq/marine.htm*	All	2009 – Tier 3 2014 – Tier 4 for 800 hp or greater	Commercial marine diesel engines with displacement less than 30 liters per cylinder
CARB	Low Sulfur Fuel Requirement for Harbor Craft *www.arb.ca.gov/regact/carblohc/carblohc.htm*	DPM, PM, NO_x, and SO_x	2006 – 15 ppm in SCAQMD area	Use of low sulfur diesel fuel in commercial harbor craft operating in SCAQMD
CARB	Regulation to Reduce Emissions from Diesel Engines on Commercial Harbor Craft *www.arb.ca.gov/regact/2010/chc10/chc10.htm*	DPM, PM, and NO_x	2009 to 2020 - schedule varies depending on engine model year	Most harbor craft with home port in SCAQMD must meet more stringent emissions limits according to a compliance schedule
CAAP	CAAP Measure – HC 1 Performance Standards for Harbor Craft *www.cleanairactionplan.org/strategies/harbor-craft*	All	Varies	Modernization of harbor craft operating at POLA upon lease renewal

Table 2.3: Cargo Handling Equipment Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
EPA	Emission Standards for Non-Road Diesel Powered Equipment *www.epa.gov/otaq/standards/nonroad/nonroadci.htm*	All	2008 through 2015	All non-road equipment
CARB	Cargo Handling Equipment Regulation *http://www.arb.ca.gov/regact/2011/cargo11/cargo11.htm*	All	2007 through 2017; Opacity test compliance starting in 2016	All Cargo handling equipment
CARB	New Emission Standards, Test Procedures, for Large Spark Ignition (LSI) Engine Forklifts and Other Industrial Equipment *www.arb.ca.gov/regact/2008/lsi2008/lsi2008.htm*	All	2007 – first phase 2010 – second phase	Emission standards for large spark-ignition engines with 25 hp or greater
CARB	Fleet Requirements for Large Spark Ignition Engines *www.arb.ca.gov/regact/2010/offroadlsi10/lsifinalreg.pdf*	All	2009 through 2013	More stringent emissions requirements for fleets of large spark-ignition engines equipment
CAAP	CAAP Measure – CHE1 Performance Standards for CHE	All	2007 through 2014	Turnover to Tier 4 cargo handling equipment per lease renewal agreement

Table 2.4: Locomotives Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
EPA	Emission Standards for New and Remanufactured Locomotives and Locomotive Engines- Latest Regulation *www.epa.gov/otaq/standards/nonroad/locomotives.htm*	DPM and NO_x	2011 through 2013 – Tier 3 2015 – Tier 4	All new and remanufactured locomotive engines
EPA	Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel *www.epa.gov/otaq/fuels/dieselfuels/regulations.htm*	SO_x and PM	2010	All locomotive engines
CARB	Low Sulfur Fuel Requirement for Intrastate Locomotives *www.arb.ca.gov/msprog/offroad/loco/loco.htm#intrastate*	SO_x, NO_x, and PM	2007	Intrastate locomotives, mainly switchers
CARB	Statewide 1998 and 2005 Memorandum of Understanding (MOUs) *www.arb.ca.gov/msprog/offroad/loco/loco.htm#intrastate*	NO_x	2010	Union Pacific and BNSF locomotives
CAAP	CAAP Measure – RL1 Pacific Harbor Line (PHL) Rail Switch Engine Modernization	PM	2010	Pacific Harbor Line switcher engines
CAAP	CAAP Measure – RL2 Class 1 Line-haul and Switcher Fleet Modernization	All	2023 – Tier 3	Class 1 locomotives at ports
CAAP	CAAP Measure – RL3 New and Redeveloped Near-Dock Rail Yards	All	2020 – Tier 4	New near-dock rail yards

Table 2.5: Heavy-Duty Vehicles Emission Regulations, Standards and Policies

Agency	Regulation/Standard/Policy	Targeted Pollutants	Years Effective	Impact
CARB/ EPA	Emission Standards for New 2007+ On-Road Heavy-Duty Vehicles *www.arb.ca.gov/msprog/onroadhd/reducstd.htm*	NO_x and PM	2007 2010	All new on-road diesel heavy-duty vehicles
CARB	Heavy-Duty Vehicle On-Board Diagnostics (OBD and OBDII) Requirement *www.arb.ca.gov/msprog/obdprog/section1971_1_clean2013.pdf*	NO_x and PM	2010 +	All new on-road heavy-duty vehicles
CARB	ULSD Fuel Requirement *www.arb.ca.gov/regact/ulsd2003/ulsd2003.htm*	All	2006 - ULSD	All on-road heavy-duty vehicles
CARB	Drayage Truck and Bus Regulation (amended in 2011 and 2014) *www.arb.ca.gov/msprog/onroad/porttruck/drayagevtruckbus.pdf*	All	Phase in started in 2009	All drayage trucks operating at California ports
CARB	Low NO_x Software Upgrade Program 2007 *www.arb.ca.gov/msprog/hdsoftware/hdsoftware.htm*	NO_x	Starting 2005	1993 to 1998 on-road heavy-duty vehicles that operate in California
CARB	Heavy-Duty Vehicle Greenhouse Gas Emission Reduction Regulation *www.arb.ca.gov/cc/hdghg/hdghg.htm*	CO_2	Phase 1 starting in 2012	Heavy-duty tractors that pull 53-foot+ trailers in California
CARB	Assembly Bill 32 requiring GHG reductions targets and Governor's Executive Order B – 30-15 *www.arb.ca.gov/cc/ab32/ab32.htm*	CO_2	GHG emissions reduction goals in 2020	All operations in California
CAAP	CAAP Measure – HDV1 Performance Standards for On-Road Heavy-Duty Vehicles; Clean Truck Program	All	Phase in started in 2008	Requires on-road heavy-duty vehicles that operate at POLA to have 2007 or newer Model Year (MY) engines by 2012

SECTION 3 OCEAN-GOING VESSELS

Source Description

Based on activity data obtained from the Marine Exchange of Southern California (MarEx), there were a total of 1,865 ocean-going vessels (OGVs, ships, or vessels) activities (arrivals not including shifts) to the Port in 2016. These vessels are grouped by the type of cargo they are designed to carry and fall into one of the following vessel categories or types:

- Auto carrier
- Bulk carrier
- Containership
- Cruise vessel
- General cargo
- Miscellaneous vessel
- Ocean-going tugboat
- Refrigerated vessel (Reefer)
- RoRo
- Tanker

From an emissions contribution perspective, the three predominant vessel types are: containerships, tankers, and cruise ships, with containerships being the most significant vessel category. Emission sources on all vessel categories include main engines (propulsion), auxiliary engines (generators), and auxiliary boilers (boilers).

Emission Estimation Methodology Updates

The methodology to estimate 2016 emissions from OGVs is the same as described in Section 3 of the Port of Los Angeles 2013 Air Emissions Inventory.[5] The following improvements were made in estimating 2016 OGV emissions:

- For propulsion engines, updated low load adjustment (LLA) factor table by adding SO_x and CO_2 LLA factors for all non-MAN slow speed engines. These factors are applicable to loads less than 20%.
- For propulsion engines, updated load adjustment factors (LAF) tables by adding SO_x and CO_2 LAF factors for all MAN slow speed engines. These factors are applicable to 0% to 100% load range.
- Added Vessel Boarding Data (VBP) related to vessel operation collected since the 2015 EI.
- Use of mode specific boiler load instead of average load at all modes. The VBP data was enhanced to include boiler loads by mode (e.g. transit, maneuvering, at-berth, and anchor). Past boiler data collection efforts resulted in average fuel consumption that helped calculate the boiler default value that was applied consistently across all modes when boilers are assumed to operate. Between 2014 and 2017, boiler-by-mode data was collected for 80 vessels and an additional 162 sister vessels which made it possible to estimate boiler loads by mode as shown in Table 3.5.

[5] *www.portoflosangeles.org/pdf/2013_Air_Emissions_Inventory_Full_Report.pdf*

Table 3.1 presents the numbers of arrivals, departures, and shifts associated with vessels at the Port in 2016.

Table 3.1: 2016 Total OGV Activities

Vessel Type	Arrival	Departure	Shift	Total
Auto Carrier	77	81	10	168
Bulk	89	83	52	224
Container - 1000	4	4	0	8
Container - 2000	202	203	21	426
Container - 3000	36	36	6	78
Container - 4000	269	269	40	578
Container - 5000	156	155	40	351
Container - 6000	154	153	26	333
Container - 7000	57	57	7	121
Container - 8000	217	219	56	492
Container - 9000	45	45	8	98
Container - 10000	37	38	3	78
Container - 11000	23	22	1	46
Container - 12000	10	10	0	20
Container - 13000	39	39	0	78
Container - 14000	1	1	0	2
Container - 17000	1	1	0	2
Cruise	118	118	0	236
General Cargo	50	46	47	143
Ocean Tugboat (ATB/ITB)	12	12	23	47
Miscellaneous	9	7	0	16
Reefer	19	19	29	67
RoRo	24	24	20	68
Tanker - Chemical	127	128	232	487
Tanker - Handysize	35	36	63	134
Tanker - Panamax	54	43	115	212
Total	**1,865**	**1,849**	**799**	**4,513**

DB ID693

Geographical Domain
The geographical domain or overwater boundary for OGVs includes the berths and waterways in the Port proper and all vessel movements within the 40 nautical mile (nm) arc from Point Fermin as shown previously in Figure 1.1. The northern boundary is the Ventura County line and the southern boundary is the Orange County line. It should be noted that the overwater boundary extends further off the coast to incorporate the South Coast air quality modeling domain, although most of the vessel movements occur within the 40 nm arc.

Data and Information Acquisition
Similar to previous inventories, various 2016 sources of data and operational knowledge about the Port's marine activities are used to compile the data necessary to estimate emissions from OGV:

- Marine Exchange of Southern California
- Vessel Speed Reduction Program speed data
- Los Angeles Pilot Service
- IHS Maritime Data
- VBP data
- ESI fuel and engine data
- Port tanker load and discharge activity data
- Port and terminal shore power activity data, including usage of alternative at-berth emission control technologies (AMECS and METS-1)

Operational Profiles
Tables 3.2 and 3.3 summarize the hotelling times in hours at berth and at anchorage. Hotelling time is the entire duration of time that a ship spends at berth or anchorage for each visit.

Table 3.2: 2016 Hotelling Times at Berth, hours

Vessel Type	Berth Hotelling Time, hours		
	Min	Max	Avg
Auto Carrier	5.7	165.5	19.2
Bulk	11.2	235.8	71.3
Container - 1000	23.6	25.2	24.6
Container - 2000	10.2	83.5	30.5
Container - 3000	10.4	62.3	45.4
Container - 4000	8.3	225.2	27.4
Container - 5000	8.5	119.6	46.8
Container - 6000	9.1	116.3	64.2
Container - 7000	8.6	85.2	64.8
Container - 8000	8.3	128.9	67.3
Container - 9000	13.8	95.7	67.9
Container - 10000	13.5	104.3	78.2
Container - 11000	25.3	97.4	76.7
Container - 12000	86.4	111.1	100.8
Container - 13000	79.3	121.8	98.3
Container - 14000	110.4	110.4	110.4
Container - 17000	60.2	60.2	60.2
Cruise	8.6	35.5	10.7
General Cargo	4.3	157.6	59.1
Ocean Tugboat (ATB/ITB)	11.9	84.7	33.9
Miscellaneous	2.5	3862.42	462.48
Reefer	5.0	93.3	33.5
RoRo	13.3	179.4	32.5
Tanker - Chemical	5.8	142.6	36.4
Tanker - Handysize	15.1	88.7	43.2
Tanker - Panamax	20.9	292.6	54.5

DB ID705

Table 3.3: 2016 Hotelling Times at Anchorage, hours

Vessel Type	Min	Max	Avg	Vessel Count
Auto Carrier	29.8	52.9	41.3	3
Bulk	2.8	361.8	48.1	40
Container - 2000	1.8	41.1	13.8	7
Container - 3000	2.0	27.0	12.6	3
Container - 4000	0.7	83.1	22.0	18
Container - 5000	3.5	20.1	11.4	4
Container - 6000	0.5	43.3	12.4	11
Container - 7000	6.9	194.8	58.7	2
Container - 8000	2.2	6.7	4.1	4
Container - 9000	7.4	7.4	7.4	1
General Cargo	2.7	318.3	63.1	26
Ocean Tugboat (ATB/ITB)	1.9	196.3	33.6	4
Reefer	5.0	75.1	31.6	6
Tanker - Chemical	0.5	476.0	41.5	87
Tanker - Handysize	2.0	206.6	44.7	16
Tanker - Panamax	3.6	1,372.8	90.7	38

DB ID705

Emissions Estimation Methodology
Table 3.4 presents the auxiliary engine load defaults by vessel type, by mode, used to estimate emissions. Values in this table are based on VBP data.

Table 3.4: Average Auxiliary Engine Load Defaults (except for Diesel-Electric Cruise Vessels), kW

Vessel Type	Transit	Maneuvering	Berth Hotelling	Anchorage Hotelling
Auto Carrier	520	1,238	859	622
Bulk	255	675	150	253
Bulk - Heavy Load	255	675	150	253
Container - 1000	545	1,058	429	1,000
Container - 2000	981	2,180	1,035	1,008
Container - 3000	602	2,063	516	559
Container - 4000	1,434	2,526	1,161	1,200
Container - 5000	1,811	3,293	945	967
Container - 6000	1,453	2,197	990	1,645
Container - 7000	1,107	3,086	2,456	1,000
Container - 8000	1,494	2,753	902	986
Container - 9000	1,501	2,942	1,037	968
Container - 10000	2,300	2,350	1,450	1,129
Container - 11000	2,500	3,500	1,500	2,000
Container - 12000	2,460	3,300	1,780	2,000
Container - 13000	1,865	3,085	982	1,015
Container - 14000	2,500	3,500	1,500	1,015
Container - 17000	1,500	1,750	1,000	1,000
Container - 18000	1,500	1,750	1,000	1,250
Cruise	7,290	9,787	6,004	7,782
General Cargo	516	1,439	722	180
Ocean Tug (ATB/ITB)	79	208	102	79
Miscellaneous	643	597	228	200
Reefer	513	1,540	890	513
RoRo	434	1,301	751	434
Tanker - Chemical	658	890	816	402
Tanker - Handysize	537	601	820	560
Tanker - Panamax	561	763	623	379

For diesel electric cruise ships, house load defaults are listed in Table 3.5. The auxiliary engine load defaults for the diesel electric cruise ships have changed from the previous EI reports. They were updated to account for larger cruise ship sizes and were obtained from the most recent VBP data and interviews with the cruise vessel industry.

Table 3.5: Diesel Electric Cruise Ship Average Auxiliary Engine Load Defaults, kW

Passenger Range	Transit	Maneuvering	Berth Hotelling
<1,500	3,500	4,000	3,000
1,500 < 2,000	7,000	8,000	6,500
2,000 < 2,500	10,500	11,500	9,500
2,500 < 3,000	11,000	12,000	10,000
3,000 < 3,500	11,500	13,000	10,500
3,500 < 4,000	12,000	13,500	11,000
4,000 < 4,500	12,500	14,000	12,000
4,500 < 5,000	13,000	14,500	13,000
5,000 < 5,500	13,500	15,500	13,500
5,500 < 6,000	14,000	16,000	14,000
6,000 < 6,500	14,500	16,500	14,500
6,500+	15,000	17,000	15,000

Table 3.6 presents the load defaults for the auxiliary boilers by vessel type and by mode. Please note that the auxiliary boiler loads in 2016 have changed from previous EI reports in that there is a different value by mode as compared to the past that one average boiler load value was used across all modes. The boiler load enhancement is due to more detailed boiler information acquired through VBP over the last few years. Auxiliary boiler load used for all tankers while being loaded at-berth is 875 kW, unless a vessel-specific boiler load for tanker loading is provided from VBP.

Table 3.6: Auxiliary Boiler Load Defaults (except for Diesel-Electric Cruise Vessels) by Mode, kW

Vessel Type	Transit	Maneuvering	Berth Hotelling	Anchorage Hotelling
Auto Carrier	87	184	314	305
Bulk	35	94	125	125
Bulk - Heavy Load	35	94	125	125
Container - 1000	106	213	273	270
Container - 2000	141	282	361	358
Container - 3000	164	328	420	416
Container - 4000	195	371	477	472
Container - 5000	247	473	579	572
Container - 6000	182	567	615	611
Container - 7000	259	470	623	619
Container - 8000	228	506	668	673
Container - 9000	381	613	677	675
Container - 10000	384	458	581	581
Container - 11000	330	575	790	790
Container - 12000	330	575	790	790
Container - 13000	203	420	612	612
Container - 14000	203	420	612	612
Container - 17000	216	485	647	647
Container - 18000	216	485	647	647
Cruise	282	361	612	306
General Cargo	56	124	160	160
Ocean Tug (ATB/ITB)	0	0	0	0
Miscellaneous	33	65	96	96
Reefer	104	237	304	304
RoRo	67	148	259	251
Tanker - Chemical	59	136	568	255
Tanker - Handysize	144	144	2,586	144
Tanker - Panamax	167	351	3,421	451

The low load adjustment (LLA) factors applied to 2-stroke non-MAN propulsion engines were updated to include SO_x and CO_2 LLA factors[6]. The updated LLA factors for non-MAN propulsion engines are presented in Table 3.7.

Table 3.7: 2-Stroke non-MAN Propulsion Engines Low Load Adjustment Factors

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
2%	7.29	7.29	7.29	4.63	3.30	9.68	21.18	3.28	4.63	21.18
3%	4.33	4.33	4.33	2.92	2.45	6.46	11.68	2.44	2.92	11.68
4%	3.09	3.09	3.09	2.21	2.02	4.86	7.71	2.01	2.21	7.71
5%	2.44	2.44	2.44	1.83	1.77	3.89	5.61	1.76	1.83	5.61
6%	2.04	2.04	2.04	1.60	1.60	3.25	4.35	1.59	1.60	4.35
7%	1.79	1.79	1.79	1.45	1.47	2.79	3.52	1.47	1.45	3.52
8%	1.61	1.61	1.61	1.35	1.38	2.45	2.95	1.38	1.35	2.95
9%	1.48	1.48	1.48	1.27	1.31	2.18	2.52	1.31	1.27	2.52
10%	1.38	1.38	1.38	1.22	1.26	1.96	2.20	1.25	1.22	2.20
11%	1.30	1.30	1.30	1.17	1.21	1.79	1.96	1.21	1.17	1.96
12%	1.24	1.24	1.24	1.14	1.17	1.64	1.76	1.17	1.14	1.76
13%	1.19	1.19	1.19	1.11	1.14	1.52	1.60	1.14	1.11	1.60
14%	1.15	1.15	1.15	1.08	1.11	1.41	1.47	1.11	1.08	1.47
15%	1.11	1.11	1.11	1.06	1.09	1.32	1.36	1.08	1.06	1.36
16%	1.08	1.08	1.08	1.05	1.06	1.24	1.26	1.06	1.05	1.26
17%	1.06	1.06	1.06	1.03	1.05	1.17	1.18	1.04	1.03	1.18
18%	1.04	1.04	1.04	1.02	1.03	1.11	1.11	1.03	1.02	1.11
19%	1.02	1.02	1.02	1.01	1.01	1.05	1.05	1.01	1.01	1.05
20%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

[6] USEPA, Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data, EPA420-R-00-002, February 2000, Table 3-5

Tables 3.8 and 3.9 present the load adjustment factors (LAF) used across the entire engine load range for MAN 2-stroke propulsion engines with slide valves (Table 3.8) and with conventional valves (Table 3.9). Revised CO_2 and SO_x LAFs shown in the tables below are based on the test data from the San Pedro Bay Ports' (SPBP) MAN Slide Valve Low-Load Emissions Test Final Report (Slide Valve Test.[7]

Table 3.8: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Slide Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
1%	0.36	0.36	0.36	1.90	1.10	0.12	1.36	1.10	1.90	1.36
2%	0.37	0.37	0.37	1.86	1.10	0.12	1.32	1.10	1.86	1.32
3%	0.38	0.38	0.38	1.82	1.09	0.12	1.28	1.09	1.82	1.28
4%	0.38	0.38	0.38	1.78	1.09	0.12	1.24	1.09	1.78	1.24
5%	0.39	0.39	0.39	1.74	1.09	0.12	1.20	1.09	1.74	1.20
6%	0.40	0.40	0.40	1.70	1.08	0.12	1.17	1.08	1.70	1.17
7%	0.41	0.41	0.41	1.67	1.08	0.12	1.14	1.08	1.67	1.14
8%	0.41	0.41	0.41	1.63	1.08	0.12	1.11	1.08	1.63	1.11
9%	0.42	0.42	0.42	1.60	1.07	0.12	1.08	1.07	1.60	1.08
10%	0.43	0.43	0.43	1.57	1.07	0.12	1.05	1.07	1.57	1.05
11%	0.44	0.44	0.44	1.53	1.07	0.26	1.02	1.07	1.53	1.02
12%	0.45	0.45	0.45	1.50	1.07	0.39	0.99	1.07	1.50	0.99
13%	0.45	0.45	0.45	1.47	1.06	0.52	0.97	1.06	1.47	0.97
14%	0.46	0.46	0.46	1.45	1.06	0.64	0.94	1.06	1.45	0.94
15%	0.47	0.47	0.47	1.42	1.06	0.75	0.92	1.06	1.42	0.92
16%	0.48	0.48	0.48	1.39	1.06	0.85	0.90	1.06	1.39	0.90
17%	0.49	0.49	0.49	1.37	1.05	0.95	0.88	1.05	1.37	0.88
18%	0.49	0.49	0.49	1.34	1.05	1.04	0.86	1.05	1.34	0.86
19%	0.50	0.50	0.50	1.32	1.05	1.12	0.84	1.05	1.32	0.84
20%	0.51	0.51	0.51	1.30	1.05	1.20	0.82	1.05	1.30	0.82
21%	0.52	0.52	0.52	1.28	1.04	1.27	0.81	1.04	1.28	0.81
22%	0.53	0.53	0.53	1.26	1.04	1.34	0.79	1.04	1.26	0.79
23%	0.54	0.54	0.54	1.24	1.04	1.40	0.78	1.04	1.24	0.78
24%	0.54	0.54	0.54	1.22	1.04	1.46	0.76	1.04	1.22	0.76
25%	0.55	0.55	0.55	1.20	1.03	1.51	0.75	1.03	1.20	0.75

[7] *http://www.cleanairactionplan.org/documents/man-slide-valve-low-load-emissions-test.pdf*

Table 3.8 (continued): Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Slide Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
26%	0.56	0.56	0.56	1.19	1.03	1.55	0.74	1.03	1.19	0.74
27%	0.57	0.57	0.57	1.17	1.03	1.59	0.73	1.03	1.17	0.73
28%	0.58	0.58	0.58	1.16	1.03	1.63	0.72	1.03	1.16	0.72
29%	0.59	0.59	0.59	1.14	1.03	1.66	0.71	1.03	1.14	0.71
30%	0.60	0.60	0.60	1.13	1.02	1.68	0.70	1.02	1.13	0.70
31%	0.60	0.60	0.60	1.12	1.02	1.70	0.70	1.02	1.12	0.70
32%	0.61	0.61	0.61	1.10	1.02	1.72	0.69	1.02	1.10	0.69
33%	0.62	0.62	0.62	1.09	1.02	1.74	0.69	1.02	1.09	0.69
34%	0.63	0.63	0.63	1.08	1.02	1.75	0.68	1.02	1.08	0.68
35%	0.64	0.64	0.64	1.07	1.02	1.75	0.68	1.02	1.07	0.68
36%	0.65	0.65	0.65	1.06	1.01	1.75	0.68	1.01	1.06	0.68
37%	0.66	0.66	0.66	1.05	1.01	1.75	0.67	1.01	1.05	0.67
38%	0.67	0.67	0.67	1.05	1.01	1.75	0.67	1.01	1.05	0.67
39%	0.68	0.68	0.68	1.04	1.01	1.74	0.67	1.01	1.04	0.67
40%	0.69	0.69	0.69	1.03	1.01	1.73	0.67	1.01	1.03	0.67
41%	0.70	0.70	0.70	1.03	1.01	1.72	0.67	1.01	1.03	0.67
42%	0.70	0.70	0.70	1.02	1.01	1.71	0.68	1.01	1.02	0.68
43%	0.71	0.71	0.71	1.02	1.01	1.69	0.68	1.01	1.02	0.68
44%	0.72	0.72	0.72	1.01	1.00	1.67	0.68	1.00	1.01	0.68
45%	0.73	0.73	0.73	1.01	1.00	1.65	0.69	1.00	1.01	0.69
46%	0.74	0.74	0.74	1.00	1.00	1.62	0.69	1.00	1.00	0.69
47%	0.75	0.75	0.75	1.00	1.00	1.60	0.70	1.00	1.00	0.70
48%	0.76	0.76	0.76	1.00	1.00	1.57	0.70	1.00	1.00	0.70
49%	0.77	0.77	0.77	0.99	1.00	1.54	0.71	1.00	0.99	0.71
50%	0.78	0.78	0.78	0.99	1.00	1.51	0.71	1.00	0.99	0.71

Table 3.8 (continued): Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Slide Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
51%	0.79	0.79	0.79	0.99	1.00	1.48	0.72	1.00	0.99	0.72
52%	0.80	0.80	0.80	0.99	1.00	1.45	0.73	1.00	0.99	0.73
53%	0.81	0.81	0.81	0.99	1.00	1.41	0.74	1.00	0.99	0.74
54%	0.82	0.82	0.82	0.99	1.00	1.38	0.75	1.00	0.99	0.75
55%	0.83	0.83	0.83	0.98	0.99	1.35	0.75	0.99	0.98	0.75
56%	0.84	0.84	0.84	0.98	0.99	1.31	0.76	0.99	0.98	0.76
57%	0.85	0.85	0.85	0.98	0.99	1.27	0.77	0.99	0.98	0.77
58%	0.86	0.86	0.86	0.98	0.99	1.24	0.78	0.99	0.98	0.78
59%	0.87	0.87	0.87	0.98	0.99	1.20	0.80	0.99	0.98	0.80
60%	0.88	0.88	0.88	0.98	0.99	1.16	0.81	0.99	0.98	0.81
61%	0.89	0.89	0.89	0.98	0.99	1.13	0.82	0.99	0.98	0.82
62%	0.90	0.90	0.90	0.98	0.99	1.09	0.83	0.99	0.98	0.83
63%	0.91	0.91	0.91	0.99	0.99	1.06	0.84	0.99	0.99	0.84
64%	0.92	0.92	0.92	0.99	0.99	1.02	0.85	0.99	0.99	0.85
65%	0.93	0.93	0.93	0.99	0.99	0.98	0.87	0.99	0.99	0.87
66%	0.94	0.94	0.94	0.99	0.99	0.95	0.88	0.99	0.99	0.88
67%	0.95	0.95	0.95	0.99	0.99	0.92	0.89	0.99	0.99	0.89
68%	0.97	0.97	0.97	0.99	0.99	0.88	0.91	0.99	0.99	0.91
69%	0.98	0.98	0.98	0.99	0.99	0.85	0.92	0.99	0.99	0.92
70%	0.99	0.99	0.99	0.99	0.99	0.82	0.93	0.99	0.99	0.93
71%	1.00	1.00	1.00	0.99	0.99	0.79	0.95	0.99	0.99	0.95
72%	1.01	1.01	1.01	0.99	0.99	0.76	0.96	0.99	0.99	0.96
73%	1.02	1.02	1.02	0.99	0.99	0.74	0.98	0.99	0.99	0.98
74%	1.03	1.03	1.03	0.99	0.99	0.71	0.99	0.99	0.99	0.99
75%	1.04	1.04	1.04	0.99	0.99	0.69	1.00	0.99	0.99	1.00

Table 3.8 (continued): Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Slide Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
76%	1.05	1.05	1.05	0.99	0.99	0.66	1.02	0.99	0.99	1.02
77%	1.06	1.06	1.06	0.99	0.99	0.64	1.03	0.99	0.99	1.03
78%	1.07	1.07	1.07	0.99	0.99	0.63	1.05	0.99	0.99	1.05
79%	1.09	1.09	1.09	0.99	0.99	0.61	1.06	0.99	0.99	1.06
80%	1.10	1.10	1.10	0.99	0.99	0.60	1.08	0.99	0.99	1.08
81%	1.11	1.11	1.11	0.99	0.99	0.58	1.09	0.99	0.99	1.09
82%	1.12	1.12	1.12	0.99	0.99	0.57	1.10	0.99	0.99	1.10
83%	1.13	1.13	1.13	0.98	0.99	0.57	1.12	0.99	0.98	1.12
84%	1.14	1.14	1.14	0.98	0.99	0.56	1.13	0.99	0.98	1.13
85%	1.15	1.15	1.15	0.98	0.99	0.56	1.15	0.99	0.98	1.15
86%	1.16	1.16	1.16	0.98	0.99	0.56	1.16	0.99	0.98	1.16
87%	1.18	1.18	1.18	0.97	0.99	0.56	1.18	0.99	0.97	1.18
88%	1.19	1.19	1.19	0.97	0.99	0.57	1.19	0.99	0.97	1.19
89%	1.20	1.20	1.20	0.96	0.99	0.58	1.20	0.99	0.96	1.20
90%	1.21	1.21	1.21	0.96	0.99	0.59	1.22	0.99	0.96	1.22
91%	1.22	1.22	1.22	0.95	1.00	0.61	1.23	1.00	0.95	1.23
92%	1.23	1.23	1.23	0.95	1.00	0.63	1.24	1.00	0.95	1.24
93%	1.25	1.25	1.25	0.94	1.00	0.65	1.25	1.00	0.94	1.25
94%	1.26	1.26	1.26	0.93	1.00	0.67	1.27	1.00	0.93	1.27
95%	1.27	1.27	1.27	0.93	1.00	0.70	1.28	1.00	0.93	1.28
96%	1.28	1.28	1.28	0.92	1.00	0.73	1.29	1.00	0.92	1.29
97%	1.29	1.29	1.29	0.91	1.00	0.77	1.30	1.00	0.91	1.30
98%	1.31	1.31	1.31	0.90	1.00	0.81	1.31	1.00	0.90	1.31
99%	1.32	1.32	1.32	0.89	1.00	0.85	1.32	1.00	0.89	1.32
100%	1.33	1.33	1.33	0.88	1.00	0.90	1.34	1.00	0.88	1.34

Table 3.9: Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Conventional Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
1%	0.84	0.84	0.84	1.91	1.11	1.38	2.53	1.11	1.91	2.53
2%	0.83	0.83	0.83	1.86	1.11	1.36	2.45	1.11	1.86	2.45
3%	0.83	0.83	0.83	1.82	1.10	1.34	2.37	1.10	1.82	2.37
4%	0.82	0.82	0.82	1.77	1.10	1.33	2.30	1.10	1.77	2.30
5%	0.82	0.82	0.82	1.72	1.10	1.31	2.23	1.10	1.72	2.23
6%	0.81	0.81	0.81	1.68	1.09	1.29	2.16	1.09	1.68	2.16
7%	0.81	0.81	0.81	1.64	1.09	1.28	2.10	1.09	1.64	2.10
8%	0.80	0.80	0.80	1.60	1.09	1.26	2.03	1.09	1.60	2.03
9%	0.80	0.80	0.80	1.56	1.08	1.25	1.97	1.08	1.56	1.97
10%	0.79	0.79	0.79	1.52	1.08	1.24	1.91	1.08	1.52	1.91
11%	0.79	0.79	0.79	1.49	1.08	1.22	1.86	1.08	1.49	1.86
12%	0.78	0.78	0.78	1.45	1.07	1.21	1.80	1.07	1.45	1.80
13%	0.78	0.78	0.78	1.42	1.07	1.20	1.75	1.07	1.42	1.75
14%	0.78	0.78	0.78	1.39	1.07	1.19	1.70	1.07	1.39	1.70
15%	0.77	0.77	0.77	1.36	1.06	1.18	1.65	1.06	1.36	1.65
16%	0.77	0.77	0.77	1.33	1.06	1.17	1.61	1.06	1.33	1.61
17%	0.77	0.77	0.77	1.30	1.06	1.16	1.56	1.06	1.30	1.56
18%	0.77	0.77	0.77	1.28	1.06	1.15	1.52	1.06	1.28	1.52
19%	0.76	0.76	0.76	1.25	1.05	1.14	1.48	1.05	1.25	1.48
20%	0.76	0.76	0.76	1.23	1.05	1.13	1.44	1.05	1.23	1.44
21%	0.76	0.76	0.76	1.20	1.05	1.13	1.41	1.05	1.20	1.41
22%	0.76	0.76	0.76	1.18	1.05	1.12	1.37	1.05	1.18	1.37
23%	0.76	0.76	0.76	1.16	1.04	1.11	1.34	1.04	1.16	1.34
24%	0.75	0.75	0.75	1.14	1.04	1.10	1.31	1.04	1.14	1.31
25%	0.75	0.75	0.75	1.12	1.04	1.10	1.28	1.04	1.12	1.28

Table 3.9 (continued): Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Conventional Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
26%	0.75	0.75	0.75	1.11	1.04	1.09	1.25	1.04	1.11	1.25
27%	0.75	0.75	0.75	1.09	1.04	1.08	1.22	1.04	1.09	1.22
28%	0.75	0.75	0.75	1.07	1.03	1.08	1.20	1.03	1.07	1.20
29%	0.75	0.75	0.75	1.06	1.03	1.07	1.17	1.03	1.06	1.17
30%	0.75	0.75	0.75	1.05	1.03	1.07	1.15	1.03	1.05	1.15
31%	0.75	0.75	0.75	1.03	1.03	1.06	1.13	1.03	1.03	1.13
32%	0.75	0.75	0.75	1.02	1.03	1.06	1.11	1.03	1.02	1.11
33%	0.75	0.75	0.75	1.01	1.02	1.05	1.09	1.02	1.01	1.09
34%	0.75	0.75	0.75	1.00	1.02	1.05	1.08	1.02	1.00	1.08
35%	0.76	0.76	0.76	0.99	1.02	1.04	1.06	1.02	0.99	1.06
36%	0.76	0.76	0.76	0.98	1.02	1.04	1.05	1.02	0.98	1.05
37%	0.76	0.76	0.76	0.98	1.02	1.03	1.04	1.02	0.98	1.04
38%	0.76	0.76	0.76	0.97	1.02	1.03	1.02	1.02	0.97	1.02
39%	0.76	0.76	0.76	0.96	1.01	1.02	1.01	1.01	0.96	1.01
40%	0.76	0.76	0.76	0.96	1.01	1.02	1.00	1.01	0.96	1.00
41%	0.77	0.77	0.77	0.95	1.01	1.01	0.99	1.01	0.95	0.99
42%	0.77	0.77	0.77	0.95	1.01	1.01	0.99	1.01	0.95	0.99
43%	0.77	0.77	0.77	0.94	1.01	1.01	0.98	1.01	0.94	0.98
44%	0.78	0.78	0.78	0.94	1.01	1.00	0.97	1.01	0.94	0.97
45%	0.78	0.78	0.78	0.94	1.01	1.00	0.97	1.01	0.94	0.97
46%	0.78	0.78	0.78	0.94	1.01	0.99	0.96	1.01	0.94	0.96
47%	0.79	0.79	0.79	0.94	1.00	0.99	0.96	1.00	0.94	0.96
48%	0.79	0.79	0.79	0.93	1.00	0.98	0.96	1.00	0.93	0.96
49%	0.79	0.79	0.79	0.93	1.00	0.98	0.96	1.00	0.93	0.96
50%	0.80	0.80	0.80	0.93	1.00	0.98	0.96	1.00	0.93	0.96

Table 3.9 (continued): Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Conventional Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
51%	0.80	0.80	0.80	0.94	1.00	0.97	0.95	1.00	0.94	0.95
52%	0.81	0.81	0.81	0.94	1.00	0.97	0.95	1.00	0.94	0.95
53%	0.81	0.81	0.81	0.94	1.00	0.96	0.95	1.00	0.94	0.95
54%	0.82	0.82	0.82	0.94	1.00	0.96	0.95	1.00	0.94	0.95
55%	0.82	0.82	0.82	0.94	1.00	0.96	0.96	1.00	0.94	0.96
56%	0.83	0.83	0.83	0.94	1.00	0.95	0.96	1.00	0.94	0.96
57%	0.84	0.84	0.84	0.95	1.00	0.95	0.96	1.00	0.95	0.96
58%	0.84	0.84	0.84	0.95	1.00	0.95	0.96	1.00	0.95	0.96
59%	0.85	0.85	0.85	0.95	1.00	0.94	0.96	1.00	0.95	0.96
60%	0.86	0.86	0.86	0.95	0.99	0.94	0.97	0.99	0.95	0.97
61%	0.86	0.86	0.86	0.96	0.99	0.93	0.97	0.99	0.96	0.97
62%	0.87	0.87	0.87	0.96	0.99	0.93	0.97	0.99	0.96	0.97
63%	0.88	0.88	0.88	0.96	0.99	0.93	0.98	0.99	0.96	0.98
64%	0.89	0.89	0.89	0.97	0.99	0.93	0.98	0.99	0.97	0.98
65%	0.89	0.89	0.89	0.97	0.99	0.92	0.98	0.99	0.97	0.98
66%	0.90	0.90	0.90	0.98	0.99	0.92	0.99	0.99	0.98	0.99
67%	0.91	0.91	0.91	0.98	0.99	0.92	0.99	0.99	0.98	0.99
68%	0.92	0.92	0.92	0.98	0.99	0.91	0.99	0.99	0.98	0.99
69%	0.93	0.93	0.93	0.99	0.99	0.91	1.00	0.99	0.99	1.00
70%	0.94	0.94	0.94	0.99	0.99	0.91	1.00	0.99	0.99	1.00
71%	0.94	0.94	0.94	0.99	0.99	0.91	1.00	0.99	0.99	1.00
72%	0.95	0.95	0.95	1.00	0.99	0.91	1.01	0.99	1.00	1.01
73%	0.96	0.96	0.96	1.00	0.99	0.91	1.01	0.99	1.00	1.01
74%	0.97	0.97	0.97	1.00	0.99	0.91	1.01	0.99	1.00	1.01
75%	0.98	0.98	0.98	1.01	0.99	0.90	1.01	0.99	1.01	1.01

Table 3.9 (continued): Load Adjustment Factors for MAN 2-Stroke Propulsion Engines with Conventional Valves

Load	PM	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
76%	0.99	0.99	0.99	1.01	0.99	0.90	1.01	0.99	1.01	1.01
77%	1.00	1.00	1.00	1.01	0.99	0.90	1.01	0.99	1.01	1.01
78%	1.01	1.01	1.01	1.01	0.99	0.91	1.01	0.99	1.01	1.01
79%	1.03	1.03	1.03	1.02	0.99	0.91	1.01	0.99	1.02	1.01
80%	1.04	1.04	1.04	1.02	0.99	0.91	1.01	0.99	1.02	1.01
81%	1.05	1.05	1.05	1.02	0.99	0.91	1.01	0.99	1.02	1.01
82%	1.06	1.06	1.06	1.02	0.99	0.91	1.01	0.99	1.02	1.01
83%	1.07	1.07	1.07	1.02	0.99	0.92	1.01	0.99	1.02	1.01
84%	1.08	1.08	1.08	1.02	0.99	0.92	1.00	0.99	1.02	1.00
85%	1.10	1.10	1.10	1.02	0.99	0.92	1.00	0.99	1.02	1.00
86%	1.11	1.11	1.11	1.02	0.99	0.93	0.99	0.99	1.02	0.99
87%	1.12	1.12	1.12	1.02	0.99	0.93	0.99	0.99	1.02	0.99
88%	1.13	1.13	1.13	1.02	0.99	0.94	0.98	0.99	1.02	0.98
89%	1.15	1.15	1.15	1.01	0.99	0.95	0.97	0.99	1.01	0.97
90%	1.16	1.16	1.16	1.01	0.99	0.95	0.97	0.99	1.01	0.97
91%	1.17	1.17	1.17	1.01	0.99	0.96	0.96	0.99	1.01	0.96
92%	1.19	1.19	1.19	1.00	0.99	0.97	0.94	0.99	1.00	0.94
93%	1.20	1.20	1.20	1.00	0.99	0.98	0.93	0.99	1.00	0.93
94%	1.22	1.22	1.22	0.99	0.99	0.99	0.92	0.99	0.99	0.92
95%	1.23	1.23	1.23	0.99	0.99	1.01	0.91	0.99	0.99	0.91
96%	1.24	1.24	1.24	0.98	0.99	1.02	0.89	0.99	0.98	0.89
97%	1.26	1.26	1.26	0.97	1.00	1.03	0.87	1.00	0.97	0.87
98%	1.28	1.28	1.28	0.97	1.00	1.05	0.86	1.00	0.97	0.86
99%	1.29	1.29	1.29	0.96	1.00	1.07	0.84	1.00	0.96	0.84
100%	1.31	1.31	1.31	0.95	1.00	1.08	0.82	1.00	0.95	0.82

Emission Estimates
The following tables present the estimated OGV emissions categorized in different ways, such as by engine type, by operating mode, and by vessel type. A summary of the OGV emission estimates by vessel type for all pollutants for the year 2016 is presented in Table 3.10. The criteria pollutant emissions are in tons per year (tpy), while the greenhouse gas emissions are in tonnes per year.

Table 3.10: Ocean-Going Vessel Emissions by Vessel Type

Vessel Type	PM_{10} tpy	$PM_{2.5}$ tpy	DPM tpy	NO_x tpy	SO_x tpy	CO tpy	HC tpy	CO_2e tonnes
Auto Carrier	1.0	1.0	0.9	59.5	2.0	4.9	2.1	3,009
Bulk	1.3	1.2	1.1	70.2	2.6	5.8	1.9	3,973
Container - 1000	0.0	0.0	0.0	1.7	0.1	0.2	0.1	113
Container - 2000	4.5	4.2	3.1	202.8	9.8	17.2	7.1	16,622
Container - 3000	0.8	0.7	0.7	54.2	1.6	3.8	1.6	2,734
Container - 4000	6.4	5.9	5.7	405.3	9.8	33.5	17.9	19,421
Container - 5000	5.5	5.1	4.7	308.9	7.4	36.7	17.0	18,578
Container - 6000	5.5	5.1	4.4	328.5	7.4	28.1	15.2	18,824
Container - 7000	2.1	1.9	1.7	105.1	2.1	12.8	7.1	6,014
Container - 8000	6.7	6.1	4.8	412.7	9.0	30.3	17.4	26,165
Container - 9000	1.3	1.2	0.7	83.5	1.8	3.7	2.0	6,801
Container - 10000	0.9	0.9	0.6	69.0	1.5	2.7	1.6	4,447
Container - 11000	0.7	0.7	0.5	58.4	1.1	2.2	1.2	3,270
Container - 12000	0.3	0.3	0.2	24.2	0.6	0.8	0.5	1,543
Container - 13000	1.9	1.8	1.5	104.9	4.2	9.5	4.7	6,520
Container - 14000	0.0	0.0	0.0	1.9	0.0	0.1	0.0	123
Container - 17000	0.1	0.0	0.0	3.6	0.1	0.3	0.1	193
Cruise	6.9	6.5	6.7	326.2	12.5	29.1	11.3	17,395
General Cargo	1.5	1.4	1.3	74.1	1.9	6.9	2.7	4,492
Ocean Tugboat (ATB/ITB)	0.2	0.1	0.2	7.5	0.3	0.7	0.3	363
Miscellaneous	0.2	0.1	0.1	5.0	0.5	0.4	0.2	730
Reefer	0.6	0.6	0.6	32.2	1.3	2.7	1.1	1,802
RoRo	0.8	0.7	0.7	37.9	1.5	2.7	1.0	2,040
Tanker - Chemical	4.4	4.1	3.6	201.7	8.8	18.0	6.3	14,344
Tanker - Handysize	1.8	1.7	1.1	71.0	4.9	6.3	2.5	7,099
Tanker - Panamax	4.6	4.3	2.1	150.5	13.3	13.5	5.5	21,079
Total	**60.0**	**55.7**	**47.2**	**3,200.4**	**106.1**	**272.8**	**128.3**	**207,693**

DB ID692

Table 3.11 presents summaries of emission estimates by engine type in tons per year. The emissions for the CARB-certified capture and control system to treat emissions from auxiliary engines are rolled up into the auxiliary engine emissions in this table.

Table 3.11: Ocean-Going Vessel Emissions by Engine Type

Engine Type	PM_{10} tpy	$PM_{2.5}$ tpy	DPM tpy	NO_x tpy	SO_x tpy	CO tpy	HC tpy	CO_2e tonnes
Main Engine	20.4	18.9	19.5	1,730.4	28.7	122.8	73.1	57,705.4
Auxiliary Engine	27.8	25.8	27.8	1,292.7	39.8	132.0	46.2	73,084.2
Auxiliary Boiler	11.8	10.9	0.0	177.3	37.7	18.0	9.0	76,903.1
Total	**60.0**	**55.7**	**47.2**	**3,200.4**	**106.1**	**272.8**	**128.3**	**207,693**

DB ID692

Table 3.12 presents summaries of emission estimates by the various modes in tons per year. For each mode, the engine type emissions are also listed. At-berth hotelling and at-anchorage hotelling are listed separately. Transit and harbor maneuvering emissions include both berth and anchorage calls.

Table 3.12: Ocean-Going Vessel Emissions by Mode

Mode	Engine Type	PM_{10} tpy	$PM_{2.5}$ tpy	DPM tpy	NO_x tpy	SO_x tpy	CO tpy	HC tpy	CO_2e tonnes
Transit	Main	17.9	16.6	17.0	1,555.5	26.6	104.7	57.2	53,103
Transit	Auxilary Engine	7.1	6.6	7.1	326.7	9.5	31.6	11.5	18,113
Transit	Auxiliary Boiler	0.4	0.4	0.0	6.5	1.2	0.7	0.3	2,805
Total Transit		**25.4**	**23.6**	**24.1**	**1,888.7**	**37.3**	**137.0**	**69.1**	**74,022**
Maneuvering	Main	2.5	2.3	2.5	174.9	2.1	18.1	15.9	4,602
Maneuvering	Auxilary Engine	2.8	2.6	2.8	127.6	3.7	12.4	4.5	7,078
Maneuvering	Auxiliary Boiler	0.2	0.2	0.0	3.4	0.7	0.3	0.2	1,493
Total Maneuvering		**5.5**	**5.1**	**5.3**	**305.9**	**6.5**	**30.8**	**20.5**	**13,173**
Hotelling at-berth	Main	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Hotelling at-berth	Auxilary Engine	14.9	13.9	14.9	700.7	22.3	75.0	25.4	40,405
Hotelling at-berth	Auxiliary Boiler	10.0	9.3	0.0	150.7	32.0	15.3	7.6	65,361
Total Hotelling at-berth		**24.9**	**23.2**	**14.9**	**851.3**	**54.3**	**90.2**	**33.1**	**105,765**
Hotelling at-anchorage	Main	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Hotelling at-anchorage	Auxilary Engine	3.0	2.8	3.0	137.7	4.2	13.1	4.8	7,489
Hotelling at-anchorage	Auxiliary Boiler	1.1	1.0	0.0	16.7	3.8	1.7	0.8	7,244
Total Hotelling at-anchorage		**4.1**	**3.8**	**3.0**	**154.4**	**8.0**	**14.8**	**5.6**	**14,733**
Total		**60.0**	**55.7**	**47.2**	**3,200.4**	**106.1**	**272.8**	**128.3**	**207,693**

DB ID694

SECTION 4 HARBOR CRAFT

This section presents emission estimates for the commercial harbor craft source category, including source descriptions, geographical domain, data acquisition, operational profiles, emissions estimation methodology and emission estimates.

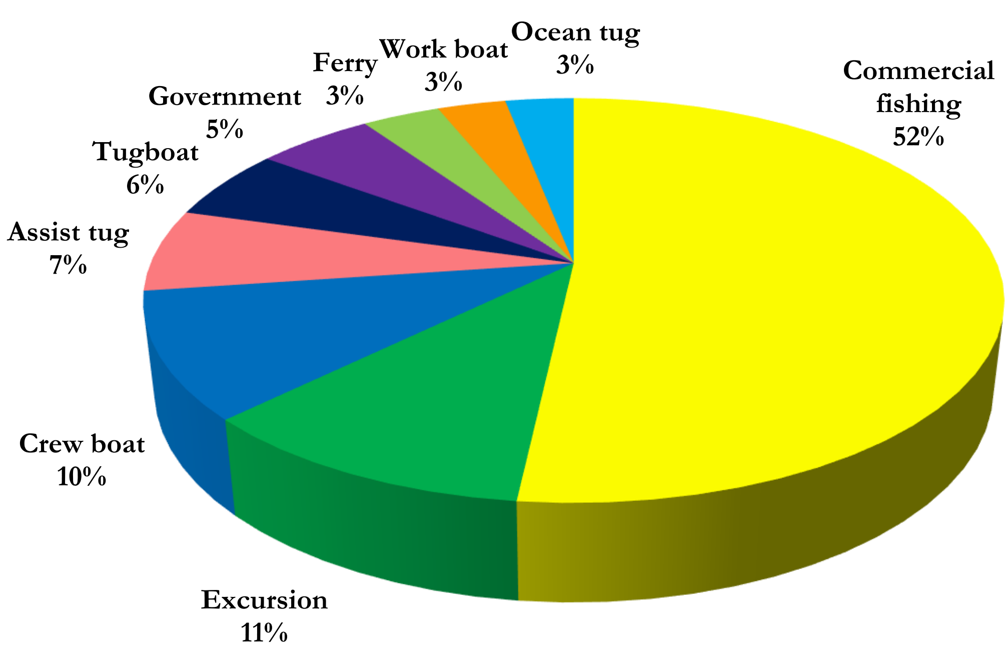
Source Description

Harbor craft are commercial vessels that spend the majority of their time within or near the port and harbor. The harbor craft emissions inventory consists of the following vessel types:

- Assist tugboats
- Commercial fishing vessels
- Crew boats
- Ferry vessels
- Excursion vessels
- Government vessels
- Tugboats
- Ocean tugs
- Work boats

Recreational vessels are not considered to be commercial harbor craft; therefore, their emissions are not included in this inventory. Figure 4.1 presents the distribution of the commercial harbor craft inventoried for the Port in 2016.

Figure 4.1: Distribution of Commercial Harbor Craft Population by Vessel Type



Ocean tugs included in this section are different from the articulated tug barge (ATB) discussed in the ocean-going section of this report. ATB are seen as specialized single vessels and are included in the marine exchange data for ocean-going vessels. The ocean tugs in this section are not rigidly connected to the barge and are typically not home-ported at the Port, but may make frequent calls with barges. They are different from tugboats because their average engine loads are higher than tugboats, which tend to idle more between jobs. Tugboats are typically home-ported in San Pedro Bay harbor and primarily operate within the harbor area, but can also operate outside the harbor depending on their work assignments.

Geographical Domain
The geographical domain for harbor craft is the same as that for ocean-going vessels.

Data and Information Acquisition
Commercial harbor craft companies were contacted to obtain key operational parameters for their vessels. These include:

- Vessel type
- Engine count
- Engine horsepower (or kilowatts) for main and auxiliary engines
- Engine model year
- Operating hours in calendar year 2016
- Vessel repower information

Operational Profiles
Tables 4.1 and 4.2 summarize the main and auxiliary engine data, respectively, for each vessel type. The averages by vessel type have been used as defaults for vessels for which the model year, horsepower, or operating hour information is missing.

There are a number of companies that operate harbor craft in both the Ports of Los Angeles and Long Beach harbors. The activity hours for the vessels that are common to both ports reflect work performed during 2016 for the Port of Los Angeles harbor only.

Table 4.1: Summary of Propulsion Engine Data by Vessel Category

Harbor Craft Type	Vessel Count	Engine Count	Model year Minimum	Model year Maximum	Model year Average	Horsepower Minimum	Horsepower Maximum	Horsepower Average	Annual Operating Hours Minimum	Annual Operating Hours Maximum	Annual Operating Hours Average
Assist tug	15	31	1980	2014	2007	600	2,575	2,020	53	1,998	1,406
Commercial fishing	118	126	1957	2016	2006	150	300	222	200	1,300	940
Crew boat	23	53	2003	2012	2009	180	1,450	572	50	1,859	812
Excursion	25	50	1972	2015	2006	250	550	365	30	3,000	1,499
Ferry	8	20	2003	2013	2010	2,250	3,110	2,341	594	1,635	1,150
Government	12	22	1993	2012	2005	68	1,770	563	0	852	373
Ocean tug	7	14	2001	2012	2006	805	3,385	1,842	200	2,129	1,087
Tugboat	13	26	2001	2014	2010	235	1,500	777	34	1,088	401
Work boat	7	13	2005	2013	2010	135	1,000	506	23	2,817	927
Total	**228**	**355**									

DB ID423

Table 4.2: Summary of Auxiliary Engine Data by Vessel Category

Harbor Craft Type	Vessel Count	Engine Count	Model year Minimum	Model year Maximum	Model year Average	Horsepower Minimum	Horsepower Maximum	Horsepower Average	Annual Operating Hours Minimum	Annual Operating Hours Maximum	Annual Operating Hours Average
Assist tug	15	30	1980	2014	2010	107	557	208	23	2,245	1,573
Commercial fishing	118	40	1957	2015	2008	10	40	26	100	1,200	767
Crew boat	23	24	1980	2015	2008	11	107	55	110	2,112	754
Excursion	25	28	1972	2014	2007	7	74	39	0	5,000	2,145
Ferry	8	16	2003	2016	2011	18	120	69	450	1,832	996
Government	12	15	2002	2012	2004	50	1555	522	10	802	171
Ocean tug	7	15	2002	2013	2007	60	253	120	200	1,680	740
Tugboat	13	22	1989	2014	2009	22	192	64	8	775	305
Work boat	7	11	1968	2013	2001	27	101	69	1	4,017	1,176
Total	**228**	**201**									

DB ID422

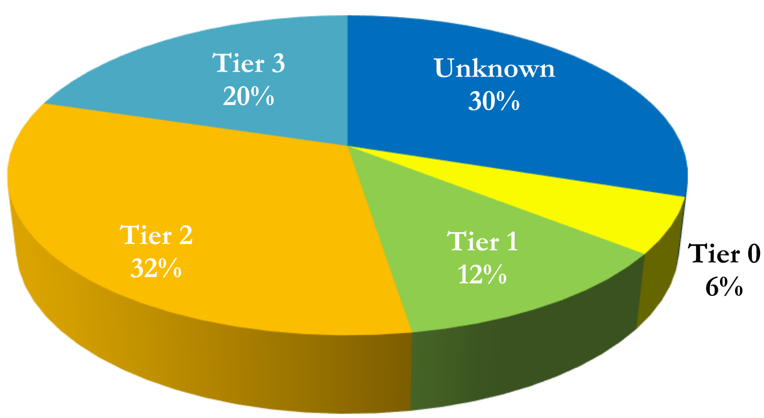
Harbor craft engines with known model year and horsepower are categorized according to their respective EPA marine engine standards (known as "tier level"). In the case where engine information gathered from harbor craft operators fails to identify the specific EPA tier level, the tier level is assigned for that engine based on engine model year and horsepower.[8] These assumptions are consistent with CARB's harbor craft emission factors, which follow the same model year grouping as EPA emissions standards for marine engines.

Table 4.3: Harbor Craft Marine Engine EPA Tier Levels

EPA Tier Level	Marine Engine Model Year Range	Horsepower Range
Tier 0	1999 and older	All
Tier 1	2000 to 2003	< 500 hp
Tier 1	2000 to 2006	> 500 hp
Tier 2	2004 up to Tier 3	< 500 hp
Tier 2	2007 up to Tier 3	> 500 hp
Tier 3	2009 and newer	0 to 120 hp
Tier 3	2013 and newer	> 120 to 175 hp
Tier 3	2014 and newer	> 175 to 500 hp
Tier 3	2013 and newer	> 500 to 750 hp
Tier 3	2012 to 2017	> 750 to 1,900 hp
Tier 3	2013 to 2016	> 1,900 to 3,300 hp
Tier 3	2014 to 2016	> 3,300 hp

Figure 4.2 provides the distribution by Tier of all harbor craft propulsion and auxiliary engines operating at the Port in 2016. If model year and/or horsepower information are not available, the engines are classified as "unknown."

Figure 4.2: Distribution of Harbor Craft Engines by Engine Standards



[8] CFR (Code of Federal Regulation), 40 CFR, subpart 94.8 for Tier 1 and 2 and subpart 1042.101 for Tier 3

Table 4.4 summarizes the energy consumption (kW-hr) per engine tier for 2016 harbor craft. The newer Tier 2 and Tier 3 engines make up the majority of the harbor craft energy consumption, which contributes to reduce emissions due higher use of cleaner engines. Energy consumption of harbor craft engines with unknown tier is distributed among other tiers based on defaults used for missing model year or horsepower for emissions calculations.

Table 4.4: Harbor Craft Energy Consumption by Engine Tier, kW-hr and %

Engine Tier	2016 kW-hr	2016 % of Total
Tier 0	1,105,933	1%
Tier 1	14,411,754	16%
Tier 2	55,457,507	63%
Tier 3	17,282,958	20%
Total	**88,258,152**	**100%**

Emissions Estimation Methodology
The emissions calculation methodology and the emission rates are same as the ones used to estimate harbor craft emissions for the Port's 2013 EI[9]. Harbor craft emissions are estimated for each engine individually, based on the engine's model year, power rating, and annual hours of operation. The Port's harbor craft emission calculation methodology is similar to the methodology used by the CARB emissions inventory for commercial harbor craft operating in California[10].

Emission Estimates
Table 4.5 summarizes the estimated 2015 harbor craft emissions by vessel type and engine type. In order for the total emissions to be consistently displayed for each pollutant, the individual values in each table column do not, in some cases, add up to the listed total in the table. This is because there are fewer decimal places displayed (for readability) than are included in the calculated total. The criteria pollutants are listed as tons per year while the CO_2e values are listed as tonnes (metric tons) per year.

[9] *www.portoflosangeles.org/environment/studies_reports.asp*
[10] CARB, *Commercial Harbor Craft Regulatory Activities*, Appendix B: Emissions Estimation Methodology for Commercial Harbor Craft Operating in California. *www.arb.ca.gov/msei/chc-appendix-b-emission-estimates-ver02-27-2012.pdf.*

Table 4.5: Harbor Craft Emissions by Vessel and Engine Type

Harbor Craft Type	Engine Type	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Assist Tug	Auxiliary	0.6	0.5	0.6	20.3	0.0	17.9	2.9	2,055
	Propulsion	6.5	6.0	6.5	183.3	0.2	126.5	18.6	14,716
Assist Tug Total		**7.1**	**6.6**	**7.1**	**203.6**	**0.2**	**144.4**	**21.6**	**16,771**
Commercial Fishing	Auxiliary	0.1	0.1	0.1	2.0	0.0	1.9	0.8	169
	Propulsion	1.5	1.4	1.5	46.2	0.0	30.6	4.7	3,478
Commercial Fishing Total		**1.6**	**1.5**	**1.6**	**48.2**	**0.0**	**32.5**	**5.4**	**3,647**
Crew boat	Auxiliary	0.1	0.1	0.1	2.0	0.0	1.6	0.5	157
	Propulsion	1.9	1.8	1.9	58.5	0.1	38.6	6.0	4,904
Crew boat Total		**2.0**	**1.9**	**2.0**	**60.5**	**0.1**	**40.2**	**6.4**	**5,061**
Excursion	Auxiliary	0.3	0.3	0.3	5.7	0.0	4.8	1.9	477
	Propulsion	2.7	2.5	2.7	77.2	0.1	47.9	7.6	5,494
Excursion Total		**3.0**	**2.7**	**3.0**	**82.9**	**0.1**	**52.7**	**9.5**	**5,970**
Ferry	Auxiliary	0.1	0.1	0.1	3.2	0.0	2.4	0.6	269
	Propulsion	5.2	4.8	5.2	141.2	0.1	95.2	14.2	11,134
Ferry Total		**5.3**	**4.9**	**5.3**	**144.3**	**0.1**	**97.6**	**14.9**	**11,403**
Government	Auxiliary	0.1	0.1	0.1	2.8	0.0	1.2	0.3	167
	Propulsion	1.1	1.0	1.1	22.9	0.0	8.7	2.0	1,395
Government Total		**1.3**	**1.2**	**1.3**	**25.7**	**0.0**	**9.9**	**2.3**	**1,562**
Ocean Tug	Auxiliary	0.1	0.1	0.1	3.6	0.0	2.7	0.5	311
	Propulsion	5.2	4.8	5.2	148.4	0.1	81.1	13.3	10,771
Ocean Tug		**5.3**	**4.9**	**5.3**	**152.0**	**0.1**	**83.9**	**13.8**	**11,082**
Tugboat	Auxiliary	0.0	0.0	0.0	0.9	0.0	0.7	0.2	73
	Propulsion	0.4	0.4	0.4	12.3	0.0	9.6	1.3	1,072
Tugboat Total		**0.4**	**0.4**	**0.4**	**13.1**	**0.0**	**10.2**	**1.5**	**1,145**
Work boat	Auxiliary	0.1	0.1	0.1	1.5	0.0	1.1	0.3	123
	Propulsion	0.6	0.5	0.6	18.9	0.0	14.0	1.9	1,584
Work boat Total		**0.7**	**0.6**	**0.7**	**20.3**	**0.0**	**15.2**	**2.3**	**1,708**
Harbor Craft Total		**26.7**	**24.6**	**26.7**	**750.9**	**0.7**	**486.6**	**77.6**	**58,348**

DB ID427

SECTION 5 CARGO HANDLING EQUIPMENT

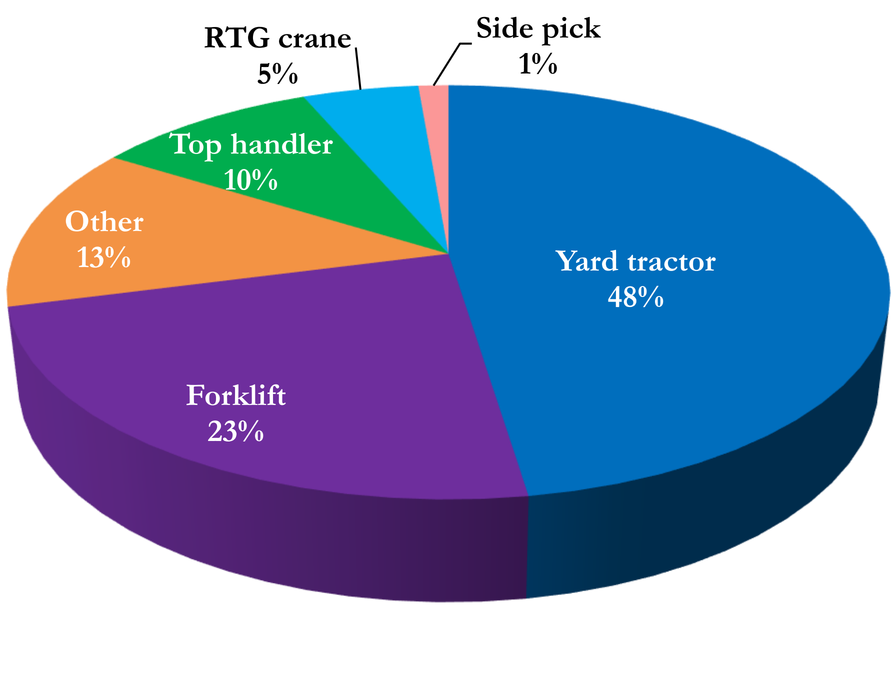
This section presents emissions estimates for the CHE source category, including source descriptions, geographical domain, data acquisition, operational profiles, emissions estimation methodology, and emission estimates.

Source Description

The CHE category includes equipment that moves cargo (including cargo in containers, general cargo, and bulk cargo) to and from marine vessels, railcars, and on-road trucks. The equipment is typically operated at marine terminals or at rail yards and not on public roadways. This inventory includes cargo handling equipment fueled by diesel, gasoline, propane, liquefied natural gas (LNG), and electricity. Due to the diversity of cargo handled by the Port's terminals, there is a wide range of equipment types.

Figure 5.1 presents the population distribution of the 2,202 pieces of equipment inventoried at the Port for calendar year 2016. The 13% for other equipment captures a variety of terminal equipment, such as bulldozer, cone vehicle, excavator, loader, man lift, material handler, rail pusher, reach stacker, skid steer loader, straddle carrier, sweeper, and truck.

Figure 5.1: CHE Count Distribution by Equipment Type



Geographical Domain
The geographical domain for CHE is the terminals within the Port.

Data and Information Acquisition
The maintenance and/or CHE operating staff of each terminal were contacted in person, by e-mail, or by telephone to obtain equipment count and activity information on the CHE specific to their terminal's operation for the 2016 calendar year:

Operational Profiles
Table 5.1 summarizes the cargo handling equipment data collected from the terminals and facilities for the calendar year 2016. The table includes the count of all equipment as well as the range and the average of horsepower, model year, and annual operating hours by equipment type for equipment with known operating parameters. The averages by CHE engine and fuel type were used as defaults for the missing information.

The table includes the characteristics of main and small auxiliary engines (20 kW) for rubber tired gantry cranes (RTGs) in the RTG crane row. These averages are not used as defaults for either the main or auxiliary engine. Instead the separate averages for main and auxiliary engines are used for the RTG cranes. The count column is equipment count, not engine count. For the electric-powered equipment shown in the table, "na" denotes "not applicable" for engine size, model year and operating hours.

Table 5.1: CHE Engine Characteristics for All Terminals

Equipment	Engine Type	Count	Power (hp)			Model Year			Annual Activity Hours		
			Min	Max	Average	Min	Max	Average	Min	Max	Average
Stacking Crane	Electric	31	na	na	na	na	na	na	na	na	na
Bulldozer	Diesel	3	200	310	255	2006	2007	2007	134	345	242
Cone Vehicle	Diesel	23	25	35	32	2010	2016	2014	14	2,007	661
Crane	Diesel	9	130	950	341	1969	2014	1998	0	1,130	392
Crane	Electric	3	na	na	na	na	na	na	na	na	na
Pallet jack	Electric	7	na	na	na	na	na	na	na	na	na
Wharf crane	Electric	84	na	na	na	na	na	na	na	na	na
Excavator	Diesel	1	371	371	371	2010	2010	2010	0	0	0
Forklift	Diesel	118	56	388	181	1985	2016	2010	0	3,209	671
Forklift	Electric	8	na	na	na	na	na	na	na	na	na
Forklift	Gasoline	7	45	45	45	2010	2012	2011	311	2,151	1,004
Forklift	Propane	381	32	200	74	1988	2016	2000	0	5,436	636
Loader	Diesel	10	55	460	259	1999	2015	2009	0	4,996	1,466
Loader	Electric	2	na	na	na	na	na	na	na	na	na
Man lift	Diesel	18	49	152	81	1998	2015	2006	33	490	252
Man lift	Electric	3	na	na	na	na	na	na	na	na	na
Man lift	Gasoline	1	60	60	60	2007	2007	2007	72	72	72
Material handler	Diesel	12	322	475	386	2000	2011	2007	0	3,656	1,361
Miscellaneous	Diesel	1	268	268	268	2007	2007	2007	667	667	667
Miscellaneous	Electric	2	na	na	na	na	na	na	na	na	na
Rail pusher	Diesel	2	194	200	197	2000	2012	2006	0	81	41
Reach stacker	Diesel	1	250	250	250	2013	2013	2013	12	12	12
RMG cranes	Electric	10	na	na	na	na	na	na	na	na	na
Hybrid RTG	Diesel	6	197	302	285	2011	2015	2014	353	2,486	1,687
RTG crane	Diesel	106	27	779	491	1998	2015	2007	0	3,725	1,424
Side pick	Diesel	29	152	275	235	2000	2016	2010	0	2,668	1,036
Skid steer loader	Diesel	4	56	75	68	1994	2012	2005	88	1,195	502
Straddle carrier	Diesel	28	425	425	425	2013	2015	2014	3,033	3,759	3,388
Sweeper	Diesel	5	96	260	158	2000	2009	2005	428	1,689	907
Sweeper	Gasoline	4	190	205	200	2002	2005	2004	0	2,660	1,018
Top handler	Diesel	214	250	400	326	1998	2016	2010	0	3,956	1,899
Truck	Diesel	20	185	540	344	2005	2013	2007	246	1,511	722
Truck	Propane	1	na	na	na	1973	1973	1973	93	93	93
Yard tractor	Diesel	851	173	250	229	1995	2016	2011	0	5,805	1,559
Yard tractor	LNG	17	230	230	230	2009	2010	2010	284	2,470	987
Yard tractor	Propane	180	174	231	199	2000	2011	2007	0	3,635	1,489
Total count		**2,202**									

DB ID228

Table 5.2 is a summary of the emission reduction technologies utilized in cargo handling equipment, including diesel oxidation catalysts (DOC), diesel particulate filters (DPF), and BlueCAT retrofit for large-spark ignition (LSI) engines. There is significantly less equipment with DOCs than in earlier years because the older equipment equipped with DOCs are being phased out of the terminal fleets.

Table 5.2: Count of CHE Utilizing Emission Reduction Technologies

Equipment	DOC Installed	On-Road Engines	DPF Installed	Vycon Installed	BlueCAT LSI Equip
Forklift	0	0	44	0	215
RTG crane	6	0	43	1	0
Side pick	0	0	13	0	0
Top handler	0	0	105	0	0
Yard tractor	0	801	4	0	0
Sweeper	0	1	2	0	0
Other	0	12	40	0	0
Total	**6**	**814**	**251**	**1**	**215**

DB ID234

Table 5.3 shows the distribution of equipment by fuel type.

Table 5.3: Count of CHE Equipment by Fuel Type

Equipment	Electric	LNG	Propane	Gasoline	Diesel	Total
Forklift	8	0	381	7	118	514
Wharf crane	84	0	0	0	0	84
RTG crane	0	0	0	0	112	112
Side pick	0	0	0	0	29	29
Top handler	0	0	0	0	214	214
Yard tractor	0	17	180	0	851	1,048
Sweeper	0	0	0	4	5	9
Other	58	0	0	1	132	191
Total	**150**	**17**	**562**	**12**	**1,461**	**2,202**

DB ID235

Table 5.4 summarizes the distribution of diesel cargo handling equipment's engines by off-road diesel engine standards[11] (Tier 0, 1, 2, 3, 4 interim, and 4 final) based on model year and horsepower range. The table also lists the count of each type of equipment using on-road diesel engines. The table does not reflect the fact that some of the engines may be cleaner than the Tier level they are certified to because of use of emissions control devices added to existing equipment. The "Unknown" Tier column shown in the table represents equipment with missing horsepower or model year information necessary for Tier level classifications.

Table 5.4: Count of Diesel Engines by Engine Standards

Equipment Type	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4i	Tier 4	Unknown Tier	On-road Engine	Total Diesel Engines
Yard tractor	4	0	0	0	0	46	0	801	851
Forklift	7	1	9	38	39	14	10	0	118
Top handler	0	17	34	55	34	74	0	0	214
Other	5	9	13	27	32	32	2	12	132
RTG crane	0	12	53	17	42	12	0	0	136
Side pick	0	4	4	5	0	10	6	0	29
Sweeper	0	2	0	2	0	0	0	1	5
Total	**16**	**45**	**113**	**144**	**147**	**188**	**18**	**814**	**1,485**
Percent	**1%**	**3%**	**8%**	**10%**	**10%**	**13%**	**1%**	**55%**	

DB ID878

Table 5.5 summarizes the energy consumption (kW-hr) for the diesel equipment by engine tier and the other engine types (ie gasoline, propane and LNG). Energy consumption of cargo handling equipment engines with unknown tier is distributed among other tiers based on defaults used for missing model year or horsepower for emissions calculations.

[11] EPA, *Nonroad Compression-Ignition Engines- Exhaust Emission Standards,* June 2004

Table 5.5: Diesel Equipment Energy Consumption by Engine Tier, kW-hr and %

Engine Type	Engine Tier	Energy Consumption kW-hr	Pecent Total
Diesel	Tier 0	642,976	0.3%
Diesel	Tier 1	1,664,198	0.8%
Diesel	Tier 2	12,542,813	6.1%
Diesel	Tier 3	21,820,022	10.7%
Diesel	Tier 4i	25,632,085	12.5%
Diesel	Tier 4	36,658,048	17.9%
Diesel	Onroad engines	85,542,113	41.8%
Gasoline		494,111	0.2%
Propane		18,641,161	9.1%
LNG		1,125,669	0.5%
Total		**204,763,196**	**100.0%**

Emissions Estimation Methodology

The emissions calculation methodology used to estimate CHE emissions is consistent with CARB's latest methodology for estimating emissions from CHE[12]. The NO_x emission rates for the newer diesel on-road engines within a certain horsepower range were updated based on discussions with CARB.

Emission Estimates

Table 5.6 summarizes the CHE emissions by terminal type and Table 5.7 provides a more detailed summary of cargo handling equipment emissions by equipment and engine type. The other category is for intermodal yard and other facilities located on port property.

Table 5.6: CHE Emissions by Terminal Type

Terminal Type	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Auto	0.0	0.0	0.0	0.1	0.0	2.2	0.2	34
Break-Bulk	0.5	0.5	0.5	26.3	0.1	16.3	2.3	5,659
Container	5.5	5.1	4.1	379.9	1.6	632.8	57.8	145,980
Cruise	0.0	0.0	0.0	0.7	0.0	1.4	0.1	64
Dry Bulk	0.1	0.1	0.1	7.0	0.0	3.9	0.6	454
Liquid	0.0	0.0	0.0	0.2	0.0	0.4	0.1	53
Other	0.4	0.4	0.2	20.5	0.1	95.4	8.1	7,413
Total	**6.5**	**6.0**	**4.8**	**434.7**	**1.7**	**752.5**	**69.0**	**159,658**

DB ID237

[12] CARB, Appendix B: Emission Estimation Methodology for Cargo Handling Equipment Operating at Ports and Intermodal Rail Yards in California at *www.arb.ca.gov/regact/2011/cargo11/cargoappb.pdf, viewed 22 July 2015*

Tables 5.7 present the emissions by cargo handling equipment type and engine type.

Table 5.7: CHE Emissions by Equipment and Engine Type

Equipment	Engine	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Bulldozer	Diesel	0.0	0.0	0.0	0.3	0.0	0.1	0.0	62
Cone vehicle	Diesel	0.0	0.0	0.0	0.8	0.0	1.0	0.1	132
Crane	Diesel	0.1	0.1	0.1	3.0	0.0	1.3	0.2	323
Excavator	Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Forklift	Diesel	0.1	0.1	0.1	9.9	0.0	9.1	0.7	2,221
Forklift	Gasoline	0.0	0.0	0.0	0.2	0.0	5.3	0.4	76
Forklift	Propane	0.3	0.3	0.0	16.2	0.0	97.2	4.2	2,847
Loader	Diesel	0.0	0.0	0.0	3.8	0.0	2.6	0.4	1,067
Man lift	Diesel	0.0	0.0	0.0	1.0	0.0	0.7	0.1	105
Man lift	Gasoline	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2
Material handler	Diesel	0.1	0.1	0.1	11.6	0.0	4.4	1.0	2,056
Miscellaneous	Diesel	0.0	0.0	0.0	0.3	0.0	0.1	0.0	52
Rail pusher	Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5
Reach stacker	Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
RTG crane	Diesel	1.2	1.1	1.2	69.3	0.1	26.5	5.4	13,377
Side pick	Diesel	0.1	0.0	0.1	2.9	0.0	5.1	0.5	2,533
Skid steer loader	Diesel	0.0	0.0	0.0	0.3	0.0	0.3	0.0	39
Straddle carrier	Diesel	0.1	0.1	0.1	9.1	0.1	9.8	1.5	4,623
Sweeper	Diesel	0.1	0.1	0.1	1.6	0.0	1.1	0.2	330
Sweeper	Gasoline	0.0	0.0	0.0	5.9	0.0	25.6	1.3	417
Top handler	Diesel	1.3	1.2	1.3	154.3	0.5	95.1	15.9	45,032
Truck	Diesel	0.2	0.2	0.2	5.5	0.0	3.0	0.4	1,456
Truck	Propane	0.0	0.0	0.0	0.2	0.0	0.4	0.0	11
Yard tractor	Diesel	1.4	1.3	1.4	79.6	0.9	151.1	8.4	68,134
Yard tractor	LNG	0.0	0.0	0.0	1.1	0.0	0.1	3.6	745
Yard tractor	Propane	1.4	1.4	0.0	57.8	0.0	312.4	24.6	14,013
Total		**6.5**	**6.0**	**4.8**	**434.7**	**1.70**	**752.5**	**69.0**	**159,658**

DB ID237

SECTION 6 LOCOMOTIVES

This section presents emission estimates for the railroad locomotives source category, including source description, geographical domain, data and information acquisition, operational profiles, the emissions estimation methodology, and the emissions estimates.

Source Description

Railroad operations are typically described in terms of two different types of operations, line haul and switching. Line haul refers to the movement of cargo by train over long distances. Line haul operations occur at or near the Port as the initiation or termination of a line haul trip, as cargo is either picked up for transport to destinations across the country or is dropped off for shipment overseas. Switching refers to short movements of rail cars, such as in the assembling and disassembling of trains at various locations in and around the Port, sorting of the cars of inbound cargo trains into contiguous "fragments" for subsequent delivery to terminals, and the short distance hauling of rail cargo within the Port. It is important to recognize that "outbound" rail freight is cargo that has arrived on vessels and is being shipped to locations across the U.S., whereas "inbound" rail freight is destined for shipment out of the Port by vessel. This is contrary to the usual port terminology of cargo off-loaded from vessels referred to as "inbound" and that loaded onto vessels as "outbound." Outbound rail cargo is also referred to as eastbound and inbound rail cargo is also referred to as westbound.

The Port is served by three railway companies:

- Burlington Northern Santa Fe Railway Company (BNSF)
- Union Pacific Railroad (UP)
- Pacific Harbor Line (PHL)

BNSF and UP provide line haul service to and from the Port and also operate switching services at their off-port locations, while PHL performs most of the switching operations within the Port. Locomotives used for line haul operations are typically equipped with large, powerful engines of 4,000 hp or more, while switch engines are smaller, typically having one or more engines totaling 1,200 to 3,000 hp. The locomotives used in switching service at the Port are primarily new, low-emitting locomotives specifically designed for switching duty. The switching locomotives are operated by PHL within the Port and by UP at the near-port railyard.

Geographical Domain
The specific activities included in this emissions inventory are movements of cargo within Port boundaries, and directly to or from Port-owned properties such as terminals and on-Port rail yards, within and to the boundary of the SoCAB. The inventory does not include rail movements of cargo that occur solely outside the Port, such as off-port rail yard switching, and movements that neither begin or end at a Port property, such as east-bound line hauls that initiate in central Los Angeles intermodal yards. Please refer to Section 1 for a description of the geographical domain of the emissions inventory with regard to locomotive operations.

Data and Information Acquisition
To estimate emissions associated with maritime industry-related activities of locomotives operating both within the Port and outside the Port to the boundary of the SoCAB, information has been obtained from:

- Previous emissions studies
- Port cargo statistics
- Input from railroad operators
- Published information sources
- CARB MOU line-haul fleet compliance data

The Port continues to use the most recent, locally-specific data available, including MOU compliance data reflective of actual recent line haul fleet mix characteristics in the SoCAB.

Operational Profiles
The goods movement rail system in terms of the activities that are carried out by locomotive operators is the same as described in detail in Section 6 of the Port's 2013 EI report.

Emissions Estimation Methodology
The emissions calculation methodology used to estimate locomotive emissions is consistent with the methodology described in detail in Section 6 of the Port's 2013 EI.[13] Below are tables that are specific to this 2016 EI.

Table 6.1 presents the MOU compliance information submitted by both railroads and the composite of both railroads' pre-Tier 0 through Tier 4 locomotive NO_x emissions for calendar year 2015, showing a weighted average NO_x emission factor of 5.48 g/hphr.[14] The 2015 reports were used instead of the 2016 because of the timing of the inventory data collection phase and of the posting of the compliance reports by CARB. The emission factors based on the 2016 compliance report will be used for the 2017 EI.

[13] *http://www.portoflosangeles.org/environment/studies_reports.asp*
[14] Notes from railroads' MOU compliance submissions:
1. For more information on the U.S. EPA locomotive emission standards please visit. *http://www.epa.gov/oms/locomotives.htm.*
2. Number of locomotives is the sum of all individual locomotives that visited or operated within the SoCAB at any time during 2014.

Table 6.1: MOU Compliance Data, MWhrs and g NO_x/hp-hr

Tier	Number of Locomotives	Megawatt-hours (MWhrs)	%MWhrs by Tier Level	Wt'd Avg NO_x (g/bhp-hr)	Tier Contribution to Fleet Average (g/bhp-hr)
BNSF					
Pre-Tier 0	27	15	0.0%	13.0	0.00
Tier 0	166	6,049	2.7%	7.5	0.20
Tier 1	1,280	77,662	35%	6.2	2.15
Tier 2	1,107	92,689	41%	4.5	1.86
Tier 3	939	46,425	21%	4.3	0.89
Tier 4	132	1,336	0.6%	1.2	0.01
ULEL	0	0	0%	-	-
Total BNSF	**3,651**	**224,176**	**100%**		**5.1**
UP					
Pre-Tier 0	73	374	0.2%	12.4	0.02
Tier 0/0+	2,372	54,676	26.4%	7.7	2.03
Tier 1/1+	1,887	30,358	15%	6.6	0.97
Tier 2/2+	1,868	64,554	31%	5.0	1.56
Tier 3	1,111	50,817	25%	4.7	1.15
Tier 4	33	101	0.0%	1	0.00
ULEL	59	6,451	3%	2.6	0.1
Total UP	**7,403**	**207,332**	**100%**		**5.8**
			ULEL Credit Used		0.3
			UP Fleet Average		**5.5**
Both RRs, excluding ULELs and ULEL credits					
Pre-Tier 0	100	389	0%	12.4	0.01
Tier 0	2,538	60,726	14%	7.7	1.10
Tier 1	3,167	108,021	25%	6.3	1.60
Tier 2	2,975	157,244	37%	4.7	1.74
Tier 3	2,050	97,242	23%	4.5	1.03
Tier 4	165	1,437	0.34%	1.2	0.004
Total both	**10,995**	**425,057**	**100%**		**5.48**

Emission factors for particulate matter (PM_{10}, $PM_{2.5}$, and DPM), HC, and CO were calculated using the tier-specific emission rates for those pollutants published by EPA[15] and used to develop weighted average emission factors using the megawatt hour (MWhr) figures provided in the railroads' submissions. These results are presented in Table 6.2.

Table 6.2: Fleet MWhr and PM, HC, CO Emission Factors, g/hp-hr

Engine Tier	MW-hr	% of MW-hr	EPA Tier-specific PM_{10}	EPA Tier-specific HC	EPA Tier-specific CO	Fleet Composite PM_{10}	Fleet Composite HC	Fleet Composite CO
				g/hp-hr			g/hp-hr	
Pre-Tier 0	389	0%	0.32	0.48	1.28	0.00	0.00	0.00
Tier 0	60,726	14%	0.32	0.48	1.28	0.05	0.07	0.18
Tier 1	108,021	25%	0.32	0.47	1.28	0.08	0.12	0.33
Tier 2	157,244	37%	0.18	0.26	1.28	0.07	0.10	0.47
Tier 3	97,242	23%	0.08	0.13	1.28	0.02	0.03	0.29
Tier 4	1,437	0.34%	0.015	0.04	1.28	0.00	0.00	0.00
Total	**425,057**	**100%**				**0.21**	**0.31**	**1.28**

Table 6.3 summarizes the emission factors for line haul locomotives, presented in units of g/hp-hr. The greenhouse gas emission factors are unchanged from the previous EI.

Table 6.3: Emission Factors for Line Haul Locomotives, g/hp-hr

	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4
EF, g/bhp-hr	0.21	0.20	0.21	5.48	0.005	1.28	0.31	494	0.013	0.040

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

On-Port Line Haul Emissions
The estimated number of trains per year, locomotives per train, and on-port hours per train are multiplied together to calculate total locomotive hours per year. This activity information is summarized in Table 6.4.

Table 6.4: Estimated On-Port Line Haul Locomotive Activity

Activity Measure	Inbound	Outbound	Total
Trains per Year	3,386	3,446	6,832
Locomotives per Train	3	3	N/A
Hours on Port per Trip	1	2.5	N/A
Locomotive Hours per Year	10,158	25,845	36,003

Out-of-Port Line Haul Emissions
For out-of-port line haul estimates, the following table has updated values for the 2016 EI. Table 6.5 lists the estimated totals of travel distance, out-of-port trains per year, out-of-port million gross tons (MMGT), out-of-port MMGT-miles, gallons of fuel used, and horsepower-hours. The gross ton-miles are calculated by multiplying distance by number of trains by the average weight of a train, estimated to be 7,276 tons. Fuel consumption is calculated by multiplying gross ton-miles by the average fuel consumption factor of 0.993 gallons per thousand gross ton-miles. Overall horsepower hours are calculated by multiplying the fuel used by the fuel consumption conversion factor of 20.8 hp-hr/gal.

Table 6.5: Gross Ton-Mile, Fuel Use, and Horsepower-hour Estimate

	Distance miles	Trains per year	MMGT per year	MMGT-miles per year
Alameda Corridor	21	5,089	37	777
Central LA to Air Basin Boundary	84	5,089	37	3,108
Million gross ton-miles				**3,885**
Estimated gallons of fuel (millions)				**3.86**
Estimated million horsepower-hours				**80.3**

Emission Estimates

A summary of estimated emissions from locomotive operations related to the Port is presented below in Table 6.6. These emissions include operations within the Port and maritime industry-related emissions outside the Port out to the boundary of the SoCAB. The "maritime industry-related" off-port activity is associated with cargo movements having either their origin or termination at the Port. Emissions resulting from the movement of cargo originating or terminating at one of the off-port rail yards are not included. The criteria pollutants are listed as tons per year while the CO_2e values are listed as tonnes (metric tons) per year.

In order for the total emissions to be consistently displayed for each pollutant, the individual values in the table entries do not, in some cases, add up to the totals listed in the table. This is because there are fewer decimal places displayed (for readability) than are included in the calculated totals.

Table 6.6: Locomotive Operations Estimated Emissions

Activity Component	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Switching	0.5	0.5	0.5	50.5	0.07	20.9	2.5	7,145
Line Haul	28.0	26.6	28.0	729.4	0.67	170.4	41.3	60,242
Total	**28.5**	**27.1**	**28.5**	**780.0**	**0.74**	**191.3**	**43.8**	**67,387**

DB ID696

SECTION 7 HEAVY-DUTY VEHICLES

This section presents emission estimates for the HDV emission source category, including source description, geographical domain, data and information acquisition, operational profiles, the emissions estimation methodology, and the emission estimates.

Source Description

Heavy-duty vehicles (specifically heavy-duty trucks) are used extensively to move cargo, particularly containerized cargo, to and from the marine terminals. Trucks deliver cargo to both local and national destinations. The local activity is often referred to as drayage and includes the transfer of containers between terminals and off-port railcar loading facilities. In the course of their daily operations, both local and national destined trucks are driven onto and through the terminals, where they deliver and/or pick up cargo. They are also driven on the public roads within the Port boundaries and on the public roads outside the Port.

While most of the trucks that service the Port's terminals are diesel-fueled vehicles, alternatively-fueled trucks, primarily those fueled by LNG, made approximately 5% of the terminal calls in 2016, according to the Port's Clean Truck Program (CTP) activity records and the Port Drayage Truck Registry (PDTR). Vehicles using fuel other than diesel fuel do not emit diesel particulate matter, so the diesel particulate emission estimates presented in this inventory have been adjusted to take the alternative-fueled trucks into account.

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 the study area is the container chassis, built to accommodate standard-sized cargo containers. Additional trailer types include tankers, boxes, and flatbeds. A tractor traveling without an attached trailer is called a "bobtail" while a tractor pulling an unloaded container trailer chassis is known simply as a "chassis." These vehicles are all classified as heavy HDVs regardless of their actual weight because the classification is based on gross vehicle weight rating (GVWR), which is a rating of the vehicle's total carrying capacity. Therefore, the emission estimates do not distinguish among the different configurations.

Geographical Domain

The two major geographical components of truck activities have been evaluated for this inventory:

- On-terminal operations, which include waiting for terminal entry, transiting the terminal to drop off and/or pick up cargo, and departing the terminal.
- On-road operations, consisting of travel on public roads within the SoCAB. This also includes travel on public roads within the Port boundaries and those of the adjacent Port of Long Beach.

Data and Information Acquisition

Information regarding on-terminal truck activity, such as average times and distances while on the terminals, is collected during in-person and/or telephone interviews with terminal personnel. For on-road operations, the volumes (number of trucks), distances, and average speeds on roadway segments between defined intersections are estimated using trip generation and travel demand models that have been developed for these purposes. The trip generation model is used to develop truck trip numbers for container terminals, while the terminal interviews are used to obtain trip counts associated with non-container terminals.

Operational Profiles

Table 7.1 illustrates both the range and average of reported container terminal operating characteristics of on-terminal truck activities at port container terminals, while Table 7.2 shows similar summary data for the non-container terminals and facilities. The total numbers of terminal calls in 2016 were 3,973,290 associated with the Port's container terminals and 1,017,751 associated with the non-container facilities. The total number of container terminal calls is based on the trip generation model on which truck travel estimates are based, while non-container terminal calls were obtained from the terminal operators. The non-container terminal number includes activity at the Port's peel-off yard that operated in 2016, totaling 28,309 calls. The peel-off yard was put established improve terminal efficiency by allowing containers off-loaded from ships to be quickly removed from the container terminal and placed in the yard, to be picked up for further transport at a later time.

Table 7.1: Summary of Reported Container Terminal Operating Characteristics

	Speed (mph)	Distance (miles)	Gate In (hours)	Unload/ Load (hours)	Gate Out (hours)
Maximum	15	1.50	0.25	0.9	0.13
Minimum	10	0.90	0.08	0.31	0.00
Average	12.5	1.32	0.14	0.57	0.04

Table 7.2: Summary of Reported Non-Container Facility Operating Characteristics

	Speed (mph)	Distance (miles)	Gate In (hours)	Unload/ Load (hours)	Gate Out (hours)
Maximum	20	1.30	0.08	0.47	0.05
Minimum	0	0.02	0.00	0.00	0.00
Average	7.5	0.50	0.03	0.12	0.01

Table 7.3 presents further detail on the on-terminal operating parameters, listing total estimated miles traveled and hours of idling on-terminal and waiting at entry gates. Terminals are listed by type.

Table 7.3: Estimated On-Terminal VMT and Idling Hours by Terminal

Terminal Type	Total Miles Traveled	Total Hours Idling (all trips)
Container	1,905,404	1,359,188
Container	1,074,938	652,129
Container	865,754	334,758
Container	730,139	277,453
Container	441,646	343,503
Container	431,750	289,273
Auto	1,463	994.5
Break Bulk	23,552	5,299
Break Bulk	12,421	7,949
Dry Bulk	3,300	1056
Dry Bulk	1,250	375
Liquid Bulk	3125	375
Liquid Bulk	18	0
Other	481,830	216,824
Other	189,800	27,740
Other	188,369	27,531
Other	67,600	8,320
Other	2,831	13,305
Other	1,900	3,325
Other	40	320
Total	**6,427,127**	**3,569,716**

Emissions Estimation Methodology

The general emissions estimating methodology for the Port's on-road truck fleet is the same as described in section 7.0 of the Port's 2013 EI report, with the updates reported in the 2014 EI report regarding the EMFAC2014 model, which was again used to estimate emission factors. Table 7.4 summarizes the speed-specific composite emission factors developed from the EMFAC2014 model and the model year distribution discussed below.

Table 7.4: Speed-Specific Composite Exhaust Emission Factors

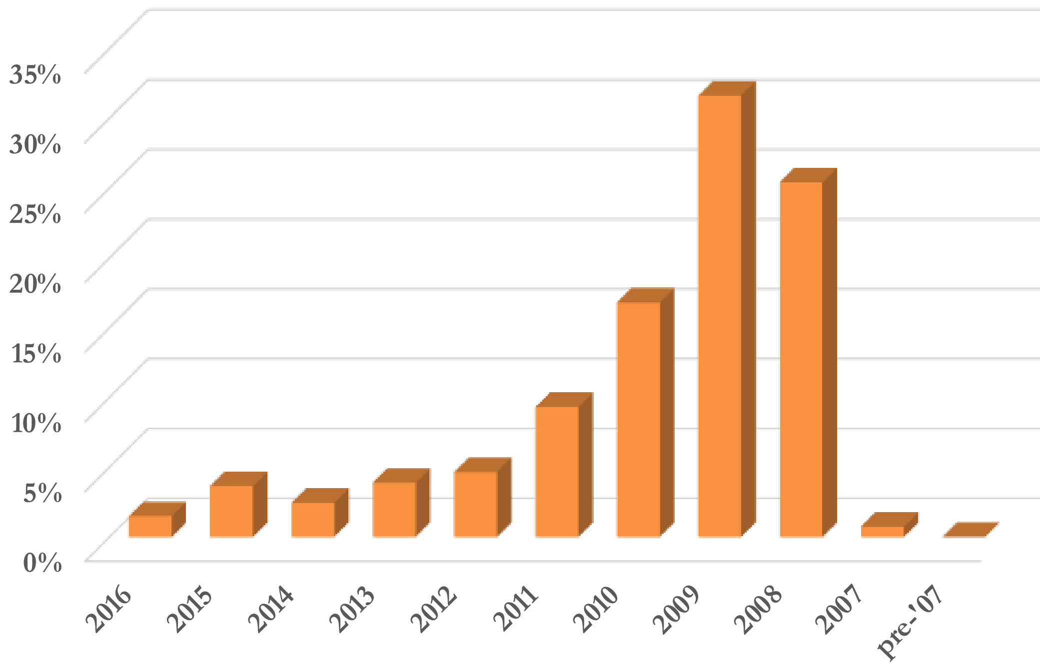
Speed (mph)	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2	N_2O	CH_4	Units
0 (Idle)	0.0062	0.0059	0.0059	33.6824	0.0474	2.8228	1.0224	5,063	0.1629	0.0601	g/hr
5	0.0697	0.0667	0.0662	20.0210	0.0173	5.1795	1.3412	3,461	0.0617	0.0789	g/mi
10	0.0628	0.0601	0.0596	16.9144	0.0173	4.1926	1.0840	3,082	0.0617	0.0638	g/mi
15	0.0540	0.0517	0.0513	12.9872	0.0173	2.9449	0.7579	2,603	0.0617	0.0446	g/mi
20	0.0482	0.0461	0.0458	10.3990	0.0173	2.1257	0.5448	2,286	0.0617	0.032	g/mi
25	0.0439	0.0420	0.0417	9.0039	0.0173	1.5606	0.3996	2,087	0.0617	0.0235	g/mi
30	0.0405	0.0387	0.0385	8.2115	0.0173	1.1542	0.2952	1,949	0.0617	0.0174	g/mi
35	0.0377	0.0361	0.0358	7.6443	0.0173	0.8548	0.2182	1,841	0.0617	0.0128	g/mi
40	0.0354	0.0338	0.0336	7.2118	0.0173	0.6345	0.1613	1,754	0.0617	0.0095	g/mi
45	0.0334	0.0319	0.0317	6.8656	0.0173	0.4724	0.1194	1,681	0.0617	0.0070	g/mi
50	0.0317	0.0303	0.0301	6.5815	0.0173	0.3533	0.0885	1,619	0.0617	0.0052	g/mi
55	0.0302	0.0289	0.0287	6.3460	0.0173	0.2661	0.0657	1,565	0.0617	0.0039	g/mi
60	0.0295	0.0283	0.0281	6.2447	0.0173	0.2317	0.0567	1,541	0.0617	0.0033	g/mi
65	0.0295	0.0283	0.0281	6.2697	0.0173	0.2317	0.0567	1,541	0.0617	0.0033	g/mi
70	0.0295	0.0283	0.0281	6.2889	0.0173	0.2317	0.0567	1,541	0.0617	0.0033	g/mi

Model Year Distribution

Because vehicle emissions vary according to the vehicle's model year and age, the activity level of trucks within each model year is an important part of developing emission estimates. The 2016 model year distribution for the current emissions inventory is based on call data originating from radio frequency identification (RFID) data, which tracked nearly 4.5 million truck calls made to the Port of Los Angeles and the Port of Long Beach in 2016, as well as model year data drawn from the PDTR. The PDTR contains model year information on all registered drayage trucks serving the Port and the fuel type used by each truck, from which an adjustment factor was developed for non-diesel fueled vehicles. The RFID data provided the number of calls made by each model year of truck.

The distribution of the model years of the trucks that called at Port and POLB terminals during 2016, which was used to develop the composite emission factors listed above, is presented in Figure 7.1. The call weighted average age of the trucks calling at San Pedro Bay port terminals in 2016 was approximately 6 years, about a year older than 5-year average in 2015.

Figure 7.1: Model Year Distribution of the Heavy-Duty Truck Fleet



Emission Estimates

The estimates of 2016 HDV emissions are presented in this section. As discussed above, on-terminal emissions are based on terminal-specific information such as the number of trucks passing through the terminal and the distance they travel on-terminal, and the Port-wide totals are the sum of the terminal-specific estimates. The on-road emissions have been estimated using travel demand model results to estimate how many miles in total the trucks travel along defined roadways in the SoCAB on the way to their first cargo drop-off point. The on-terminal estimates include the sum of driving and idling emissions calculated separately. The idling emissions are likely to be somewhat over-estimated because the idling estimates are based on the entire time that trucks are on terminal (except for driving time), which does not account for times that trucks are turned off while on terminal. No data source has been identified that would provide a reliable estimate of the average percentage of time the trucks' engines are turned off while on terminal. The on-road estimates include idling emissions as a normal part of the driving cycle because the average speeds include estimates of normal traffic idling times, and the emission factors are designed to take this into account.

In order for the total emissions to be consistently displayed for each pollutant, the individual values in each table column do not, in some cases, add up to the listed total in the tables. This is because there are fewer decimal places displayed for readability than are included in the calculated total.

Emission estimates for HDV activity associated with Port terminals and other facilities are presented in the following tables. Table 7.5 summarizes emissions from HDVs associated with all Port terminals.

Table 7.5: HDV Emissions

Activity Location	VMT	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
On-Terminal	6,427,127	0.4	0.4	0.41	237	0.3	35.8	10.4	36,447
On-Road	209,452,595	7.6	7.3	7.21	1,620	4.0	102.7	25.9	351,963
Total	**215,879,722**	**8.0**	**7.7**	**7.6**	**1,857**	**4.3**	**138.5**	**36.3**	**388,411**

Table 7.6 presents HDV emissions associated with container terminal activity separately from emissions associated with other port terminals and facilities.

Table 7.6: HDV Emissions Associated with Container Terminals

Activity Location	VMT	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
On-Terminal	5,449,629	0.4	0.4	0.3	209	0.3	30.9	9.0	32,016
On-Road	195,129,819	7.1	6.8	6.7	1,508	3.7	95.9	24.2	327,984
Total	**200,579,448**	**7.4**	**7.1**	**7.1**	**1,716**	**4.0**	**126.8**	**33.2**	**360,000**

Table 7.7 presents emissions associated with other port terminals and facilities separately.

Table 7.7: HDV Emissions Associated with Other Port Terminals

Activity Location	VMT	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
On-Terminal	977,498	0.1	0.1	0.1	28	0.0	4.9	1.4	4,432
On-Road	14,322,776	0.5	0.5	0.5	112	0.3	6.8	1.7	23,979
Total	**15,300,274**	**0.6**	**0.6**	**0.6**	**140**	**0.3**	**11.7**	**3.1**	**28,411**

SECTION 8 SUMMARY OF 2016 EMISSION RESULTS

Table 8.1 summarizes the 2016 total maritime industry-related emissions associated with the Port of Los Angeles by category. Tables 8.2 through 8.4 present DPM, NO_x and SO_x emissions in the context of Port-wide and air basin-wide emissions by source category and subcategory.

Table 8.1: Emissions by Source Category

Category	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
Ocean-going vessels	60.0	55.7	47.2	3,200.4	106.1	272.8	128.3	207,693
Harbor craft	26.7	24.6	26.7	750.9	0.7	486.6	77.6	58,348
Cargo handling equipment	6.5	6.0	4.8	434.7	1.7	752.5	69.0	159,658
Locomotives	28.5	27.1	28.5	780.0	0.7	191.3	43.8	67,387
Heavy-duty vehicles	8.0	7.7	7.6	1,857.0	4.3	138.5	36.3	388,411
Total	**129.6**	**121.1**	**114.8**	**7,022.9**	**113.5**	**1,841.7**	**355.0**	**881,496**

DB ID457

Table 8.2: DPM Emissions by Category and Percent Contribution

Category	Subcategory	DPM Emissions	Percent DPM Emissions of Total Category	Port	SoCAB AQMP
OGV	Auto carrier	0.9	2%	1%	0.0%
OGV	Bulk vessel	1.1	2%	1%	0.0%
OGV	Containership	28.8	61%	25%	1.1%
OGV	Cruise	6.7	14%	6%	0.3%
OGV	General cargo	1.3	3%	1%	0.1%
OGV	Other	0.9	2%	1%	0.0%
OGV	Reefer	0.6	1%	0%	0.0%
OGV	Tanker	6.9	15%	6%	0.3%
OGV	**Subtotal**	**47**	**100%**	**41%**	**1.8%**
Harbor Craft	Assist tug	7.1	27%	6%	0.3%
Harbor Craft	Harbor tug	0.4	2%	0%	0.0%
Harbor Craft	Commercial fishing	1.6	6%	1%	0.1%
Harbor Craft	Ferry	5.3	20%	5%	0.2%
Harbor Craft	Ocean tugboat	5.3	20%	5%	0.2%
Harbor Craft	Government	1.3	5%	1%	0.0%
Harbor Craft	Excursion	3.0	11%	3%	0.1%
Harbor Craft	Crewboat	2.0	8%	2%	0.1%
Harbor Craft	Work boat	0.7	2%	1%	0.0%
Harbor Craft	**Subtotal**	**27**	**100%**	**23%**	**1.0%**
CHE	RTG crane	1.2	25%	1%	0.0%
CHE	Forklift	0.1	3%	0%	0.0%
CHE	Top handler, side pick	1.4	28%	1%	0.1%
CHE	Other	0.7	15%	1%	0.0%
CHE	Yard tractor	1.4	30%	1%	0.1%
CHE	**Subtotal**	**5**	**100%**	**4%**	**0.2%**
Locomotives	Switching	0.5	2%	0%	0.0%
Locomotives	Line haul	28.0	98%	24%	1.1%
Locomotives	**Subtotal**	**28**	**100%**	**25%**	**1.1%**
HDV	On-Terminal	0.4	5%	0%	0.0%
HDV	On-Road	7.2	95%	6%	0.3%
HDV	**Subtotal**	**8**	**100%**	**7%**	**0.3%**
Port	**Total**	**115**		**100%**	**4.4%**
SoCAB AQMP	**Total**	**2,620**			

Table 8.3: NO_x Emissions by Category and Percent Contribution

Category	Subcategory	NO_x Emissions	Percent NO_x Emissions of Total Category	Port	SoCAB AQMP
OGV	Auto carrier	59	2%	1%	0.0%
OGV	Bulk vessel	70	2%	1%	0.0%
OGV	Containership	2,165	68%	31%	1.4%
OGV	Cruise	326	10%	5%	0.2%
OGV	General cargo	74	2%	1%	0.0%
OGV	Other	50	2%	1%	0.0%
OGV	Reefer	32	1%	0%	0.0%
OGV	Tanker	423	13%	6%	0.3%
OGV	**Subtotal**	**3,200**	**100%**	**46%**	**2.1%**
Harbor Craft	Assist tug	204	27%	2.9%	0.1%
Harbor Craft	Harbor tug	13	2%	0.2%	0.0%
Harbor Craft	Commercial fishing	48	6%	0.7%	0.0%
Harbor Craft	Ferry	144	19%	2.1%	0.1%
Harbor Craft	Ocean tugboat	152	20%	2.2%	0.1%
Harbor Craft	Government	26	3%	0.4%	0.0%
Harbor Craft	Excursion	83	11%	1.2%	0.1%
Harbor Craft	Crewboat	61	8%	0.9%	0.0%
Harbor Craft	Work boat	20	3%	0.3%	0.0%
Harbor Craft	**Subtotal**	**751**	**100%**	**11%**	**0.5%**
CHE	RTG crane	69	16%	1.0%	0.0%
CHE	Forklift	26	6%	0.4%	0.0%
CHE	Top handler, side pick	157	36%	2.2%	0.1%
CHE	Other	43	10%	0.6%	0.0%
CHE	Yard tractor	138	32%	2.0%	0.1%
CHE	**Subtotal**	**435**	**100%**	**6%**	**0.3%**
Locomotives	Switching	51	6%	0.7%	0.0%
Locomotives	Line haul	729	94%	10.4%	0.5%
Locomotives	**Subtotal**	**780**	**100%**	**11%**	**0.5%**
HDV	On-Terminal	237	13%	3%	0.2%
HDV	On-Road	1,620	87%	23%	1.0%
HDV	**Subtotal**	**1,857**	**100%**	**26%**	**1.2%**
Port	**Total**	**7,023**		**100%**	**4.5%**
SoCAB AQMP	**Total**	**155,572**			

Table 8.4: SO_x Emissions by Category and Percent Contribution

Category	Subcategory	SO_x Emissions	Percent SO_x Emissions of Total Category	Port	SoCAB AQMP
OGV	Auto carrier	2.0	2%	2%	0%
OGV	Bulk vessel	2.6	2%	2%	0%
OGV	Containership	56.6	53%	50%	1%
OGV	Cruise	12.5	12%	11%	0%
OGV	General cargo	1.9	2%	2%	0%
OGV	Other	2.2	2%	2%	0%
OGV	Reefer	1.3	1%	1%	0%
OGV	Tanker	27.0	25%	24%	0%
OGV	**Subtotal**	**106**	**100%**	**93%**	**2%**
Harbor Craft	Assist tug	0.2	29%	0%	0%
Harbor Craft	Harbor tug	0.0	2%	0%	0%
Harbor Craft	Commercial fishing	0.0	6%	0%	0%
Harbor Craft	Ferry	0.1	20%	0%	0%
Harbor Craft	Ocean tugboat	0.1	19%	0%	0%
Harbor Craft	Government	0.0	3%	0%	0%
Harbor Craft	Excursion	0.1	10%	0%	0%
Harbor Craft	Crewboat	0.1	9%	0%	0%
Harbor Craft	Work boat	0.0	3%	0%	0%
Harbor Craft	**Subtotal**	**0.7**	**100%**	**1%**	**0%**
CHE	RTG crane	0.1	9%	0%	0%
CHE	Forklift	0.0	2%	0%	0%
CHE	Top handler, side pick	0.5	32%	0%	0%
CHE	Other	0.1	7%	0%	0%
CHE	Yard tractor	0.9	51%	1%	0%
CHE	**Subtotal**	**1.7**	**100%**	**1%**	**0%**
Locomotives	Switching	0.1	9%	0%	0%
Locomotives	Line haul	0.7	91%	1%	0%
Locomotives	**Subtotal**	**0.7**	**100%**	**1%**	**0%**
HDV	On-Terminal	0.3	7%	0%	0%
HDV	On-Road	4.0	93%	4%	0%
HDV	**Subtotal**	**4.3**	**100%**	**4%**	**0%**
Port	**Total**	**114**		**100%**	**1.8%**
SoCAB AQMP	**Total**	**6,317**			

In order to put the maritime industry-related emissions into context, the following figures compare the Port's contributions to the total emissions in the South Coast Air Basin by major emission source category. The 2016 SoCAB emissions are based on the 2016 AQMP Appendix III.[16] Due to rounding, the percentages may not total 100%.

Figure 8.1: PM_{10} Emissions in the South Coast Air Basin

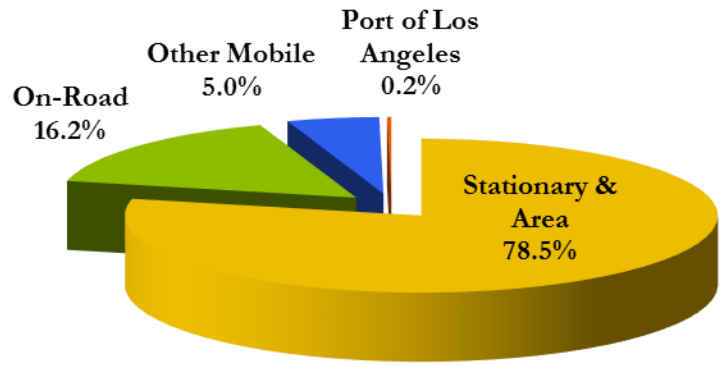
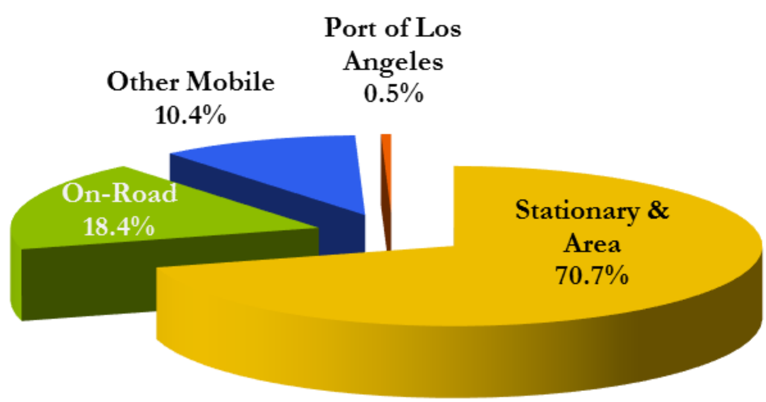


Figure 8.2: $PM_{2.5}$ Emissions in the South Coast Air Basin



[16] SCAQMD, *Final 2016 AQMP Appendix III, Base & Future Year Emissions Inventories*, March 2017.

Figure 8.3: DPM Emissions in the South Coast Air Basin

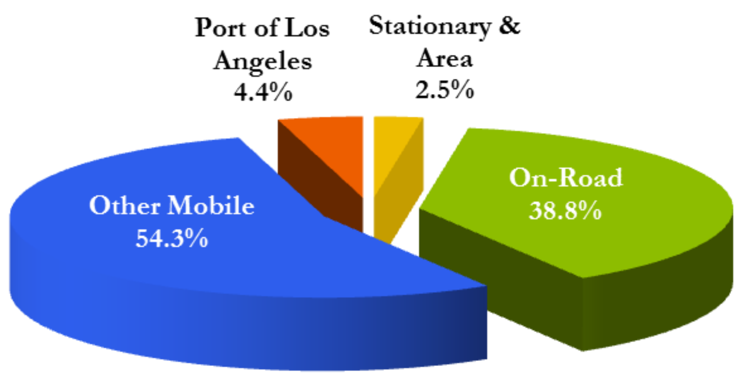


Figure 8.4: NO_x Emissions in the South Coast Air Basin

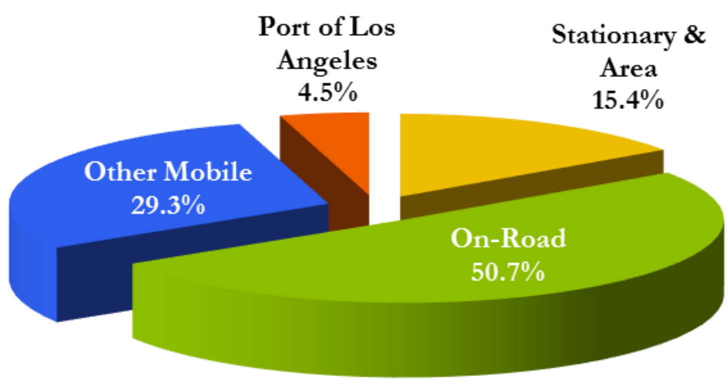


Figure 8.5: SO_x Emissions in the South Coast Air Basin

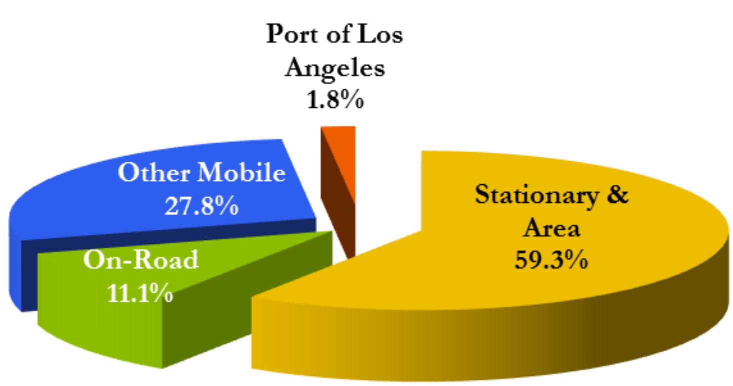
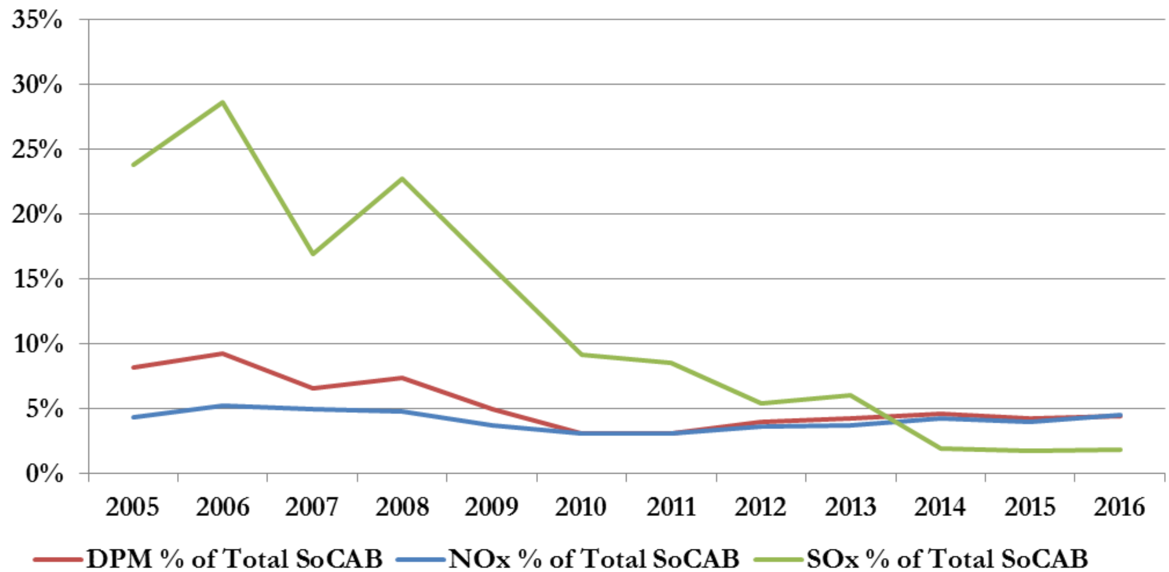


Figure 8.6 presents a comparison of the maritime industry-related mobile source emissions associated with the Port to the total SoCAB emissions from 2005 to 2016.

Figure 8.6: Emissions Contribution in the South Coast Air Basin



SECTION 9 COMPARISON OF 2016 AND PREVIOUS YEARS' FINDINGS AND EMISSION ESTIMATES

This section compares 2016 emissions to those in the previous year and in 2005, in terms of overall emissions, and for each source category. Comparisons by emission source categories are addressed in separate subsections in table and chart formats, with the explanation of the findings and differences in emissions.

The tables and charts in this section summarize the percent change from the previous year (2016 vs 2015) and for the CAAP Progress (2016 vs 2005) using 2016 methodology for emissions comparison. CAAP progress is tracked by comparing emissions each year to 2005 emissions, because 2005 is considered the baseline year for CAAP.

Table 9.1 compares emissions efficiency in 2016 as compared to 2005 and the previous year. A positive percent change for the emissions efficiency comparison means an improvement in efficiency.

Table 9.1: Emissions Efficiency Metric, tons/10,000 TEUs

EI Year	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2e
2016	0.146	0.137	0.130	7.93	0.13	2.08	0.40	995
2015	0.185	0.171	0.162	9.53	0.16	2.32	0.48	1,145
2005	1.267	1.096	1.175	21.65	6.66	5.02	1.14	1,378
Previous Year (2015-2016)	**21%**	**20%**	**20%**	**17%**	**19%**	**10%**	**17%**	**13%**
CAAP Progress (2005-2016)	**88%**	**88%**	**89%**	**63%**	**98%**	**59%**	**65%**	**28%**

Ocean-Going Vessels
There were improvements and changes to the OGV emission calculation methodology in this inventory. The improvements implemented in OGV emission calculation methodology for the current emissions inventory are discussed in Section 3 of this report.

The various emission reduction strategies implemented for ocean-going vessels are listed in Table 9.2. The table lists the percentage of calls that participated in the strategy for 2015, the previous year, and 2005. The following OGV emission reductions strategies are listed:

- Shore Power refers to vessel calls using shore power at berth, instead of running their diesel-powered auxiliary engines;
- VSR refers to the vessels reducing their transit speed to 12 knots or lower within 20 and 40 nm of the Port;
- ESI refers to the number of vessel calls using ship-specific SO_x fuel correction factors that were developed and used based on fuel quality data provided as part of the ESI program;
- Engine International Air Pollution Prevention (EIAPP) refers to the number of vessel calls using ship-specific NO_x emission factors for main and auxiliary engines, where vessel specific EIAPP Certificate data was available through the ESI program or the VBP.

In 2016, in addition to the shore power calls listed in the table, an additional 5% of vessel calls used alternative technology to comply with the At-Berth Regulation. The alternative technology includes the Maritime Emissions Treatment System (METS) and Advanced Maritime Emission Control System (AMECS).

Table 9.2: OGV Emission Reduction Strategies

Year	Shore Power	VSR 20 nm	VSR 40 nm	ESI	EIAPP Main Eng	EIAPP Aux Eng
2016	37%	92%	80%	61%	62%	61%
2015	36%	93%	83%	56%	51%	49%
2005	2%	65%	na	0%	5%	5%

DB ID1731

Fuel switching from heavy fuel oil (HFO) to low sulfur content fuel such as marine gas oil (MGO) or marine distillate oil (MDO) is also a major emission reduction strategy for OGV. In 2005, fuel switching was voluntary and only 7% of main engines and 27% of auxiliary engines switched fuel. In 2015 and 2016, all vessels switched fuel (100%) to 0.1% sulfur content MGO to comply with Phase II of CARB's marine fuel regulation and the North American Emissions Control Area (ECA) requirements.

Table 3 summarizes the main engine tier levels for 2016, previous year and 2005. The no tier level is for vessels that do not have diesel engines, such as steamships. IMO Tier I refers to calls by vessels meeting or exceeding IMO's Tier I standard (2000 and newer vessels) and IMO Tier II refers to calls by vessels meeting or exceeding IMO's Tier II standard.

Table 9.3: OGV Main Engine Tiers

Year	IMO Tier 0	IMO Tier I	IMO Tier II	IMO Tier III	No Tier
2016	11%	65%	19%	0%	5%
2015	12%	67%	17%	0%	4%
2005	59%	37%	0%	0%	4%

DB ID1778

Table 9.4 presents the ship emissions source activity in terms of total energy consumption (expressed as kW-hrs). In 2016, the total energy consumption decreased by 18% compared to the previous year and decreased by 29% compared to 2005.

Table 9.4: OGV Energy Consumption Comparison, kW-hr

Year	All Engines Total kW-hr	Main Eng Total kW-hr	Aux Eng Total kW-hr	Boiler Total kW-hr
2016	266,344,731	80,142,794	104,199,738	81,468,655
2015	322,910,996	74,787,555	142,783,766	105,288,561
2005	375,883,856	116,098,665	187,017,287	72,767,905
Previous Year (2015-2016)	**-18%**	**7%**	**-27%**	**-23%**
CAAP Progress (2005-2016)	**-29%**	**-31%**	**-44%**	**12%**

DB ID704

Table 9.5 compares the OGV emissions for calendar years 2016, the previous year and 2005. Reductions in OGV emissions are mainly attributed to increased participation in the Port's VSR program, the CARB shore power regulation, CARB marine fuel regulation, and the Port's ESI-based incentive program.

Table 9.5: OGV Emissions Comparison

EI Year	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
2016	60	56	47	3,200	106	273	128	207,693
2015	73	68	57	3,688	124	312	143	252,015
2005	534	429	466	5,295	4,825	470	213	288,251
Previous Year (2015-2016)	**-18%**	**-18%**	**-17%**	**-13%**	**-15%**	**-13%**	**-10%**	**-18%**
CAAP Progress (2005-2016)	**-89%**	**-87%**	**-90%**	**-40%**	**-98%**	**-42%**	**-40%**	**-28%**

DB ID692

Table 9.6 shows the emissions efficiency changes between 2016, previous year, and 2005. A positive percent change for the emissions efficiency comparison means an improvement in efficiency.

Table 9.6: OGV Emissions Efficiency Metric Comparison, tons/10,000 TEUs

EI Year	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC
2016	0.07	0.06	0.05	3.61	0.12	0.31	0.15
2015	0.09	0.08	0.07	4.52	0.15	0.38	0.18
2005	0.71	0.57	0.62	7.08	6.45	0.63	0.29
Previous Year (2015-2016)	**24%**	**24%**	**24%**	**20%**	**22%**	**19%**	**17%**
CAAP Progress (2005-2016)	**90%**	**86%**	**89%**	**36%**	**98%**	**39%**	**39%**

Harbor Craft
The methodology used to estimate harbor craft emissions for this 2016 inventory did not change from the methodology used in the previous year inventory.

Table 9.7 summarizes the number of harbor craft inventoried for 2016, the previous year and 2005. Overall, the total vessel count decreased by 4% between 2015 and 2016 and decreased by 20% between 2005 and 2016.

Table 9.7: Harbor Craft Count Comparison

Harbor Vessel Type	2016	2015	2005
Assist tug	15	15	16
Commercial fishing	118	119	156
Crew boat	23	23	14
Excursion	25	26	24
Ferry	8	8	7
Government	12	13	26
Ocean tug	7	8	7
Tugboat	13	16	21
Work boat	7	9	14
Total	**228**	**237**	**285**

DB ID196

Table 9.8 summarizes the percent distribution of engines based on EPA's engine standards. The increase in unknowns from previous year to 2016 is due to new commercial fishing vessels added to the list that have unknown horsepower and model year.

Tier 1, 2 and 3 categorization of engines for the Port's harbor craft inventory is based on EPA's emission standards for marine engines[17]. Tier 0 engines are unregulated engines built prior to the promulgation of the EPA emission standards. The percentages in the "unknown" column represent engines missing model year, horsepower, or both.

[17] Code of Federal Regulation, *40 CFR, subpart 94.8 for Tier 1 and 2 and subpart 1042.101 for Tier 3*

Table 9.8: Harbor Craft Engine Standards Comparison by Tier

Year	Tier 0	Tier 1	Tier 2	Tier 3	Unknown
2016	6%	12%	32%	20%	30%
2015	8%	13%	35%	19%	26%
2005	15%	33%	3%	0%	49%

DB ID1631

Table 9.9 summarizes the overall energy consumption of harbor craft (kW-hr) which decreased by 4% in 2016 compared to the previous year. The energy consumption increased by 3% in 2016 as compared to 2005.

Table 9.9: Harbor Craft Comparison

Year	Vessel Count	Engine Count	Energy Consumption kW-hr
2016	228	556	88,258,152
2015	237	570	92,289,747
2005	285	578	86,105,024
Previous Year (2015-2016)	**-4%**	**-2%**	**-4%**
CAAP Progress (2005-2016)	**-20%**	**-4%**	**3%**

Table 9.10 shows the harbor craft energy consumption (kW-hr) comparison by engine tier for calendar years 2016, previous year and 2005.

Table 9.10: Harbor Craft Energy Consumption Comparison by Engine Tier, kW-hr

Engine Tier	2016 % of Total	2015 % of Total	2005 % of Total
Tier 0	1%	3%	55%
Tier 1	16%	20%	30%
Tier 2	63%	59%	15%
Tier 3	20%	17%	0%
Total	**100%**	**100%**	**100%**

Table 9.11 shows the emissions comparisons for calendar 2016, the previous year, and 2005 for harbor craft. In 2016, emissions for all pollutants decreased as compared to the previous year, except for CO emissions which remained the same. The decrease is mainly due to newer engines for various vessel types.

Table 9.11: Harbor Craft Emission Comparison

Year	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
2016	27	25	27	751	1	487	78	58,348
2015	30	28	30	819	0.7	495	81	61,013
2005	55	51	55	1,318	6.3	364	87	56,925
Previous Year (2015-2016)	**-11%**	**-11%**	**-11%**	**-8%**	**-4%**	**-2%**	**-4%**	**-4%**
CAAP Progress (2005-2016)	**-52%**	**-52%**	**-52%**	**-43%**	**-89%**	**34%**	**-11%**	**2%**

DB ID427

Compared to 2005, emissions decreased except for CO and CO_2. The increase in CO is more directly related to an increase in Tier 2 and Tier 3 engines that have higher CO emission rates compared to pre-Tier 2. Due to the stringency of PM and (NO_x + HC) standards of Tier 2 engines, less stringent Tier 2 CO standards were adopted which resulted in higher CO emission rates. There has been an increase in Tier 2 and Tier 3 engines due to vessel repowers and also due to new vessels bought by companies over the last few years. The increase in CO_2 is mainly due to the 3% increase in energy consumption in 2016 as compared to 2005.

Table 9.12 shows the emissions efficiency changes in 2016 as compared to previous year and 2005. It should be noted that total harbor craft emissions were used for this efficiency comparison although emissions from several harbor craft types (e.g., commercial fishing vessels) are not dependent on container throughput. A positive percent for the emissions efficiency comparison means an improvement in efficiency.

Table 9.12: Harbor Craft Emissions Efficiency Metric Comparison, tons/10,000 TEUs

Year	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2e
2016	0.03	0.03	0.03	0.85	0.00	0.55	0.09	66
2015	0.04	0.03	0.04	1.00	0.00	0.61	0.10	75
2005	0.07	0.07	0.07	1.76	0.01	0.49	0.12	76
Previous Year (2015-2016)	**19%**	**18%**	**19%**	**16%**	**0%**	**9%**	**11%**	**12%**
CAAP Progress (2005-2016)	**59%**	**59%**	**59%**	**52%**	**88%**	**-13%**	**25%**	**13%**

Cargo Handling Equipment
The methodology used to estimate CHE emissions for the 2016 inventory did not change from the methodology used in the previous year inventory.

Table 9.13 shows that while the number of units of cargo handling equipment increased by 4%, the overall energy consumption (measured as total kW-hrs, the product of the rated engine size in kW, annual operating hours and load factors) decreased by 6% in 2016 as compared to 2015. Despite an increase in TEU, the 6% decrease in energy consumption in 2016 as compared to previous year, is mainly due to the improved efficiency at container terminals seen in 2016 and the introduction of electric equipment for the first full year at one terminal. From 2005 to 2016, there was a 24% increase in population and 18% increase in activity level.

Table 9.13: CHE Count and Activity Comparison

Year	Count	Energy Consumption (kW-hrs)	TEU	Activity per TEU
2016	2,202	204,763,196	8,856,783	23
2015	2,109	218,764,609	8,160,458	27
2005	1,782	173,108,402	7,484,624	23
Previous Year (2015-2016)	**4%**	**-6%**	**9%**	**-14%**
CAAP Progress (2005-2016)	**24%**	**18%**	**18%**	**0%**

Table 9.14 summarizes the numbers of pieces of cargo handling equipment using various engine and power types, including electric, LNG, diesel, propane, and gasoline.

Table 9.14: Count of CHE Equipment Type

Equipment	Electric	LNG	Propane	Gasoline	Diesel	Total
2016						
Forklift	8	0	381	7	118	514
Wharf crane	84	0	0	0	0	84
RTG crane	0	0	0	0	112	112
Side pick	0	0	0	0	29	29
Top handler	0	0	0	0	214	214
Yard tractor	0	17	180	0	851	1,048
Sweeper	0	0	0	4	5	9
Other	58	0	0	1	132	191
Total	**150**	**17**	**562**	**12**	**1,461**	**2,202**
	6.8%	**0.8%**	**25.5%**	**0.5%**	**66.3%**	
2015						
Forklift	10	0	369	8	122	509
Wharf crane	84	0	0	0	0	84
RTG crane	0	0	0	0	113	113
Side pick	0	0	0	0	31	31
Top handler	0	0	0	0	192	192
Yard tractor	0	17	180	2	813	1,012
Sweeper	0	0	0	2	5	7
Other	44	0	0	0	117	161
Total	**138**	**17**	**549**	**12**	**1,393**	**2,109**
	6.5%	**0.8%**	**26.0%**	**0.6%**	**66.1%**	
2005						
Forklift	0	0	263	8	151	422
Wharf crane	67	0	0	0	0	67
RTG crane	0	0	0	0	98	98
Side pick	0	0	0	0	41	41
Top handler	0	0	0	0	127	127
Total	**79**	**0**	**316**	**11**	**1,376**	**1,782**
	4.4%	**0.0%**	**17.7%**	**0.6%**	**77.2%**	

DB ID235

Table 9.15 summarizes the number and percentage of diesel-powered CHE with various emission controls by equipment type in 2016, the previous year and 2005. The emission controls for CHE include: DOC retrofits, DPF retrofits, on-road engines (CHE equipped with on-road certified engines instead of off-road engines), use of ULSD with a maximum sulfur content of 15 ppm. Several items to note include:

- Since some emission controls can be used in combination with others, the number of units of equipment with controls (shown in Table 9.17) cannot be added across to come up with the total equipment count (counts of equipment with controls would be greater than the total equipment counts).
- With implementation of the Port's CAAP measure for CHE and CARB's CHE regulation, the relative percentage of cargo handling equipment equipped with new on-road engines increased when compared to 2005.
- Mainly due to equipment turnover, the DOC count has decreased since 2005 as older equipment with DOCs has been replaced with newer equipment that does not require the use of DOCs.
- ULSD has been used by all diesel equipment since 2006. For 2005, ULSD was used by some diesel equipment, but not all.

Table 9.15: Count of CHE Diesel Equipment Emissions Control Matrix

Equipment	DOC Installed	On-Road Engines	DPF Installed	ULSD Fuel	Total Diesel-Powered Equipment	% of Diesel Powered Equipment DOC Installed	On-Road Engines	DPF Installed	ULSD Fuel
2016									
Forklift	0	0	44	118	118	0%	0%	37%	100%
RTG crane	6	0	43	112	112	5%	0%	38%	100%
Side pick	0	0	13	29	29	0%	0%	45%	100%
Top handler	0	0	105	214	214	0%	0%	49%	100%
Yard tractor	0	801	4	851	851	0%	94%	0%	100%
Sweeper	0	1	2	5	5	0%	20%	40%	100%
Other	0	12	40	132	132	0%	9%	30%	100%
Total	**6**	**814**	**251**	**1,461**	**1,461**	**0.4%**	**56%**	**17%**	**100%**
2015									
Forklift	0	0	40	122	122	0%	0%	33%	100%
RTG crane	6	0	41	113	113	5%	0%	36%	100%
Side pick	0	0	14	31	31	0%	0%	45%	100%
Top handler	0	0	106	192	192	0%	0%	55%	100%
Yard tractor	10	777	4	813	813	1%	96%	0%	100%
Sweeper	0	0	2	5	5	0%	0%	40%	100%
Other	0	10	22	117	117	0%	9%	19%	100%
Total	**16**	**787**	**229**	**1,393**	**1,393**	**1%**	**56%**	**16%**	**100%**
2005									
Forklift	3	0	0	27	151	2%	0%	0%	18%
RTG crane	0	0	0	36	98	0%	0%	0%	37%
Side pick	14	0	0	16	41	34%	0%	0%	39%
Top handler	48	0	0	79	127	38%	0%	0%	62%
Yard tractor	520	164	0	483	848	61%	19%	0%	57%
Sweeper	0	0	0	0	8	0%	0%	0%	0%
Other	0	1	0	65	103	0%	1%	0%	63%
Total	**585**	**165**	**0**	**706**	**1,376**	**43%**	**12%**	**0%**	**51%**

DB ID234

Table 9.16 compares the total number of cargo handling equipment units with off-road diesel engines (meeting Tier 0, 1, 2, 3 4i, and 4 off-road diesel engine standards) and those equipped with on-road diesel engines for 2016, the previous year and 2005. Since classification of engine standards is based on the engine's model year and horsepower, equipment with missing horsepower or model year information are listed separately under the Unknown Tier column in this table.

Implementation of the CAAP's CHE measure and CARB's CHE regulation have resulted in a steady increase in the prevalence of newer and cleaner equipment (i.e., primarily Tier 2, Tier 3, and Tier 4) replacing the older and higher-emitting equipment (Tier 0, Tier 1, and Tier 2). In addition, the number of units with on-road engines, which are even cleaner than Tier 3 off-road engines, has significantly increased since 2005. Note that Tier 3, 4i, and 4 engines were not available in 2005; therefore, "NA" is used for comparison of current year to 2005 for these engine categories.

Table 9.16: Count of CHE Diesel Engine Tier and On-road Engine

Year	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4i	Tier 4	On-road Engine	Unknown Tier	Total Diesel Engines
2016	16	45	113	144	147	188	814	18	1,485
2015	26	54	113	151	141	123	787	22	1,417
2005	256	582	360	0	0	0	165	13	1,376
Previous Year (2015-2016)	**-38%**	**-17%**	**0%**	**-5%**	**4%**	**53%**	**3%**	**-18%**	**5%**
CAAP Progress (2005-2016)	**-94%**	**-92%**	**-69%**	**NA**	**NA**	**NA**	**393%**	**38%**	**8%**

DB ID878

Table 9.17 shows the equipment energy consumption (kW-hr) comparison by engine type.

Table 9.17: Distribution of CHE Energy Consumption by Engine Type, %

Engine Type	Engine Tier	2016 % of Total	2015 % of Total	2005 % of Total
Diesel	Tier 0	0.3%	0.3%	11.0%
Diesel	Tier 1	0.8%	2.0%	39.3%
Diesel	Tier 2	6.1%	7.5%	31.2%
Diesel	Tier 3	10.7%	13.3%	0.0%
Diesel	Tier 4i	12.5%	12.8%	0.0%
Diesel	Tier 4	17.9%	9.6%	0.0%
Diesel	Onroad engines	41.8%	43.8%	12.0%
Gasoline		0.2%	0.2%	0.3%
Propane		9.1%	10%	6.2%
LNG		0.5%	0.5%	0.0%
Total		**100.0%**	**100.0%**	**100.0%**

Table 9.18 shows the cargo handling equipment emissions comparisons for 2016, the previous year and 2005. Compared to the previous year, all emissions decreased due to significant number of Tier 0 and 1 equipment turnover to Tier 4. The reductions in 2016 emissions compared to 2005 emissions are largely due to the implementation of the Port's CHE measures and CARB's CHE regulation. The efforts resulted in the introduction of newer equipment with cleaner engines and the installation of emission controls. The increase in CO_2 is mainly due to the increase in energy consumption in 2016 as compared to 2005.

Table 9.18: CHE Emissions Comparison

Year	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
2016	6	6	5	435	2	752	69	159,658
2015	9	9	7	557	2	760	85	170,780
2005	54	50	53	1,573	9	822	92	134,621
Previous Year (2015-2016)	**-29%**	**-29%**	**-33%**	**-22%**	**-6%**	**-1%**	**-19%**	**-7%**
CAAP Progress (2005-2016)	**-88%**	**-88%**	**-91%**	**-72%**	**-82%**	**-8%**	**-25%**	**19%**

DB ID237

Table 9.19 shows the emissions efficiency changes in 2016 from 2005 and previous year. A positive percentage change for the emissions efficiency comparison means an improvement in efficiency.

Table 9.19: CHE Emissions Efficiency Metric Comparison, tons/10,000 TEUs

Year	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2e
2016	0.007	0.007	0.005	0.491	0.002	0.849	0.078	180
2015	0.011	0.010	0.009	0.683	0.002	0.932	0.104	209
2005	0.072	0.066	0.071	2.102	0.013	1.099	0.123	180
Previous Year (2015-2016)	**36%**	**30%**	**44%**	**28%**	**0%**	**9%**	**25%**	**14%**
CAAP Progress (2005-2016)	**90%**	**89%**	**93%**	**77%**	**85%**	**23%**	**37%**	**0%**

Locomotives

The methodology used to estimate locomotive emissions in this 2016 inventory is the same as that used in the previous year inventory. Table 9.20 shows the throughput comparisons for locomotives for 2016, the previous year, and 2005.

Table 9.20: Throughput Comparison, million TEUs

Throughput	2005	2015	2016
Total	7.48	8.16	8.86
On-dock lifts	1.02	1.19	1.14
On-dock TEUs	1.84	2.14	2.06
% On-Dock	25%	26%	23%

Table 9.21 shows the locomotive emission estimates for calendar years 2016, the previous year, and 2005. Compared to 2005, the decrease in emissions are due to PHL's and UP's fleet turnover to the latest ultra-low emissions switching locomotives, the use of ULSD, and the Class 1 railroads' compliance with the MOU and introduction of newer locomotives. CO_2e emissions have been reduced since 2005 despite the increase in rail throughput through the freight movement efficiency improvements implemented by the railroads and terminals.

Table 9.21: Locomotive Emission Comparison

Year	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_x tons	SO_x tons	CO tons	HC tons	CO_2e tonnes
2016	28	27	28	780	1	191	44	67,387
2015	30	28	30	819	0.8	194	46	68,432
2005	57	53	57	1,712	98.0	237	89	82,201
Previous Year (2015-2016)	**-6%**	**-1%**	**-6%**	**-5%**	**-1%**	**-2%**	**-4%**	**-2%**
CAAP Progress (2005-2016)	**-50%**	**-49%**	**-50%**	**-54%**	**-99%**	**-19%**	**-51%**	**-18%**

DB ID428

Table 9.22 shows the emissions efficiency changes in 2016 from the previous year and from 2005. A positive percentage for the emissions efficiency comparison means an improvement in efficiency. For the CAAP progress (2016 vs. 2005), emissions efficiencies have improved for all pollutants. Compared to previous year, emissions efficiencies improved for all pollutants, except for SO_x and CO_2 which remained the same.

Table 9.22: Locomotive Emissions Efficiency Metric Comparison, tons/10,000 TEUs

Year	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2e
2016	0.03	0.03	0.03	0.88	0.00	0.22	0.05	76
2015	0.04	0.03	0.04	1.00	0.00	0.24	0.06	84
2005	0.08	0.07	0.08	2.29	0.13	0.32	0.12	110
Previous Year (2015-2016)	**14%**	**9%**	**14%**	**12%**	**0%**	**9%**	**13%**	**9%**
CAAP Progress (2005-2016)	**58%**	**56%**	**58%**	**62%**	**99%**	**32%**	**59%**	**31%**

Heavy-Duty Vehicles

No major changes were made in the emission estimating methodology for 2016 compared with the 2015 emissions inventory. The EMFAC2014 model was used for 2016 as it was for the 2015 inventory, along with regional travel demand modeling based on the number of containers moved through each terminal and terminal-specific characteristics. Vehicle start emissions of NO_x have been estimated for model year 2010 and newer trucks using the methodology described in the 2014 emissions inventory report.

Table 9.23 shows the total port-wide idling time based on information provided by the terminal operators which, as noted previously, relates to time spent on terminal that may not solely be time spent idling. Total idling increased 11% as compared to the previous year and increased by 18% since 2005. The idling increased due to increase in TEU throughput.

Table 9.23: HDV Idling Time Comparison, hours

Year	Total Idling Time (hours)
2016	3,569,716
2015	3,222,306
2005	3,017,252
Previous Year (2015-2016)	**11%**
CAAP Progress (2005-2016)	**18%**

Table 9.24 summarizes the average age of the truck fleet in 2016, the previous year and 2005. The average age of the trucks visiting the Port was 6 years in 2016.

Table 9.24: Fleet Weighted Average Age, years

Year	Call-Weighted Average Age (years)
2016	6
2015	5
2005	11

Table 9.25 summarizes the HDV emissions for 2016, the previous year and 2005. The HDV emissions of all pollutants have decreased significantly from 2005 largely due to increasingly stringent on-road engine emission standards and the implementation of the CTP.

Table 9.25: HDV Emissions Comparison

Year	VMT	PM_{10} tpy	$PM_{2.5}$ tpy	DPM tpy	NO_x tpy	SO_x tpy	CO tpy	HC tpy	CO_2e tonnes
2016	215,879,722	8.0	7.7	7.6	1,857	4	139	36	388,411
2015	211,248,692	8.3	8.0	7.7	1,895	4	135	36	381,737
2005	266,434,761	248	238	248	6,307	45	1,865	368	469,260
Previous Year (2015-2016)	**2%**	**-4%**	**-4%**	**-2%**	**-2%**	**2%**	**3%**	**0%**	**2%**
CAAP Progress (2005-2016)	**-19%**	**-97%**	**-97%**	**-97%**	**-71%**	**-90%**	**-93%**	**-90%**	**-17%**

As an overall measure of the changes in HDV emissions independent of changes in throughput, Table 9.26 illustrates the changes in emissions in average grams per mile (g/mi) between 2005 and 2016 and between 2015 and 2016. The units of grams per mile are used because they show the changes independent of changes in throughput or vehicle mileage, which can complicate the comparisons. The figures have been calculated by dividing overall HDV emissions by overall miles traveled, and include idling emissions as well as emissions from driving at various speeds, on-terminal and on-road. Particulate emissions have been reduced most dramatically from 2005 to 2016, followed by the other pollutants except for CO_2e, which is strongly tied to fuel consumption, which has not changed significantly since 2005. The CTP and engine emission standards are responsible for most reductions, including the particulate and NO_x decreases, while fuel sulfur standards, specifically the introduction of ultra-low sulfur diesel fuel (ULSD), are responsible for the SO_x reduction.

Table 9.26: Fleet Average Emissions, g/mile

Year	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2e
2016	0.0337	0.0323	0.032	7.8034	0.0181	0.582	0.1525	1,799
2015	0.0358	0.0342	0.0333	8.14	0.018	0.58	0.16	1,807
2005	0.8457	0.8091	0.8457	21.48	0.153	6.35	1.25	1,761
% Change (2015-2016)	**-6%**	**-6%**	**-4%**	**-4%**	**0%**	**0%**	**-5%**	**0%**
% Change (2005-2016)	**-96%**	**-96%**	**-96%**	**-64%**	**-88%**	**-91%**	**-88%**	**2%**

Figure 9.1 illustrates the HDV model year distribution for calendar years 2009 through 2016, showing the peak of 2009 model year trucks that largely persists in each calendar year. The elevated percentages of newer, 2010+ trucks in calendar year 2016 can also be seen in the figure.

Figure 9.1: Model Year Distribution

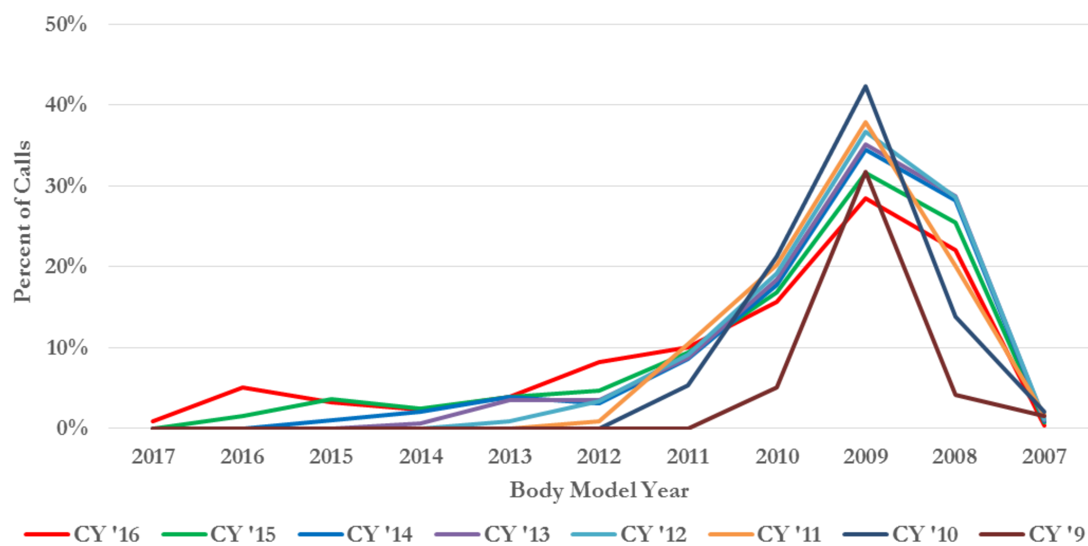


Table 9.27 shows the emissions efficiency changes for HDVs. A positive percentage for the emissions efficiency comparison means an improvement in efficiency. Comparing 2016 to 2005 for CAAP progress, HDV emissions efficiency has improved for all pollutants. Comparing 2016 to the previous year, emissions efficiency improved for most pollutants, except for SO_x and HC which remained the same.

Table 9.27: HDV Emissions Efficiency Metrics Comparison, tons/10,000 TEUs

Year	PM_{10}	$PM_{2.5}$	DPM	NO_x	SO_x	CO	HC	CO_2e
2016	0.0091	0.0087	0.0086	2.096	0.005	0.16	0.04	438
2015	0.0102	0.0098	0.0095	2.323	0.005	0.17	0.04	468
2005	0.3320	0.3177	0.3320	8.432	0.060	2.49	0.49	627
Previous Year (2015-2016)	**11%**	**11%**	**10%**	**10%**	**0%**	**6%**	**0%**	**6%**
CAAP Progress (2005-2016)	**97%**	**97%**	**97%**	**75%**	**92%**	**94%**	**92%**	**30%**

CAAP Standards and Progress

One of the main purposes of the annual inventories is to provide a progress update on achieving the CAAP's San Pedro Bay Standards. These standards consist of the following emission reduction goals, compared to the 2005 inventories:

- Emission Reduction Standard:
  - By 2014, achieve emission reductions of 72% for DPM, 22% for NO_x, and 93% for SO_x
  - By 2023, achieve emission reductions of 77% for DPM, 59% for NO_x, and 93% for SO_x
- Health Risk Reduction Standard: 85% reduction by 2020

Due to the many emission reduction measures undertaken by the Port, as well as statewide and federal regulations and standards, the 2014 emission reduction standard continued to be met and exceeded in 2016 for DPM, NO_x, and SO_x. Looking towards the future, the 2023 emission reduction standard has been met and exceeded for DPM and SO_x. Below is a summary of DPM, NO_x, and SO_x percent reductions as compared to the 2014/2023 emission reduction standards.

Table 9.28: Reductions as Compared to 2014 and 2023 Emission Reduction Standard

Pollutant	2016 Actual Reductions	2014 Emission Reduction Standard	2023 Emission Reduction Standard
DPM	87%	72%	77%
NO_x	57%	22%	59%
SO_x	98%	93%	93%

The Emission Reduction Standards are represented as a percentage reduction of emissions from 2005 levels, and are tied to the regional SoCAB attainment dates for the federal $PM_{2.5}$ and ozone ambient air quality standards in the 2007 AQMP. The following tables show the standardized estimates of emissions by source category for calendar years 2016, previous years, and 2005 using current year methodology.

Table 9.29: DPM Emissions Comparison by Source Category, tpy

Category	2005	2015	2016
Ocean-Going Vessels	466	57	47
Harbor Craft	55	30	27
Cargo Handling Equipment	53	7	5
Locomotives	57	30	28
Heavy-Duty Vehicles	248	8	8
Total	**879**	**132**	**115**
% Cumulative Change		**-85%**	**-87%**

Table 9.30: NO_x Emissions Comparison by Source Category, tpy

Category	2005	2015	2016
Ocean-Going Vessels	5,295	3,688	3,200
Harbor Craft	1,318	819	751
Cargo Handling Equipment	1,573	557	435
Locomotives	1,712	819	780
Heavy-Duty Vehicles	6,307	1,895	1,857
Total	**16,206**	**7,778**	**7,023**
% Cumulative Change		**-52%**	**-57%**

Table 9.31: SO_x Emissions Comparison by Source Category, tpy

Category	2005	2015	2016
Ocean-Going Vessels	4,825	124	106
Harbor Craft	6	1	1
Cargo Handling Equipment	9	2	2
Locomotives	98	1	1
Heavy-Duty Vehicles	45	4	4
Total	**4,983**	**132**	**114**
% Cumulative Change		**-97%**	**-98%**